Preserving the intelligibility of digital archives of contemporary music with live electronics: a theoretical and practical framework

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Abstract

This research provides a theoretical and practical framework for the preservation of digital artifacts with a focus on the sustainability of the repertoire of contemporary music with live electronics. The sustainability of instrumental music relies on the organology of musical instruments, the teaching of instrumental practices, and musical notation. In the context of music with live electronics, these three principles are challenged by several factors: the rapid obsolescence of idiosyncratic software for live electronics, the complex social context of the production of these digital artifacts, and the difficulty in providing a prescriptive notation. This thesis investigates the impact of these issues on digital archives theory and models and further conceptualises the notion of performance of digital archives with a focus on the sociological context of digital object creation.

This research is divided into three complementary studies at the intersection of three research fields: digital archives, knowledge management, music research.

The first study provides a conceptual framework for preserving the intelligibility of digital artifacts. It builds on the notion of *significant properties* and proposes a framework for *significant knowledge*, which accounts for the tacit dimension of the knowledge involved in the production of these artifacts. A knowledge management model was selected and operationalised in the context of documentation process of electroacoustic and mixed music. We invited composers to respond to an online survey to test the operationalisation of the model and relied on non-parametric statistics to evaluate its relevance. Our findings highlight the benefits of using this model for contemporary music preservation and the potential for expanding this operationalisation to other artistic contexts.

The second study focusses on the specification of the creative process underlying the production of digital artifacts. We applied grounded theory to secondary ethnographic data (including interviews, video recordings of work sessions and written reports) of a 2-year creative process of a string quartet with live electronics. The actors included the composer, the computer music designer, performers, researchers and engineers. The outcome of this study is a rich multi-level categorisation of the creative process of a contemporary work with live electronics, which stresses the limits of standard

a posteriori documentation and shows the potential lacks in a documentation based on current music theories. This study provides an extension of the notion of digital artifacts to a broader sociological context accounting for both human and non-human agents involved in the creative process.

The third study models the main findings of both previous studies in terms of digital archives, specifically extending the OAIS (Open Archival Information System). We propose a practical framework accounting for the relationship between creative processes and digital objects during their archival lifecycle. This framework contributes to formalising the link between data producers and digital archives, in order to better relate to ingestion and appraisal policies in the context of archives of contemporary music with live electronics.

The methodological, theoretical and practical outcomes of this research may benefit other contexts, as live electronics have garnered increased interest in a wide range of artistic domains including dance, theatre and art installations. We further conceptualise the archival notion of performance of digital archives with a social extent involving both human and non-human agents, which has an impact on maintaining the intelligibility of digital objects.

Résumé

Cette recherche a pour objectif de fournir un cadre théorique et pratique de préservation des artéfacts numériques tout spécialement orienté vers la pérennité du répertoire de musique contemporaine avec électronique en temps réel. La pérennité de la musique instrumentale repose sur l'organologie des instruments de musique, l'enseignement de la pratique instrumentale, et la notation musicale. Dans le contexte des musiques électroacoustiques et mixtes, ces trois principes sont remis en cause par plusieurs facteurs : l'obsolescence rapide des logiciels idiosyncratiques de traitement du signal en temps réel, le contexte social complexe de production de ces artéfacts numériques, et la difficulté à fournir une notation prescriptive. Cette recherche questionne l'impact de ces problématiques sur la théorie et les modèles des archives numériques autour d'un intérêt particulier pour le contexte social de création des objets numériques.

Cette recherche est divisée en trois études complémentaires à l'intersection de trois domaines de recherche: l'archivage numérique, la gestion des connaissances, et le recherche musicale.

La première étude élabore un cadre conceptuel pour la préservation de l'intelligibilité des artéfacts numériques. Pour ce faire, elle part de la notion de *propriétés significatives* pour l'étendre à la notion de connaissances tacites à travers la proposition de définition et d'opérationnalisation des *connaissances significatives* impliquées dans la production des artéfacts numériques. Cette étude a donc fourni une opérationnalisation d'un modèle de gestion des connaissances en vue du processus de documentation. Un questionnaire en ligne a été disséminé auprès de la communauté des compositeurs en musique électroacoustique et mixte afin de recueillir des données relatives à cette opérationnalisation. Des méthodes statistiques non-paramétriques ont été utilisées afin d'évaluer la pertinence du modèle. Nos résultats mettent en lumière les bénéfices de l'utilisation du modèle pour la préservation du répertoire et le potentiel d'expansion de cette opérationnalisation à d'autres contextes artistiques.

La deuxième étude propose une formalisation du processus créatif soutenant la production des objets numériques dans le contexte des œuvres de musique contemporaine avec électronique en temps réel. L'analyse des données repose sur la théorie ancrée, ap-

pliquée à des données secondaires de type ethnographique (entrevues, enregistrement vidéo des séances de travail et rapports écrits) d'un processus créatif multi-agents. Les résultats de cette étude montre un riche réseau de concepts catégorisant le processus créatif des œuvres de musique contemporaine avec électronique en temps réel qui montre les faiblesses potentielles d'une documentation basée sur les théories musicales courantes. Cette étude permet d'étendre les limites de la notion d'artéfacts numériques à un contexte social plus large qui implique plusieurs agents, humains et non-humains, impliqués dans les processus créatifs.

La troisième étude modélise l'impact des deux précédentes études en termes de modèles d'archives numériques. Plus spécifiquement, elle modélise l'impact sur le modèle OAIS (Open Archival Information System). Le résultat est un cadre pratique centré sur la relation entre les processus créatifs et les objets numériques pendant leur cycle de vie d'archives. Ce cadre pratique contribue à la formalisation du lien entre producteur et archives numériques afin de mieux spécifier des politiques d'acquisition et d'évaluation dans le contexte des archives de musique contemporaine avec électronique en temps réel.

De par l'utilisation récente des technologies de traitement du signal en temps réel dans d'autres domaines artistiques, comme la danse, le théâtre, et les installations, les résultats, en termes de méthodologie et de modélisation, sont susceptibles d'avoir un impact plus large que le contexte de cette recherche. Sur la base de ces études, nous proposons une extension de la notion archivistique de performance des archives numériques, qui inclue un réseau social multi-agent, qu'ils soient humains ou non-humains, et qui se répercute sur la préservation de l'intelligibilité des objets numériques.

Contribution of Authors

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Chapter 1

Introduction

1.1 An object of research: the use of technology in contemporary music

1.1.1 Historical context

Technology use is at the heart of electroacoustic and mixed music compositions. Delalande (2003) defines electroacoustic music as music whose sounds are processed and arranged as an analogue or digital signal and presented over loudspeakers[1]. The term electroacoustic music was introduced in 1955 to encompass diverse approaches, including 'musique concrète' and electronic music (Delalande, 2003)[2]. Pierre Schaeffer coined the term 'musique concrète'

[1] Nevertheless Delalande (2003) restrains this definition to the context of what has been labelled 'serious music' (Adorno, 1941) or 'art music', a distinction that has been largely criticised (Frith, 1996, 2002; Landy, 1997; Hennion, 2003). Landy (1997) reminds us of that "the mutual exclusivity and distance between popular musics and contemporary art music are diminishing" (p. 2), and Middleton (2009) exemplifies this fact with 'crossovers' like Brian Eno.

[2] Delalande distinguishes, non-categorically, between 'musique concrète', electronic music, and acousmatic music. According to Roy, the composer François Bayle characterises, with the term 'Acousmatic music', a music composed in a studio and diffused in a hall just like the movies, Delalande states that

to describe the use of recorded sounds as compositional resources. His five *Etudes de bruit* (1848) epitomised this approach (Battier, 2003)[3]. According to Roy (2003, p. 61), 'Musique concrète' refers to a compositional process which starts from the sound (as opposed to an abstract notation), rather than the nature of sounds used during the creative process[4]. Electronic music on the other hand relies on electronic music instruments/technologies[5] and was developed primarily in the Cologne studio for Electronic Music created in 1951 (Battier, 2003)[6] with composers such as Karlheinz Stockhausen (e.g.1953's *Studie I*; 1954's *Studie II*). Risset (1999) reminds us that 'musique concrète' and electronic music for a long time remained 'antagonistic'[7] even though a few works, such as Stockhausen's 1956 work *Gesang der Jünglinge*, used both types of sound.

Mixed music combines electroacoustic music and instrumental (acoustic) music. Frengel (2010) defines it as "electroacoustic compositions involving a live component with a visible sound source (a performer) and a non-live component projected electronically through loudspeakers" (p. 96). This definition refers to the initial framework of mixed music. Indeed, mixed music first relied on a combination of instrumental music and tape music, initiated with Bruno Maderna's 1951 work *Musica su due dimensioni* (Battier, 2003). Another seminal work is Edgar Varèse's *Désert* (1950-54) which "alternates between conventional instruments and taped sounds, producing the effect of a monumental sound sculpture"

"elle se différencie donc d'une musique électroacoustique plus instrumental réalisée sur scène, à l'aide de systèmes de synthèse sonore ou de transformation de parties instrumentales ou vocales écrites" (p. 535). Battier (Battier, 2004), on the other hand, proposes a very wide definition of electroacoustic music: "electroacoustic music generally refers to a specific type of compositional approach in a well-defined historical period, starting after 1945. Other names for this technological music have been used, such as 'electronic music', 'tape music', 'live electronic music', 'computer music', 'acousmatic music', 'audio art', 'sound art', 'interactive music' and, in France, 'musique mixte' " (p. 47).

[3] *Etudes de bruit* (1848) corresponds to the first radio-diffusion, the first concert happened in 1950 at Ecole Normal de Musique (Tiffon, 1994, p. 67).

[4] Chion (1998) similarly states that "l'expression 'musique concrète', que j'ai ressuscitée, est toujours d'actualité et s'applique aussi aux sons crées par ordinateur si on la prend dans le sens original c'est-à-dire de la musique faite concrètement et fixée sur support, existant en tant que fixée" (p. 209).

[5] Meyer-Eppler (1956) states that "the purely electronic instruments do not possess any essential mechanical parts for producing the electrical oscillations. Rather, the oscillations are produced wholly by means of electronic components (vacuum tubes, ionic tubes, transistors, etc.)" (p. 4), and, According to Mumma (1974), "electronic modification of electronically generated sound and electronic modification of acoustically generated sound are the two most common procedures of live electronic music" (p. 296).

[6] Risset (1999) specifies 1950.

[7] Electronic music had a more formal relation to composition, inherited from the serial music school (Risset, 1999).

(Mumma, 1974, p. 292). Mixed music later embodied the use of live processing with pioneering works such as Karlheinz Stockhausen's 1964 *Mixtur* and *Mikrophonie* (Tiffon, 2005). *Mixtur*, for example, is a work for orchestra, sine-wave generators, and ring modulators. Analog systems were subsequently replaced with digital systems, such as the famous 4X system used for Pierre Boulez's *Répons* (Boulez & Gerzso, 1988). According to Griffiths (2010), David Wessel's 1977 work *Antony* was one of the first to use the 4A, predecessor of the 4X, developed at IRCAM (Institut de Recherche et Coordination Acoustique/Musique) by Giuseppe di Giugno. The ISPW (IRCAM Signal Processing Workstation) would eventually replace the 4X in the early 1990s (Lippe, 1996). Cadoz (2009) specifies that "less than ten years after 'Musique Concrète' and 'Electronic Music', the computer entered the musical domain with Automatic Composition (Hiller & Isaacson, 1959; Hiller, 1969) and Digital Sound Synthesis (Mathews, 1963, 1969)" (p. 222). In 1957, Max Mathews produced the first computer-synthesised sound (Risset, 1999). Winkler (1998) reminds us that "most of the computer music research and compositions during the seventies centered on sound synthesis and processing methods using mainframe computers to produce tape pieces. One notable exception was the GROOVE system, a pioneering work in real-time computer systems developed by Max Mathews and F. Richard Moore at Bell Labs. The GROOVE system, in use at Bell Labs from 1968 to 1979, featured a conducting program that enabled a person to control the tempo, dynamic level, and balance of a computer ensemble that had knowledge of a predetermined musical score" (p. 13). *Répons*, in a 1992 version, was migrated to ISPW, which ran a piece of software named *Max* (Harley, 1994, p. 236), designed by Miller Puckette and named after Max Mathews. *Max* subsequently grew into *Max/MSP* (Puckette, 2002) with the inclusion of audio signal processing. Numerous dedicated software tools for audio signal processing have emerged since then, including PD, Reaktor or SuperCollider, and their use has pervaded other artistic contexts in domains such as theatre, dance, and installation art.

Over the past four decades, the use of digital technology introduced significant changes in performing arts. Subsequently new preservation issues arose. The increased popularity of real-time sound processing software development environments urges the scientific community to address the question of preservation of music involving live electronics.

1.1.2 Preservation issues

1.1.2.1 The technological dimension

The most challenging preservation issues relate specifically to two new musical techniques:

- In the 1980s real-time sound processing of acoustic instruments with dedicated software introduced a further step in complexity, that is, the possibility to technologically enhance musical instruments in ways limited only by the composer's imagination.
- Developments in the area of human computer interaction fostered arbitrary models of interaction with virtual/digital instruments. The complex production life-cycle of these models added a new layer of intricacy to the sustainability of the artworks.

These musical techniques are expressed within idiosyncratic software produced for a specific work (Stiegler, 2003; Tiffon, 2005)[8].

1.1.2.2 The time dimension

Born (1995), in her sociological rendering of the IRCAM's (Institut de Recherche et Coordination Acoustique/Musique) creative environment, provides us with a summary of the preservation situation:

> IRCAM's software research is extremely unstable due to its embedding in a series of vertical mediations of hardware and software, all of which are themselves unstable due to technological dependence and the enforced revision of standards and premature obsolescence this entails. (Born, 1995, p. 275)

[8] According to Tiffon (2005), in the context of mixed music, "[...] l'oeuvre est dépendante d'une technologie tributaire d'une époque, ou même d'une technologie spécifiquement crée pour les desseins propres au compositeur" (p.27).

This situation is not restricted to IRCAM. As Polfreman, Sheppard, and Dearden (2006) observe, "many twentieth-century compositions that use electronic systems during performance are becoming impractical to perform as they are specified for outdated systems that over time become difficult or impossible to obtain" (p.229). Consequently, the rapid obsolescence of new musical interfaces/instruments poses a major challenge for the preservation of the repertoire.

1.1.2.3 The social dimension

Although the technological side of the preservation issue is often emphasised, the social dimension is intricately related to it. As Zattra (2006) puts it, "electroacoustic music is a complex 'object' with numerous agents and processes involved - both human and technological" (p. 113). The compositional process is entrenched in a social network, which is composed of human agents as well as technological agents (Baudouin, 2011)[9]. Furthermore, functions such as composition, instrument making, and performance, during the creative process, are transformed and made even more complex in the context of contemporary music with live electronics (Stiegler, 2003)[10]. The outcome of this situation is similar to the situation for installation art, which Coleman (2011) describes: "most of the know-how and experience of artists working in the 1960s, 1970s and 1980s still remains in the hands of individuals - the artists, asistants, technicians, historians, critics and writers. Without urgent action, this wealth of information risks disappearing as people forget, retire and pass away" (p. 218).

[9] Baudouin (2011) states: "en effet, composer avec l'ordinateur, dans les années 1960-1970, ne peut conduire à l'isolement. Un tel travail nécessite au contraire une immersion dans un environnement humain et matériel d'exception, constitué d'outils à la pointe de la technologie manoeuvrés par une élite créative, polyvalente et évoluant à l'intérieur de ses propres réseaux" p. (2).

[10] According to Stiegler (2003), "l'analyse et la synthèse des sons transforment les relations entre composition, facture instrumentale et interprétation" (p. 12); ces nouveaux instruments "souvent sinon toujours 'fabriqués' par les compositeurs eux-mêmes, échappent à la division du travail musical par laquelle se spécifiaient les rôles" (p. 12). Similarly, reflecting on his compositional process, Impett (1998) states: "in such a mode of production, the subdivisions of conventional music are folded together: composer, composition, performer, performance, instrument and environment" p. 24. A statement confirmed by Benghozi (1995) who acknowledges the creative part of sustain tasks in the broader context of the art worlds, as described by Becker (1982).

1.2 Music and preservation

1.2.1 Preservation and instrumental music: score and praxis

Music with a score[11] is considered an allographic art (Goodman, 1976). The score implies and prescribes a performance (Frangne, 2009). Seeger (1958) historically situates notation from the Greek tradition and early Christian times (for the specification of height of pitch together with height on the page) and demonstrates the transition from a descriptive notation to a prescriptive notation. The notation, ever since it became "practically entirely prescriptive" (Seeger, 1958, p. 186)[12], specifies the performance through a few dimensions, in particular: pitch, duration, intensity and timbre (Cadoz, 2009)[13].

Notation is complemented by the music practice whose teaching ensures a relevant performance. Therefore the situation, as stated by Chadabe (2001), is that "traditional instrumental music can be preserved through notation, first because traditional compositions are defined by elements which can be notated, and, second, because traditional instruments are played in standard ways" (p. 303). Nevertheless this statement should be considered cautiously; there is not only one possible performance[14] out of a unique score (S. Davies, 1988) and Stroppa (1984) points out that the level of constraint on each dimension of the score is different[15].

[11] Tiffon (2002) explicitly and historically relates the score to the paper and posits a migration from the 'logosphère' to the 'graphoshère': "À partir du XIVe siècle avec l'Ars Nova (appelation idoine), sont inventés des procédés d'écriture, inconcevables sans l'aide du papier, support technologiquement plus performant que le parchemin ou les autres supports antérieurs" (p. 3)

[12] We use Seeger's view on prescription. According to Kanno (2007, p. 232) the score encompasses both description and prescription; he considers that specifically "'prescriptive notation' is defined as a notation system in which the composer specifies the method of making music" (p. 235), a consideration shared by Impett (1998) who states that "the seductive power of conventional musical notation derives from its dual function as description and instruction. In the case of computational construction, these functions are clearly divorced" (p. 2). Kanno focusses on the distinction between sound and action while Seeger focusses on the difference between objective and subjective.

[13] Nattiez (2004b), from a musicological point of view, lists: melody; harmony; rhythm; and timbre.

[14] Performance is a specific object of research in performance studies. See (Féron & Boutard, submitted) for further literature review on the topic.

[15] Manoury (2007) states: "des oreilles très bien exercées reconnaissent, de façon immédiate et sans ambiguïté, un *la* d'un *la* + - *de ton*, mais divergeront grandement lorsqu'il faudra déterminer ce qui est un *piano* ou un *mezzo forte*" (p. 7).

1.2.2 Preservation and electroacoustic music: tradition and technology

1.2.2.1 Preservation in relation to instrumental music

Typically preservation of contemporary works with live electronics tried to restore the premises of instrumental music preservation and dissemination focussing on organology[16] and notation[17].

While Stroppa (1984) stated, "neither operational data, with their cold, technical disposition, nor the composer's graphic representations may be considered as 'scores' " (p. 179), several authors advocated for an electroacoustic music notation system (Manoury, 2007; Bernardini & Vidolin, 2005; Chadabe, 2001; Peters, Marentakis, & McAdams, 2011)[18]. In the case of specific compositional parameters, descriptive notations have been proposed: SpatDIF (Peters, Ferguson, & McAdams, 2007) for spatialisation; GDIF (Jensenius, Kvifte, & Godøy, 2006) for gesture control.

Stiegler (2003) argued that, in the context of contemporary music with live electronics, organology can not be restricted to acoustic instruments and should encompass in its scope the technical system [19]. Attempts to redefine an organology have been conducted either in terms of signal processing (Bonardi & Barthélemy, 2008)[20], which posits the instrument

[16]Traditionally, the discipline associated with the classification of instruments: "the descriptive and analytical study of musical instruments. The term was introduced by Bessaraboff to distinguish the 'scientific and engineering aspects' of instruments from the broader study of music" (Sadie, 1984, p. 916).

[17]Recently the notion of allography was endorsed by researchers and practicioners in the domaine of art installation, see Rinehart, 2004; Laurenson, 2006; Tilly, 2009. A statement also acknowledged by Millet (1997), who states: "dans bien des cas, le conservateur se doit d'être une sorte d'interprète. Lorsque entrent dans la composition des œuvres des objets qui demandent à être renouvelés, ou assemblés différemment en fonction d'un nouvel espace d'exposition, le conservateur, aussi précises que soient les consignes données par l'artiste, devra bien prendre des décisions de sa seule initiative" (p. 43).

[18]Emmerson (2006) specifically advocates for "a performance edition, one with immediate possibility of interpretation" (p. 210). A strategy he relates to the concept of urtext in instrumental music.

[19]Stiegler (2003) states that "l'organologie est un sous-domaine de l'histoire des techniques tout autant que de la musicologie. Et l'étude des techniques consiste essentiellement dans l'étude des systèmes techniques. Considérer les instruments ou les dispositifs techniques de la musique isolément n'est donc pas fécond" (p. 12).

[20]In a different context Verfaille, Guastavino, and Traube (2006), proposed a taxonomy of signal processing.

as an augmented instrument[21], or in terms of new instruments/interfaces (H. Davies, 2001; Bonardi & Barthélemy, 2008; Fishkin, 2004; *TIEM*, 2008; Vine, 2010).

Nevertheless fundamental differences between acoustic musical instruments and new digital instruments reduce the impact of these proposals. The efficiency of these approaches should be questioned on the basis of software's fast obsolescence, and the ability of each composer to develop a customised digital sound processing tool for each work (Stiegler, 2003). According to Bossis (2006), "the collection of electronic instruments is very heterogeneous and lacks the temporal stability necessary for the emergence of techniques, signs and musical languages that match their diversity" (p.102). The second limitation is the absence of any natural mapping between musical gesture (like the pressure of the hand on the instrument) and sounds generated by digital instruments (Schnell & Battier, 2002)[22]. As Drummond (2009) puts it, "mapping arbitrary interfaces to likewise arbitrarily chosen sound-generating devices creates the potential for the interrelated physical and acoustical connections between an instrument's interface and its sound output – which are typically inherent in traditional acoustic instruments – to be lost." [p.132]. The third limitation is the lack of recognition for all stakeholders of the creative process, as identified by (Zattra, 2006). This is especially important considering the fact that, according to Schnell and Battier (2002), in the specific case of electronic instruments, the score and the instrument are intertwined: a concept which they labelled the 'composed instrument'. Gurevich and Treviño (2007) summarise this third limitation:

> In an ecological framework, the performer's actions are the result of dynamic internal models of the composer and score (if it exists), as well as the instrument, performance environment, audience, and a wealth of prior experience. (p. 108)

[21] That is, "acoustic instruments with added gesture sensing capabilities, which is similar to the *hyperinstruments* pioneered at MIT" (Bevilacqua, Rasamimanana, Fléty, Lemouton, & Baschet, 2006, p. 402). Thus the sound of the acoustic instrument is augmented through sound processing. For example, see Lähdeoja, Wanderley, & Malloch, 2009. Wanderley and Depalle (2004, p. 635) refer to *extended instruments*.

[22] See also the results of a survey by Magnusson and Mendieta (2007), in particular on the difference between acoustic instruments and digital instruments. It is also enlightening to consider in this regard the statement of Smalley (2007) to assess the impact of this transformation: "the ultimate purpose of performance is to transmit music from gestural/ensemble space to be perceived in arena space" (p. 42).

1.2.2.2 Preservation in relation to technology

Technologically, the preservation of electroacoustic music has been the focus of several music and computer science publications. It has been discussed in terms of hardware (H. Davies, 2001; Battier, 2004), and software (Canazza & Orcalli, 2001; Canazza & Vidolin, 2001; Chadabe, 2001; Barthélémy, Bonardi, Boutard, & Ciavarella, 2008; Ciavarella, Bonardi, & Boutard, 2009; Wetzel, 2006). Technological preservation of digital or analog processing artefacts implies conservation, migration, emulation, or virtualisation (Bonardi & Barthélemy, 2008), a set of strategies that have been applied to several works from the repertoire (Wetzel, 2004, 2006; Bullock & Coccioli, 2005; Yong, 2006). This position, focussing on technology to preserve technology, has provided several outcomes such as the framework implemented during the INTEGRA project (Bullock & Frisk, 2007).

This approach implies that technology is the receptacle of all knowledge relevant to the production of the work. However, it does not account for the tacit knowledge involved:

> "Obsolescence and preservation are crucial problems in the study of electroacoustic music. Therefore, mental texts (of composers, technicians, etc.) are important to the preservation and analysis of musical works." (Zattra, 2007, p. 38)

It does not account for the complexity of the social process that is mediated by technology. Mediations are not specific to contemporary works with live electronics, which Hennion (1993) elegantly demonstrates in the specific case of baroque music. In 1961, for another example, Hindemith stated, "what could they do with all this cleverness, talent, and ardor, if they did not have at their disposal a well-ordered tonal system which permitted them to transform their ideas into sound? A system, that is, which regulates all conceivable successions and relations of sounds: a system arising not out of the speculations of a single genius, but out of the collective thinking and laboring of many generations of musical

producers and reproducers" (p. 77). Still, considering technological agents as active agents, these mediations are multiplied [23] and concealed[24].

1.2.2.3 Preservation in relation to digital archives and digital curation

From both a theoretical and a practical point of view, preservation of artistic works, such as musical works with technological components, raises questions that keepers of digital archives need to address. Technological components, especially digital sound processing artefacts, seem to epitomise archival issues in terms of readability, authenticity, and intelligibility (B. Lee, 2000). These issues have already partially formed the basis for several digital archives projects concerned with the preservation of musical works, such as CASPAR (Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval)

[23] As Latour (1994) puts it, "no unmediated action is possible once we enter the realm of engineers and craftsmen" (p. 29)

[24] Which Latour (1994) emphasises with the concept of black box: "each of the parts inside the black box is a black box full of parts. If any part were to break, how many humans would immediately materialise around each?" p. 37. This position invites us to consider the impact of Winkler's (1998) statement: "much of the success of Max can be attributed to contributions made from a community of programmers and composers who have greatly expanded the program's capabilities with custom libraries of additional functions that are distributed without cost by Opcode, and many more that are exchanged freely over the Internet" (p. 18), and the extent of Delalande's (2009) statement: "Les objets musicaux considérés sont le support d'un échange entre producteurs et récepteurs, et c'est en tant que tels qu'ils intéressent ce qu'il est convenu d'appeler l'analyse musicale. On les décrit seulement comme résultat d'une production donnant lieu à une réception. Mais production de qui? (Traditionnellement du compositeur seul, mais est-il légitime d'oublier un éventuel assistant et/ou les concepteurs de logiciels?) Réception par qui, dans quelles conditions? Les réponses résulteront d'une études des pratiques sociales" (p. 151). This last statement would not be complete without acknowledging the involvement of performers. Lemouton (2009) provides us with a fair rendition of their role for a specific work production, *StreicherKreis*, which will be discussed in chapter 6: "Dans l'ensemble des pièces étudiées, l'implication des instrumentistes a été très grande et cruciale tout au long des périodes de réalisations. Cet investissement personnel est beaucoup plus essentiel dans le cadre des oeuvres pour 'instruments augmentés' que dans celui des oeuvres mixtes. Pendant la période de recherche préliminaire, puisque les instruments augmentés sont encore à construire, l'implication des futurs interprètes est nécessaire pour définir le 'design' aussi bien des capteurs que des logiciels exploitant les données provenant de ceux-ci. Ce design ne peut se faire sans leur participation. Dans la phase de composition de l'oeuvre, ils doivent être présents également pour commencer à explorer les possibilités ouvertes au compositeur par l'augmentation de leurs instruments. Enfin, une fois l'oeuvre écrite, les dispositifs de captation du geste et de transformation du son réalisés, ils devront apprendre à 'jouer' de ces nouveaux instruments. C'est là qu'est l'étape sans doute la plus importante puisque ce qui est en jeu dans ces oeuvres c'est non seulement l'augmentation des possibilités sonores des instruments de musique mais surtout l'exploitation de nouveaux gestes interprétatifs".

and InterPARES II (International Research on Permanent Authentic Records in Electronic Systems)[25]. Theory and practice must come together in a consistent framework that can address preservation needs for musical works involving technological components (Boutard, Guastavino, & Turner, 2012).

In 2006 Gladney stated, "many articles about digital preservation come from the cultural heritage community, which is somewhat unfortunate as the IT community is not involved". This situation seems to have improved, since some projects, such as CASPAR, are committed to the preservation of cultural and artistic digital artefacts from an engineering point of view. Nevertheless, in this context, these artefacts represent testbed documents, which are not essentially different from any other digital document. The project, based on the OAIS (Open Archival Information System) (2002), is addresses primarily readability issues, that is to say, the ability to retrieve and process a digital file in the future (B. Lee, 2000). We argue, following InterPARES II, that the specific preservation issues these artefacts raise enlighten digital curation as a whole as well as the theory of digital archives[26].

InterPARES II addressed the question of authenticity, focussing on the interactivity of the records. In regard to electronic music, the project categorised interaction as 'experiential', that is to say, an environment that provides "user interaction driven not by pre-programmed options, but by the user's interests [...]" (Duranti & Thibodeau, 2006, p. 24). This relates to Rowe's (1993) three-dimensional classification system for interactive music systems [27] in terms of stored representation, and relates specifically to its first di-

[25]In particular, the CASPAR (Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval) project, 2006 - 2009, based on the ISO standard 14721:2003 - OAIS (Open Archival Information System), had the specific goal to implement the OAIS and validate the implementation with three testbeds, namely scientific data, cultural patrimony data, and artistic data. Another project was DOCAM (Documentation et Conservation du Patrimoine des Arts Médiatiques), 2005 - 2010, which focussed on new media arts preservation. The project offered multiple case studies and a taxonomy of works for best practices support (Ippolito, 2003). Finally, in regard to digital archives theorising, InterPARES I, II & III (International Research on Permanent Authentic Records in Electronic Systems), 1999 - 2012, addressed the question of authenticity for digital archives (Duranti, 2001b). Specifically, InterPARES II addressed the question of theorising authenticity in relation to interactive digital artefacts, including contemporary music.

[26]See section 2.2.5.2 for a discussion about digital preservation, digital curation and digital archiving.

[27]The three dimensions are: score driven to performance driven; transformative, generative, or sequenced response methods; and finally instrument paradigm systems to player paradigm systems. The first dimension relates to stored representations, the second to response methods, and the third to the role of non-human agents in the interaction process.

mension, which ranges from score-driven systems to performance-driven systems. In this context, Duranti and Thibodeau (2006) posit that preservation is ensured by a thorough description by the composer of each component's interaction with the other performance components.

Lee's (2000, p.193-204) third focus of attention is intelligibility, that is, the ability to understand the meaning of the preserved file. Intelligibility is closely related to meaningful usability, a term coined by Rothenberg (2000). Indeed, "the relationship between digital preservation and authenticity stems from the fact that meaningful preservation implies the usability of that which is preserved. That is, the goal of preservation is to allow future users to retrieve, access, decipher, view, interpret, understand, and experience documents, data, and records in meaningful and valid (that is, authentic) ways" (Rothenberg, 2000, p. 54). We argue that intelligibility has been overlooked in the course of these projects and requires research attention in order to account for meaningful re-performance of digital records (following Cunningham's (2008) view on the performance of archives, see section 2.2.5.5).

1.3 Preservation of contemporary works with live electronics: a position

Archiving musical works with technological components raises several preservation issues since the goal is not to archive the recording of the performance but the means to re-perform the work (Bernardini & Vidolin, 2005). In 2006 Bossis, on the topic of the analysis of electroacoustic works, stated, "the preoccupation with documentary sources related to the acts of creation, interpretation, and technological context becomes more and more pressing" (p.101). Our research is, indeed, at the crossroads of documents, technology, and creative processes. So far, the specific preservation issues of contemporary music with live electronics have been discussed in the context of the technology itself, either in terms of hardware, or software.

> But how do things 'contain' knowledge? How do we write our knowledge into artefacts, and how do we read that knowledge from them? By the same token, how does this relate to digital musical instruments? (Magnusson, 2009, p. 171)

These questions summarise issues digital archives should address. Our approach focusses on the knowledge involved during the creative process, which involves multiple agents, both human and technological. Consequently, this research has strong ontological as well as epistemological implications.

In the context of the preservation of musical works involving technological components, where generally we have to deal with the "consequences of limited media life expectancy and hardware and software obsolescence" (Gladney, 2009, p. 401), and where specifically migration is a fundamental mode of survival (Yong, 2006), we need to provide digital records with intelligibility for reuse, migration, and analysis. Building on Duranti and Thibodeau's (2006) recommendation for a thorough documentation we argue that preservation issues for musical works with technological components, such as digital sound processing, need to be addressed in the context of the process of their creation, that is to say a process that involves not only the composer but many agents (both human and non-human), as well as that of archival practice (Boutard et al., 2012). Thus we need to establish the potential link between creative processes, intelligibility and models of digital archives.

In order to do so, this research will investigate several research areas:

- The performance of digital archives: the issue of intelligibility as regards the sustainability in the production of digital artefacts implies a theorisation of the notion of the performance of digital records for proper management of digital archives as well as a suitable methodology of data collection for producers.
- The knowledge management of creative processes: new artistic productions with a high dependency on technology generate a significant amount of intangible expertise. The tacit and explicit knowledge (Polanyi, 1962) produced during the work's production life-cycle needs to be investigated.

- Music and human-machine interaction: new interaction interfaces imply models going beyond the classic hierarchical paradigm of text/action exemplified by the score (Gurevich & Treviño, 2007) and investigate the creative processes of contemporary works with live electronics. New compositional paradigms foster new social systems in music production (Stiegler, 2003; Delalande, 2007), involving actors such as the computer music designer, the sound engineer, and the performers, in addition to the composer.

Consequently, in the following chapter we present a literature review corresponding to these three research areas. The synthesis of the literature review is presented in section 3.2 leading to the research questions and hypotheses in section 3.3.

Chapter 2

Literature review

2.1 Introduction

The literature review presents the state of the art of research in regards to our goals, which we introduced previously (see chapter 1). We have divided this chapter according to the domains of research we have identified for their relevance to the challenge of the preservation of contemporary music with live electronics, namely digital archives research in section 2.2, knowledge management in section 2.3, and music research in section 2.4 In each section we present sociological investigations related to the domain of research, which inform our ontological and epistemological position in the context of interdisciplinary research, as discussed in the methodology chapter (see chapter 4).

2.2 Digital archives and digital curation

2.2.1 Introduction to the international context

In 2002, Lee, Slattery, Lu, Xiao, and McCrary published an article on the state of the art for digital data preservation. They listed several projects and case studies, notably CEDARS, CAMiLEON, NEDLIB, NARA, Kulfturarw, NIST, and InterPARES (1999 - 2012) (*InterPARES*, 2010). Concomitantly 2002 is the year the OAIS (Open Archival Information System) reference model (*Reference Model OAIS*, 2002) was published by CCSDS (Consultative Committee for Space Data Systems). This committee's goal was to achieve ISO standardisation (ISO 14721:2003)[1]. Since then numerous projects have arisen, e.g. CASPAR (Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval, 2006 - 2009) which proposed a strictly compliant OAIS implementation and set several testbeds in the cultural, artistic, and scientific domains. Other noteworthy projects include DPE (Digital Preservation Europe, 2006 - 2009), Planets (2007 - 2010), DOCAM (Documentation et la conservation du patrimoine des arts médiatiques, 2005 - 2010), PrestoPRIME (2009 - 2012), all of which deal with long term preservation of digital media objects. In this section, we will refer specifically to two of them, namely CASPAR and InterPARES II, for these projects have significantly addressed the questions of music artefacts preservation and interactive environments.

In 2000, Lee articulated the challenges for the preservation of documents generated during the creative process of electronic music:

> Their readability (how do we know we will be able to retrieve the digital documents?) and intelligibility (how will we know what the documents mean?), as well as adequacy of representation and authenticity (how will we know that the reliability, identity, and integrity of the document has not been compromised in some way?). (p. 193)

[1] The new ISO reference of the OAIS (2012) is ISO 14721:2012.

We are aware that these issues are not independent, but will discuss them separately for the sake of clarity.

2.2.2 Readability

2.2.2.1 Ingest and The OAIS model

In 2002 CCSDS (Consultative Committee for Space Data Systems) published the OAIS (Open Archival Information System) (*Reference Model OAIS*, 2002), a digital archive model that achieved ISO (International Organization for Standardization) standardisation in 2003: ISO 14721:2003. The OAIS defines six functional entities: ingest, archival storage, data management, administration, preservation planning, access[2]. In this research we are especially interested in the link between archives on one hand and producers and stakeholders on the other hand. From this perspective, the ingest entity is specifically relevant.

The goal of the ingest entity (see figure 2.1) is to receive submissions, ensure quality, generate AIPs (Archival Information Packages), generate descriptive information, and coordinate updates. Ellis (1993) emphasises the role of acquisition policies.

> Once the acquisition policy has been officially endorsed every acquisition should be assessed against the criteria outlined in it. However, it is worth emphasising that acquisition does not take place in a policy vacuum. (p. 142)

[2]Many concepts in the OAIS are not specific to the digital world and can be traced back to standard archival theory. Couture's (1999) last archival function, namely, *préservation*, directly relates to the functions of the preservation planning entity: "evaluating the contents of the archive and periodically recommending archival information updates to migrate current archive holdings, developing recommendations for archive standards and policies, and monitoring changes in the technology environment and in the Designated Community's service requirements and Knowledge Base" (*Reference Model OAIS*, 2002, p. 4-2). In fact, each post-ingest function in Couture's plan of action may be related to an OAIS entity: *classification*; *description* and *indexation*; *diffusion*; and *préservation*. This situation provides the basis for Cunningham's (2008) criticism of the OAIS model: "the Open Archival Information System (OAIS) reference model is deficient because it ignores the need for pre-ingest archival activity" (p. 530).

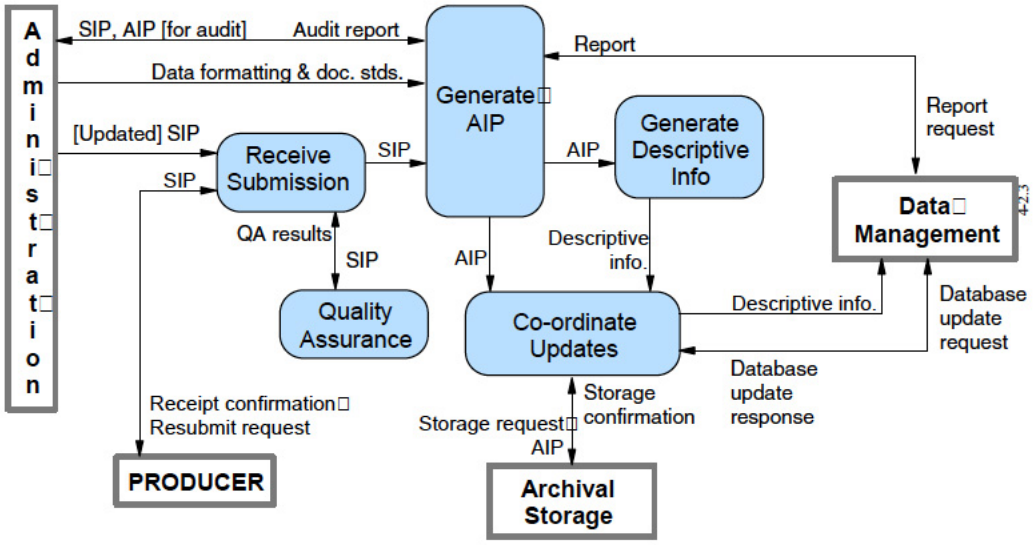

Figure 2.1 OAIS ingest entity. Adapted from *Reference Model OAIS*, 2002, p. 4-5.

In the OAIS the link between digital archives and producers is based on the submission agreement: "the Negotiate Submission Agreement function solicits desirable archival information for the OAIS and negotiates Submission Agreements with Producers" (*Reference Model OAIS*, 2002, p. 4-10). The submission agreement is composed of several submission operations based on the model negotiated between archives and producers. It identifies SIPs (Submission Information Packages) that have to be provided. The specification of acquisition is, consequently, out of the scope of the OAIS as long as the submission operations satisfy the minimal requirements for completeness in the OAIS. This limitation is acknowledged in the OAIS since this point is explicitly added to the list of potential future research areas: "standard(s) for the submission (ingest) methodology used by an archive" (*Reference Model OAIS*, 2002, p. 1-4). In this context, it is noteworthy that the TRAC (Trustworthy Repositories Audit & Certification) (2007), provided by the CRL/OCLC (Center for Research Libraries / Online Computer Library Center), specifies the need for "procedures related to ingest" (p. 81).

2.2.2.2 Representation Information

Representation information is a central concept of the OAIS and specifically addresses the question of readability. It specifies the link between the binary data and the information it embeds[3]:

> The Information Object is composed of a Data Object that is either physical or digital, and the *representation information* that allows for the full interpretation of the data into meaningful information. (*Reference Model OAIS*, 2002, p. 4-19)

Representation information is then divided into two complementary entities: *structure information* and *semantic information*. The *structure information* makes the data format explicit, "it does this by describing the format, or data structure concepts, which are to be applied to the bit sequences and that in turn result in more meaningful values such as characters, numbers, pixels, arrays, tables, etc" (*Reference Model OAIS*, 2002, p. 4-21). On the other hand, the *semantic information* is defined by exclusion, it is what is lacking in the *structure information*, and not part of the format. The OAIS acknowledges that the boundary between the two information types may be difficult to set:

> *Representation information* contains both *structure information* and *semantic information*, although in some implementations the distinction is subjective.

However, the distinction is relevant in the model, for it removes the combinatorial explosion: an element of *semantic information* may be associated to multiple elements of *structure information*.

An important characteristic of *representation information* is the specification of its recursive property, that is to say that *representation information* may imply further *rep-*

[3]From this perspective, the relation between data and information that is implied by the OAIS refers to the DIKW model described in section 2.3. On the other hand, the OAIS concept of *designated community* (that is to say, "an identified group of potential Consumers who should be able to understand a particular set of information" (*Reference Model OAIS*, 2002, p. 1-10)) directly relates to Shannon's (1948) information theory: a receiver decodes the signal into a message.

resentation information. The recursive process stops thanks to the designated community knowledge base definition. Consequently, the OAIS will not provide any further *representation information* when no further specifications are of use for a designated community to access the information. Therefore, in theory, each community may meet its specific needs or at least specify what it does not need.

From this perspective, the *representation information* addresses primarily the readability of digital archives.

2.2.2.3 Preservation Description Information

Another fundamental concept of the OAIS, not directly related to readability, is the PDI (Preservation Description Information). The PDI provides the OAIS, and specifically the *information package*[4], with relevant metadata about *provenance*, *reference*, *fixity*, and *context information*[5]. Concepts like provenance, context, and integrity, partially relate to the specification of authenticity that has been addressed in the context of the InterPARES project.

[4]The *information package* is : "the *content information* and associated *preservation description information* which is needed to aid in the preservation of the *content information*" (*Reference Model OAIS*, 2002, p. 1-11).

[5]Provenance and context refer partially to archival theory. Provenance is a core element of archival arrangement: "the principle of provenance, a European contribution to the American archival profession, stems from the French principle of *respect des fonds*, which provides that records from similar types of institutions should be grouped into fonds" (Schellenberg, 1965, p. 90). *Context information* partially relates to the principle of original order, which is that "records should be kept in the order originally imposed on them" (Schellenberg, 1965, p. 90). Identification information provides the model with identification, for example a ISBN (International Standard Book Number). Integrity information provides the way to track modification using, for instance, CRC (Cyclic Redundancy Check).

2.2.3 Authenticity

2.2.3.1 Reliability, authenticity, and integrity

Authenticity is a highly polysemic[6] word (see MacNeil & Mak, 2007), still authenticity is a central concern of archival theory[7] since archives act as a proof[8] as well as information (Rousseau & Couture, 1994). As Mak (2012) puts it, "many investigations take as their point of departure the notion of documentary authenticity that was introduced to the study of contemporary records by Luciana Duranti and others in the 1980s. This particular understanding of authenticity, founded in the discipline of diplomatics, quickly became a fixture in discussions about the creation, maintenance, use, and preservation of digital records" (p. 3)[9].

Following on the specification of value[10] by Rousseau and Couture (1994), Frey (2009) posits authenticity as an attribute of the information object, and accordingly states that the subsequent questions for digital preservation are: how to digitally preserve a physical information object, and how to preserve the authenticity of a digital information object.

[6] And highly polemical, considering this statement by Muños-Viñas (2009): "in reality authenticity is not that important: that the role that authenticity plays in conservation is fictional; or, at the very least, that authenticity, as the notion is used in conservation, has little to do with the meanings that the notion seems to convey" (p. 33). He further states: "the role of authenticity as a core value of conservation may be fictional, but this is not necessarily a criticism. Fictions may be useful or even necessary, but we (those who sustain the fiction) need to be aware that it is a fiction — or, at the very least, that the meaning we confer to the notion of authenticity has important peculiarities" (p. 38).

[7] See Park (2001) for a survey on the dimensions of authenticity for practitioners.

[8] According to MacNeil and Mak (2007) one interpretation possible for the word is "authentic as trustworthy statement of fact" (p. 27).

[9] Mak defines diplomatics as "the systematic analysis of documentary evidence. It offers a method of interpretation founded on the intimate study of archival sources, including their material, form, and the conditions of their production" (p. 4).

[10] That is to say, "chaque document, quels que soient son support ou sa nature et indépendamment de toute autre considération, par le seul fait d'exister, atteste d'une ou de plusieurs informations qu'il renferme et, partant, qu'il nous livre. C'est la valeur d'information du document. Par ailleurs, le regroupement de toutes les archives d'une personne physique ou morale en un ensemble permet, à certaines conditions, de recréer le contexte de réalisation d'un évènement, l'environnement de vie d'un personnage ou d'un organisme. Bref, cet ensemble replace ce contexte ou cet environnement dans le temps et dans l'espace, les met en relief par une présentation en perspective. Telle est leur valeur de preuve qui fait des archives des témoins privilégiés et objectifs des composantes de la vie de la personne physique ou morale qui les a constituées" (Rousseau & Couture, 1994, p. 72-73).

Under the supervision of Luciana Duranti, the InterPARES I project (1999-2001) and, more specifically, its authenticity task force, chaired by Heather MacNeil, offered a conceptualisation of authenticity in the context of digital archives. Duranti (2001a) divides the overall concept of trustworthiness between reliability and authenticity, a conceptualisation which can be traced back to the doctoral work of MacNeil (1998)[11].

On one hand, "reliability refers to the authority and trustworthiness of a record as evidence of what it is about, that is, to stand for the facts it speaks of" (Duranti, Eastwood, & MacNeil, 2002, p. 25). Reliability involves completeness of the form and control over the creation process, which requires authority, capacity, and responsibility for the record creation (Duranti, 2001a, p. 272).

On the other hand, an authentic record is "a record that is what it purports to be and is free from tampering or corruption" (MacNeil et al., 2005, p. 2)[12]. Duranti (2001a) relates the authenticity of a record to "its mode, form, and state of transmission, and on the manner of their preservation and custody" (p. 272).

Frey reminds us that reliability and authenticity are two intertwined notions[13]. Following the conceptualisation of authentic records provided in MacNeil et al., 2005[14], Moore and Marciano (2005) relate authenticity to the concept of provenance. They consider that

[11]This work was later revised, see MacNeil, 2000. MacNeil (2000) concludes that "the societal need to ensure trustworthiness has been recognised since antiquity and continues to be recognised at the end of the twentieth century. While the technological means of assessing and ensuring record trustworthiness have changed fundamentally over time as the sovereign's seal has given way to the electronic seal, the underlying principles guiding those means have remained remarkably consistent. The conceptual adjustments that have been made constitute incremental, rather than radical, change. It seems safe to predict that the pattern of technological transformation and incremental conceptual change which has characterised the evolution of methods for assessing and ensuring record trustworthiness since antiquity will survive into the coming century and into the next age of recordkeeping" (p. 119).

[12]This definition, provided by the authenticity task force of InterPARES I, is significantly broader than the definition provided in Duranti et al., 2002: "a document is authentic if it can be demonstrated that it is precisely as it was when first transmitted or set aside for preservation" (p. 27).

[13]Frey argues, "les deux notions de fiabilité et d'authenticité possèdent des caractéristiques propres qu'il est impératif de distinguer. Ces deux notions doivent, par conséquent, être intellectuellement conservées séparément. Cependant, les composantes nécessaires (signatures, sceaux, tampons, etc.) à la complétude du document, et donc à sa fiabilité, peuvent servir de présomption à l'authenticité du document. L'authenticité d'un document est tributaire de sa fiabilité" (p. 124).

[14]A similar definition is also provided in Duranti, 2001a, 272.

"authenticity is an assertion that a specific digital entity can be identified relative to the context in which it was created" (p.145). Still, Duranti (2001a) states that the goal of diplomatics is to "assess the authenticity of records of unverified provenance, independently of their context" (p. 275).

Authenticity presupposes another concept, namely integrity, which concerns "whether the object has been changed since its creation, and, if so, whether this has altered its fundamental essence"(Duranti et al., 2002, p. 29)[15]. If its integrity is intact, authenticity relates then to the question: "are the assertions made about the object, [...], true or false?" (Duranti et al., 2002, p. 29)[16]. As a consequence, the goal of archivists is "to ensure the authenticity, reliability, and long-term accessibility of permanent electronic records for current and subsequent users. Traditionally, they have done so by gathering documents, establishing provenance, and maintaining and demonstrating an unbroken chain of custody in an evidence-based approach to managing records" (Cloonan & Sanett, 2002, p. 71).

2.2.3.2 Authenticity in the context of interaction

With InterPARES II (2002 - 2007), building on the outcomes of InterPARES I, the project developed an interest for interactive systems (Duranti, 2005) and, in particular, for artistic, performance-related digital objects. In this context, Duranti and Thibodeau (2006) state that "a work of art or recording of an artistic performance may be a record" (p. 22), as long as it satisfies the requirements for records defined during InterPARES I[17]. They further add that InterPARES II do not contradict the outcomes of InterPARES I but broadens them.

[15] MacNeil (2002) states that "an authentic record is one that can be proven to be (a) what it claims to be and (b) free of falsification or inappropriate modification. To assess the authenticity of an electronic record and to maintain it over time, the preserver must be able to establish its identity and demonstrate its integrity" (p. 26). She relates the notion of identity to the ability to distinguish between records and the integrity of records to their wholeness and soundness.

[16] InterPARES builds on a last concept, namely authentication, which describes the process implied by the notion of authenticity, it is "declaration of authenticity in time resulting either by the insertion or the addition of an element or a statement to a record" (Duranti, 2001a, p.276).

[17] Duranti and Thibodeau (2006) summarize these requirements: 1) a fixed form; 2) an unchangeable content; 3) explicit linkages to other records within or outside of the digital system; 4) an identifiable administrative context; 5) an author, an addressee, and a writer; and 6) an action, in which the record participates or which the record supports either procedurally or as part of the decision making process.

Duranti and Thibodeau (2006) enumerate the different systems and their properties: interactive systems, where "each user entry or input from another system causes a response from or an action by the system" (Duranti & Thibodeau, 2006, p. 23). Experiential systems that "provide user interaction driven not by pre-programmed options, but by the user's interests" (Duranti & Thibodeau, 2006, p. 24). Finally dynamic systems, which involve multiple agents, both human and technological:

> The information they present to users or to other systems is highly variable and contingent on multiple and diverse inputs from both users and other systems. (Duranti & Thibodeau, 2006, p. 25)

This taxonomy proposes a hierarchical conceptualisation of interaction with a creator and a user/performer entitled to a certain degree of freedom. Consequently, Duranti and Thibodeau conclude that:

> on the basis of the case studies results, increasingly, both composers and InterPARES researchers are arriving at the conclusion that a work of digital music can only be reproduced if the author describes each digital, intellectual and performing component of it and the interactions among them, by producing a set of instructions for re-creating each part of the piece and the piece as a whole. (Duranti & Thibodeau, 2006, p. 36)

Roeder (2004), who conducted several case studies, during InterPARES II, in the context of musical works , states that "to an archivist, 'authenticity' has a very specific meaning. It stems from that discipline's original concerns with business and government transactions that were recorded on durable media, following established protocols and forms, and set aside" (p. 7)[18]. Relying notably on Davies (1988) for the specification of an 'authentic performance'[19], he argues, compliantly with the perspective of Duranti and Thibodeau,

[18] Roeder relies on Duranti (1998) and MacNeil (2002) for the definition of authenticity, identity and integrity.

[19] According to Roeder (2004), there is a potential relation between the concept of authenticity in archival theory and in art theory, in terms of 'connotations'.

that "in order to preserve a work so that it can be performed authentically one must also preserve these conventions by which the author intended the notation to be interpreted" (p. 8).

Building on Duranti and Thibodeau (2006) statement, we may argue that documentation and authenticity are related but, still, as Young (1988) puts it "such knowledge cannot be fully captured in propositional terms. Not even the composer will be able to describe precisely what his intentions were" (p. 232)[20]. There is a need to take into account all stakeholders of the creative process. Indeed, the point of view of different stakeholders has been emphasised in different contexts that are relevant to our research: cultural artefacts conservation (Muñoz-Viñas, 2005), digital preservation (Knight & Pennock, 2009; Dappert & Farquhar, 2009; C. A. Lee & Tibbo, 2011), music research (see section 2.4.2).

2.2.4 Intelligibility

2.2.4.1 Meaningful usability

CASPAR, which builds on the OAIS, predominantly addressed readability issues. InterPARES addressed significantly authenticity issues. As Bachimont and Blanchette (2006) put it, "intelligibility consists in being able to access the archive item in a physical form enabling the reading process and interpretation of its content". We argue that intelligibility has been overlooked in the context of digital preservation.

[20]Kivy, according to Nattiez (2004a), rejects the notion of authenticity and argues against "la 'culture de l'auteur et du texte' (1995, p. 187), contre le culte du compositeur-qui-sait-tout-de-son-œuvre et l'idéologie romantique qui y est attachée." (p. 1141). On a similar ground Stockhausen (1967) provides us with an impressive list of mediations during the recording process of the KlavierStücke with Aloys Kontarsky (including a very precise depiction of Kontarsky's meals), and concludes : "I mention the technical and material details of the recording sessions because I learned from these sessions how much the recording process, playback quality, and even the pianist's playing is dependent on all these conditions. These were the first recording sessions at which I personally had been present, and I was shaken by the extremely artificial situation, the amount of influence exercised by 'imponderables', and the technical intervention in the musical sphere" (p. 34).

Rothenberg proposed the notion of meaningful usability which closely relates to the idea of intelligibility:

> The relationship between digital preservation and authenticity stems from the fact that meaningful preservation implies the usability of that which is preserved. That is, the goal of preservation is to allow future users to retrieve, access, decipher, view, interpret, understand, and experience documents, data, and records in meaningful and valid (that is, authentic) ways. (p. 54)

Duranti (2001a) reminds us that "another key difference between electronic and non-electronic records is that the latter are kept authentic by maintaining them in the same form and state of transmission in which they were made or received and set aside, while the former are kept authentic by continuous refreshing (i.e., copying them to a new medium presenting the same technological characteristics) and periodic migration (i.e., transferring them from one hardware/software configuration to another or from one generation of digital technology to another)" (p. 273). In this context it is critical to characterise the impact of this specificity. Bachimont (2007) emphasises the fact that digital implies the destruction of the semantics of the content into non-meaningful discrete units. This specific property of the digital object enforces the need to address the intelligibility of digital records. Indeed, we may state that usability is critical to preservation; "a usable digital document can be located, retrieved, presented, and interpreted. In the end, we may find usability the most fundamental of all characteristics. Complete and authentic collections of digital material have no value if we cannot access and use them." (Dow, 2009, p.30)[21]. Distinguishing between *form* and *substance*, Bachimont and Blanchette (2006) further consider that, in the digital world, we cannot anticipate the impact of physical transformation on substance and therefore, a fortiori, on meaning[22], that implies, "archiving can never consist in the mere physical preservation of content. That is, meaning can never be fixed once and for all, in some ahistorical time bubble. Rather, it must be constantly rearticulated and explicited

[21] Similarly Rothenberg (2000) states that "an informational entity that is 'preserved' without being usable in a meaningful and valid way has not been meaningfully preserved, i.e., has not been preserved at all" (p. 54).

[22] They consider that substance is the subject of philology and the meaning of hermeneutics (Bachimont & Blanchette, 2006).

so that it remains accessible through some hermeneutical network of texts, constantly at work minimising the intelligibility gap between an archive and its users." (Bachimont & Blanchette, 2006)[23].

2.2.4.2 Significant properties

Just as authenticity is not independent of reliability, we may argue that intelligibility is not independent of authenticity (in the sense of trustworthiness) and readability, which is implied in the concept of *significant properties*. Significant properties are the characteristics that have to be preserved over time in order to ensure the accessibility, usability and meaning of the objects (Brown, 2008). They emerged during the CEDARS (1998/2002) project (Knight & Pennock, 2009) and are part of the PREMIS (Preservation Metadata: Implementation Strategies) dictionary (Xie et al., 2008).

There is a longstanding debate that concerns the conceptual difference between *significant properties* and the OAIS *representation information*. Hockx-Yu and Knight (2008) state that, according to Brown, "while the former are about the intellectual intent and apply to the abstract information object and properties of the intellectual intent, the latter are specific technical manifestations of the information object and apply to the data object, e.g. format, encoding schemes, algorithms" (p. 148). There lies the significant difference, in the separation between the intellect and the object. Significant properties relate to different levels of abstraction (Hedstrom & Lee, 2002), something that Knight and Pennock (2009) developed by relating them to the four levels of the FRBR (Functional Requirements for Bibliographic Records) model (IFLA, 1998): object, manifestation, expression, work (figure 2.2). Knight and Pennock (2009) acknowledge the overlap in definition with *representation information* in the more concrete levels of the FRBR model: manifestation and object.

[23] In the postface of the new French translation of Arno Schmidt's *Aus dem Leben eines Fauns* (2011), Stéphane Zekian recalls Claude Riehl, Arno Schmidt's emblematic French translator, who died in 2006 (Wagneur, 2006): "Claude Riehl avait coutume de dire qu'une traduction devait être refaite tous les quarante ou cinquante ans. [...] ces renouvellements s'avèrent nécessaires à la fois pour satisfaire aux critères évolutifs de la traduction littéraire, pour faire entendre les bouleversements survenus entre-temps dans la langue d'accueil, mais également pour exploiter les acquis des recherches menées dans l'intervalle sur l'auteur en question" (p. 204).

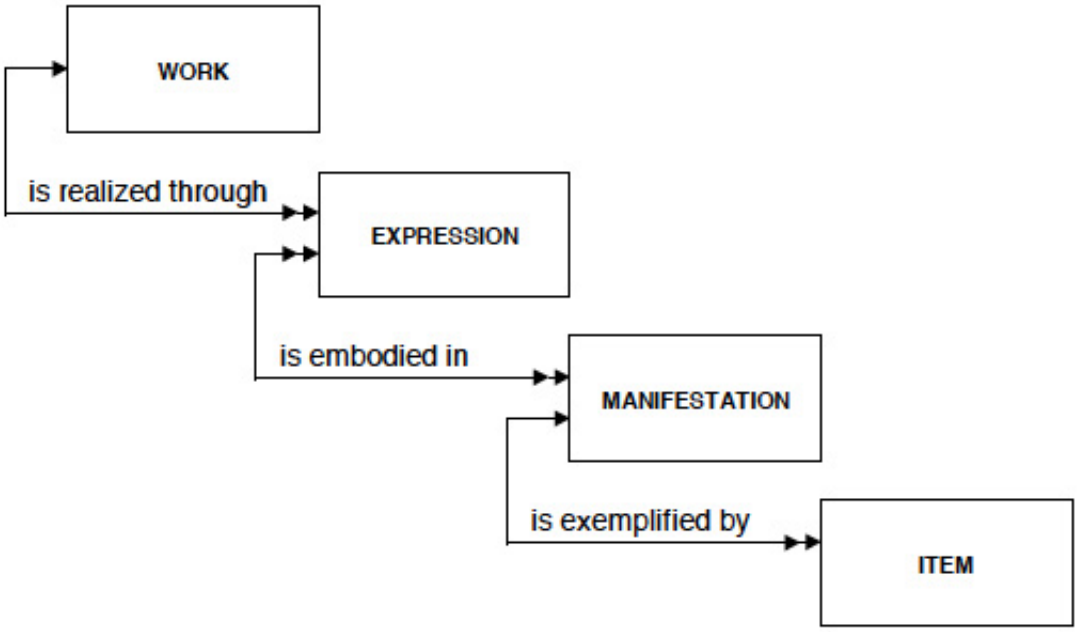

Figure 2.2 FRBR model. Adapted from IFLA, 1998, p. 13.

According to Giaretta, Matthews, Bicarregui, Lambert, and Guercio (2009), the concept of significant properties will be partially integrated in a future version of OAIS as *transformational information property*:

> An Information Property whose preservation is regarded as being necessary but not sufficient to verify that the Non-Reversible Transformation has adequately preserved information content. (p. 72)

In fact, *transformational information properties* have been included in subsequent drafts of the model (*Reference Model OAIS (Pink Book)*, 2009; *Reference Model OAIS (Magenta Book)*, 2012). Unfortunately it will not include abstraction levels as proposed by Knight and Pennock (2009). Matthews, Shaon, Bicarregui, and Jones (2010) proposed to take FRBR and significant properties into account together with the OAIS. They distinguish between software and components in a meaningful way; nevertheless, they do not formalise the link between FRBR entities and significant properties.

We argue that *significant properties*, by directly addressing the different levels of abstraction in their conceptualisation, make explicit reference to the distinction between form, substance, and meaning. As a consequence, while *representation information* relates to readability of digital information, *significant properties* are a first step towards the acknowledgment of the intelligibility of digital records.

2.2.5 Performance and the social grounds for digital archives

2.2.5.1 Introduction

The notion of performance has garnered research attention from diverse perspectives over the past ten years. The InterPARES II (International Research on Permanent Authentic Records in Electronic Systems) project focussed on interactive, dynamic and experiential documents with case studies "in the artistic, scientific, and electronic government fields, focusing on cases which make use of digital technologies in innovative ways" (Duranti & Thibodeau, 2006, p. 22). Interactive documents "include web pages delivering government services online, musical performances based on human–computer interaction, and commercial video games" (Duranti & Thibodeau, 2006, p. 31). The case of musical performances involving human–computer interaction is especially telling because it emphasizes the performance aspects of digital technologies and the subsequent issues of preservation.

2.2.5.2 Digital preservation, digital curation and digital archiving

According to Moore (2008), digital preservation theory is "based on the definition of the minimal set of preservation processes that are needed to implement management policies, and the minimal set of preservation metadata (persistent state information) needed to validate assessment criteria" (p. 64). Moore presents the three challenges of digital preservation: 1) "to incorporate new technology effectively, while conserving preservation properties such as authenticity, integrity, and chain of custody" (p. 64); 2) "the ability to characterize how prior preservation processes have been controlled by preservation management policies" (p.

64); and 3) "the ability to verify that preservation processes and management policies are working correctly" (p. 64).

While digital preservation may be related to processes, Higgins (2011) evokes the evolution of the research area to a broader context: "in the UK cultural and educational sectors, digital preservation efforts originally focussed on ensuring that material survived technical obsolescence and organisational mismanagement. Preservation implied a passive state, where material would be mothballed in an inaccessible 'dark archive', with only a few authorised users, to ensure that it retained its integrity and authenticity. Over the last few years, the focus has shifted to ensuring that digital material is managed throughout its lifecycle so that it remains accessible to those who need to use it."

This is how Higgins circumscribes digital curation, a research area that subsumes digital preservation, which is consistent with Yakel's (2007) definition of digital curation, namely, "the active involvement of information professionals in the management, including the preservation, of digital data for future use" (p. 335). But digital curation did not only extend the question of digital preservation to lifecycles, it also evolves inside a specific academic framework comprising peer-reviewed journals, research centres, and multiple conferences and workshops (see Higgins, 2011). In light of this context, Higgins argues that digital curation is an emerging new discipline. While this conclusion is debatable, the willingness of people involved in digital curation, such as Higgins, to define it as such is undeniable.

For Cunningham (2008), "the value of the phrase digital curation is that it attempts to unite into a coherent whole various threads of related professional endeavors spanning the entire life of digital information. Included within the definition of digital curation are the noble endeavors of digital preservation, digital librarianship, digital archiving, and data management" (p. 531). But Cunninghman argues that, in this attempt, digital archiving is transformed into "a technological subroutine, not a rich and complex professional endeavor in its own right" (p. 532). This reduction of the social context has implications on the readability, authenticity and intelligibility of digital archives.

2.2.5.3 Formal and social approaches to born digital records in context

The readability of digital records Brothman (1999) discussed the lack of interest of the archival community for Derrida's concept of archives (see, for example, Derrida, 1995[24]). He argues that the pragmatic view of the archivist's profession provides little interest for theorisation and that the digital era emphasises an organisational science approach to archiving: "the technologically-induced crisis of electronic records has encouraged increasing numbers in the community to dawn (sic) a corporate, 'business mantle'. All records are becoming characterised as 'business' records, and all aspects of archival practice as 'business processes' " (p. 67). He further states that "the frequent reduction of social and organizational challenges to strategic problems involving information, information technology, and information or knowledge management has an understandable appeal for record keepers – leaving aside the issue of the differences between 'information' and 'records"' (p. 68). Thus, Brothman explicitly relates the position on management with the epistemological grounds for the understanding of an objet such as archives[25]. This tendency for relating archival management and organizational science favours a reduction of the social context to a realist position for the conceptualization of digital archives and a formal approach to management in line with digital curation models such as the OAIS with an emphasis on readability[26].

Brothman's argument relates to Cunningham's (2008) depiction of the reduction of digital archiving fostered by digital curation. While Cunningham's (2008) focus is on the specification of digital archiving in relation to digital curation, we focus on the theorization of the object, namely digital archives, rather than the specification of the procedures associated with the object. In the formal approach to digital archives, emphasized by digital curation, the assumption is that the knowledge relevant to born digital records is inscribed entirely in the record and, therefore, is likely to be addressed in a framework such as the

[24]Interestingly, in this work, Derrida (1995) raises the question: "mais où commence le dehors? Cette question est la question de l'archive. Il n'en est sans doute pas d'autre" (p. 20), a question we approach from another angle in section 2.2.5.4.

[25]Similarly, Hedstrom (1991), deploring the lack of impact of archivists on the design and use of information technology, stated that "archivists have literally lost control over the definition of archive" (p. 336).

[26]See section 2.3.1.1 for a discussion about the relation between the OAIS and the DIKW model.

OAIS' (Open Archival Information System) representation information. From this perspective, the representation information provides the system with the means to formally reconstruct a representation of the digital data (e.g. format specifications). This formal approach emphasises the preservation of the readability of digital documents.

The authenticity of context management Context management emphasises that "special care has to be taken to capture, represent and preserve the information about the context in which the digital objects have been created" (Brocks, Kranstedt, Jäschke, & Hemmje, 2010, p. 198-199). Several frameworks for context specification on multiple theoretical grounds have been provided, e.g. Hurley (1994), Lee (2011), or Duranti and Thibodeau (2006). The question of context in regard to technologies such as recordkeeping systems, is limited to identification within a use context. From this perspective, if "the generation of important contextual information often does not stop at the point of creation" (C. A. Lee, 2011, p. 117), it usually starts there. A convergent point of view is the one of Duranti (2005) who states that "it is necessary to develop an understanding of the new digital objects, not only in the later phases of their life cycle, but from the moment of their creation" (p. 107). This view is consistent with the management of readability, the context is part of a metadata scheme[27] where at best we acknowledge the software environnement for records creation as a specific type of representation information. Indeed, in the OAIS, "software is often used to end the Representation Network" (*Reference Model OAIS (Pink Book)*, 2009, p. E-1). This position stresses preservation issues that highlight the need to preserve the software (see Moss, 2010). The extreme view on formal management of context is the formal logic implementation such as the one proposed by Flouris and Meghini (2007) who aim at "presenting a number of ideas towards a formal, mathematical, logic-based description of preservation as a scientific discipline, to the end of deriving a methodology resting on solid theoretical grounds". This is consistent with the view of born digital objects as formal objects made out of bits, processed formally by a computer. However, as McKemmish (2001) puts it: "the richness, complexity, diversity, and idiosyncrasies of the contexts in which records are created, managed, and used cannot be fully represented in

[27] Thévenot (1993) emphasizes the tendency to reduce objects to their properties: "la saisie des objets dans des propriétés participe de leur insertion politique et d'une civilisation des choses. [...]Plutôt que de dénoncer le formalisme de ce traitement, il importe d'en montrer la validité et les limites, par une exploration systématique des modalités du commerce avec les choses" (p. 108).

models, systems, standards, and schema, but this does not detract from their significance and strategic importance to practice. By their very nature conceptual models, metadata schema and standards, and archival descriptive systems are an exercise in reductionism" (p. 354). Reduction[28] may be justified as long as we understand and assess what is put aside, so that we consider the right strategies to adopt for context management. This is critical, since, as Moore and Smith (2007) put it, "if it is possible to define management policies for authenticity and integrity of records, one can assert that a preservation environment is complete when preservation attributes exist for each management policy that track the outcome of applying the policy". Similarly, Frey (2009) explicitely relates digital preservation to the preservation of authenticity[29].

If we need to document how "archivists construct a variety of interfaces between the past and the present through choices about what to keep, how to represent archival documents and collections, how to design systems for access, and who to admit or exclude from interactions with archives" (Hedstrom, 2002, p. 26), we have to provide an account of the context that acknowledges the role of technological mediation. Latour (1994) states that "technical action is a form of delegation that allows us to mobilise, during interactions, moves made elsewhere, earlier, by other actants" (p. 52). The consideration of technical action as part of the context of records may modify the answer to the question posed by Lee and Tibbo (2011): where's the archivist in digital curation? The consequences of the organic link between records and the social principles of delegation that their technological context implies are eminently highlighted in the context of migration. When dealing with migration we are dealing with loss, and still we attempt to preserve authenticity.

> There are components of the record that can be lost without compromising its substance and the ability to verify its authenticity overtime (sic), and others the loss of which would be equivalent to the loss of the record. (Duranti, 2001a, p. 274)

[28] A literary exemple of formal logic reduction is ironically proposed by Ben Marcus (2002): "this book required seven Simplification Batch Processes on the Language Cleaner Machine in order to render a legally binding one-hundred-word summary of its contents for the Annual Brochure of All Texts. The resulting one-hundred-word summary of this book proved too legally similar to the Declaration of Independence to be included here" (p. 53).

[29] See section 2.2.3.1.

In the context of migration we disconnect the record from its organological link to the technological environment in which it was created[30], and we replace delegation processes with new delegation processes, which may or may not be justified.

2.2.5.4 Intelligibility and the boundaries of born digital records

Postmodern theory helped archival theorists reconsider the specification of the boundaries of archives. Ketelaar (2001) stated, "archival researchers and archivists are exploring a multiplication of perspectives. They are learning (or relearning) from anthropologists, sociologists, philosophers, cultural and literary theorists: to look up from the record and through the record, looking beyond – and questioning – its boundaries [...]" (p. 132). Questioning boundaries is critical for sustaining the intelligibility of records; nevertheless, the post-modernist approach to archives tends to consider this question from the specific angle of interpretation[31], since "some of what makes a record meaningful is inscribed within it, but often much of what makes it intelligible is not. Thus most of a record's 'recordness' lies outside its physical borders within the context of its interpretation" (Nesmith, 1999, p. 144). We argue that the boundaries of archives are transformed by technology, especially digital technology, according to the status granted to technological agents. Specifically, in relation to the archival theory influenced by post-modernism, boundary issues exceed the question of interpretation and involve, as we previously stated, according to Latour's (1994) view of technological mediation, actions carried out previously by numerous agents during the creation process of record-making systems. Thus, the use of digital technology requires characterising the social context of digital records within the scope of the technological mediations involved in record-making systems so that we may be able to characterize the action of 'performing' digital archives. This question has a social dimension, related to the agents involved in the creation of a record, and a temporal dimension, related to the process of creation of the technological framework.

[30] Which in an OAIS could be interpreted as the shift from one representation information to another representation information, both potentially being software. From a formal point of view the justification for such an action could be based on the preservation of the OAIS' *Transformational Information Property*.

[31] Interpretation in this context is meant as an hermeutical process, not as the performance of a work.

The social dimension of digital records According to Cook and Schwartz (2002), "the principal impact of postmodern theory on archival practice would be to acknowledge the central role of the archivist as mediator and interpreter, as an important shaper of the documentary record of the past that will be passed to the future" (p. 183). However, this focus on archivists lessens the impact made by other agents, both human and technological, on the preservation of the intelligibility of digital records. Cunningham (2008) states that "records provide evidence of decisions and activities. They derive their meaning and value from a myriad of contextual relationships surrounding their creation and use—relationships that have to be documented and understood [...]. Because records are created within systems that support and enable human activity [...], to understand records as evidence of human activity it is necessary to understand how their systems of creation and use operated" (p. 532). This critical statement has to be investigated in the context of the social boundaries that we previously emphasized. From this perspective, the specification of the nature of stakeholders becomes critical to the preservation of the intelligibility of digital archives. As Dappert and Farquhar (2009) put it, significance is in the eye of the stakeholder. It may seem a truism to state that "a stakeholder attributes significance to something, typically in a context relevant to some purpose or goal. In the digital preservation context, significance is determined by the stakeholders involved in the preservation process. These include the producer of the digital object, the custodian who holds it, and the consumer who will access it" (Dappert & Farquhar, 2009, p. 302), but the range of stakeholders is determined by our account of technological mediation. Indeed, "neither computers nor the Internet mysteriously present themselves to users. Rather, what users see and experience when they interact with computer systems reflect design decisions made by system designers, software engineers, and programmers" (Hedstrom, 2002, p. 33). Thévenot (1993) reminds us that the consistency of technical objects is related to intricate relationships between agents, including both human and technological agents[32]. This intricacy emphasizes the complexity of technological mediation, which can not be reduced to the reflection of a design experienced by users as described by Hedstrom. Beside the principle of delegation, fundamentally "action is a property of associated entities" (Latour, 1994, p. 35).

[32]"Les sociologues et anthropologues des sciences [...] ont mis en évidence l'intrication des liens entre humains et non-humains dans des réseaux qui confèrent leur consistance aux objets scientifiques et techniques" (Thévenot, 1993, p. 85).

The temporal dimension of digital records This intricate relationship between agents, both human and technological, may be hidden by a formal approach to digital archives that focuses on readability of digital records. Indeed such a formal approach addresses the preservation of readability by providing an account of the significance of the creation process mainly as a metadata scheme for context management. A priori, this approach is sensible since the reduction it implies may be difficult to acknowledge if one takes for granted the software environment. As Latour (1999b) puts it, "scientific and technical work is made invisible by its own success. [...] Thus paradoxically, the more science and technology succeed, the more opaque and obscure they become" (p. 304). A posteriori, the technological mediation that we presented earlier extends the creation process to the creation of the technological context, namely record-making systems[33]. Thus the intricacy encompasses not only the archivist, as emphasized by a postmodern view, and the creation context of the records, formalized in digital curation models, but also the creation of the technological context, which involves controversies[34] during the design that are especially relevant to the intelligibility of the records. According to Callon (1981), technological controversies reveal negociations that frame technical choices as well as extensions of a solution to a broader context[35].

The intelligibility of digital records in context Cunningham (2008) states that "records provide evidence of decisions and activities. They derive their meaning and value from a myriad of contextual relationships surrounding their creation and use—relationships that have to be documented and understood. [...] to understand records as evidence of human activity it is necessary to understand how their systems of creation and use operated" (p. 532). Born digital records are organically linked to a social environment

[33]The Australian archival research community theorised an alternative to the archival lifecycle, namely the continuum (Atherton, 1985): "the impact of the computer on the life cycle has been striking, for with electronic data the stages in the life cycle cannot be separated" (p. 47). This view leads Cunningham (2011) to argue that in the future record-making systems may also be record-keeping systems. Whether we focus on the lifecycle or on the continuum, born-digital records are organically related to their record-making systems.

[34]See section 6.5 for a definition of controversies according to Venturini (2010).

[35]That is, "les mécanismes par lesquels certaines solutions, qui s'imposent d'abord localement, finissent pas s'étendre à toute la société" (Callon, 1981, p. 383).

that comprises record-making systems[36] previously implemented; it forms what Hutchins (1995) refers to as a cognitive ecology[37]. In this 'ecological' context, the understanding of boundaries between agents, both human and technological, is critical to the intelligibility of digital records. As Hutchins puts it, "if we fail to bound the system properly, then we may attribute the right properties to the wrong system, or (worse) invent the wrong properties and attribute them to the wrong system" (p. 356). From this perspective, Cunningham's (2008) statement: "apparently 'archiving' is now just a technological subroutine, not a rich and complex professional endeavor in its own right"(p. 532), has a specific resonance. Finally, the intricate network between agents (both human and technological), described earlier is critical to help better understand the difference (which digital curation tends to blur) between libraries, archives and museums in the digital age.

2.2.5.5 The performance of digital archives

From the point of view of archival theory, when Cook and Schwartz (2002) talk about the performance they talk about the performer, that is to say the archivist. We suggest extending the question: "How, then, should the archivist perform in our postmodern world?" (p. 172) with the following question: Who is performing in our digital world? On one hand post-modernism introduced a social emphasis in archival theory that helped to redefine the boundaries of archives. On the other hand digital curation theory tends to divide the world between the social and the technological. This process leans toward a generic methodology for the management of digital objects and for the preservation of technology on technological

[36] And, therefore, agents such as the ones identified by Hedstrom (2002), namely system designers, software engineers, and programmers.

[37] That is to say, a system "in which the various representational technologies constitute one another's functional environments" (Hutchins, 1995, p. 168). In this context, Hutchins describes the cognitive processes as part of an environment that comprises technology. Tools are not just amplifiers of cognitive activity and the cognitive task of a system is different from the cognitive tasks of individual members. As Hutchins puts it: "the firm drawing of the inside/outside boundary creates the impression that individual minds operate in isolation and encourages us to mistake the properties of complex sociocultural systems for the properties of the individual minds" (p. 355). Thévenot (1993) considers Hutchins' work to be in direct continuation of the work of Leroi-Gourhan (1945) on the technical milieu in relation to the external milieu: "constituant l'enveloppe du milieu technique, des objets matériels : outils, armes, vêtements, habitation, etc... forment le groupe technique qui s'interpose entre le milieu technique et le milieu extérieur" (Leroi-Gourhan, 1945, p. 370).

grounds. We argue that archival theory confronted with the technological world of born digital records may benefit from reintroducing social concerns as an alternative to a formal theorisation of preservation. This process may help redefine digital archives, as an object of research, in a more holistic way than digital curation tends to conceptualise it and extend the management of readability to the preservation of intelligibility.

In the context of film curatorship, Cherchi Usai, Horwath, and Loebenstein (2008) stated that the difference between two technological instances of a performance, one original and one migrated, "might be in how the work came about, and how this process shaped the result in hundred ways" (p. 109). Cunningham (2008) states that, in the digital world, records have been described as allographic, that is to say a prescription implying a subsequent interpretation.

> It is part of the character of these resources to be copied and reinterpreted in different contexts. Thus, if one of the qualities of digital materials is to be allographic, that is, to enable copying and manipulation and to be used in different ways and for different purposes, this aspect may need to be accommodated in the process of preservation. (MacNeil & Mak, 2007, p. 46)

This allographic quality relates to the loss of semantics which the principles of discretisation in the digital world implies[38]. The understanding of the prescriptive nature of digital objects is therefore critical to the theorisation of digital records as well as the archival lifecycle. The Australian archival research community conceptualises digital records as performances, that is to say a combination of a source and a process, namely "the technology required to render meaning from the source. When a source is combined with a process, a performance is created and it is this performance that provides meaning to a researcher" (Heslop, Davis, & Wilson, 2002). According to Cunningham (2008), "digital records are performances—the result of an interaction between data and technology. The preservation imperative, therefore, is not so much one of preserving the data, as of preserving the ability to recreate the performance in a way that accurately and authentically replicates

[38] Bachimont (2000) states that "le numérique ramène toutes les entités à des unités manipulées, indépendamment de la signification associée à ces unités" (p. 11).

the essential aspects of the user's experience of the record" (p. 539). In the light of our discussion we may be able to provide an extended view of the performance of digital records.

We have argued that this allographic characteristic of the digital world requires the inclusion of the principles of technological mediation, which involves multiple agents, both human and technological, within the scope of our research. The agencies involved in the performance of digital archives, highlighted by the cognitive ecology view, have an impact on our ability to maintain the intelligibility of digital archives which requires further investigation[39]. Because of the social and temporal boundaries of these agencies involved in the performance of digital archives, we need to "study innovations in the artisan's workshop, the engineer's design department, the scientist's laboratory, the marketer's trial panels, the user's home, and the many socio-technical controversies" (Latour, 2005, p. 80). As suggested by recent research on the preservation of digital artefacts musical works with technological component, this approach is likely to provide a ground for establishing contextual frameworks capable of rendering more accurate strategies to "deliver meaningful digital records as performances in context to our end users" (Cunningham, 2008, p. 540).

2.2.6 Conclusion

We have argued that the digital archiving and digital curation communities have dealt with readability and authenticity issues but that further research in needed to address intelligibility. Technology and formal models may not be sufficient to guarantee the preservation of the intelligibility of digital archives. We argue that archival theory and practice consequently need to consider the technological mediation processes at stake when digital archives are re-performed.

Archival theory, influenced by post-modern theory, introduced a social emphasis in the archival research community that helped redefine archives boundaries. On the one hand, digital curation theory tends to divide the world between human and technological agents

[39] As Latour (2005) puts it, "if you mention an agency, you have to provide the account of its action, and to do so you need to make more or less explicit which trials have produced which observable traces" (p. 53).

for management purposes. This process leans toward a generic methodology of management of digital objects and on the preservation of technology on engineering grounds. On the other hand, archival theory confronted with the technological world of digital-born records may benefit from reintroducing social concerns as an alternative to formal theorization of preservation. This process may help define the object of research, namely digital archives, in a more specific way than digital curation tends to conceptualize it.

We reinvested the question of boundaries with a focus on the conceptualisation of performance of digital records with temporal and social dimensions. We proposed a reclamation of the question of intelligibility by extending the scope of the two notions developed in the digital archives research community. On one hand the notion of significant properties is a ground for documenting the knowledge involved in the creative process of digital artefacts according to multiple levels of abstraction. In a context where tacit knowledge is considered to be critical (see chapter 6 and 7), its impact on significant properties should be investigated. On the other hand within the theory of digital archives, the notion of performance for allographic digitally-born records enlightens the relevance of the investigation of the preservation of our object of research, namely, contemporary works with live electronics. It provides us with an extended view of stakeholders and the social context of records creation and use. These two notions may help us to design better ingestion protocols between digital archives and data producers. As Hedstrom (1991) puts it, "a perspective that considers technologies as 'socially constructed' provides grounds for a cautiously optimistic view that archivists can influence key information technologies because it acknowledges that humans retain varying degrees of control over the design of technology" (p. 341)[40], a degree of control that should be investigated in light of the concept of technological mediation.

[40]See section 2.3.3.2, for a discussion about contructivism in the scope of Latour's theory.

2.3 Knowledge Management

2.3.1 Knowledge and information science

It is not our goal in this review to present the history of epistemological theories but to present different understandings of the relationship between information and knowledge that are relevant to our knowledge management concerns within information science.

2.3.1.1 DIKW

The DIKW (Data Information Knowledge Wisdom) model is a well-documented hierarchical framework based on four concepts and symbolised as a pyramid construction with wisdom on top. In this system, according to Davenport and Prusak (1998), data is "a set of discrete, objective facts about events" , information is "a message, usually in the form of a document or an audible or visible communication", and knowledge "a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information". Balmisse (2002) proposes a simpler definition: information is data in context and knowledge is information in use[41]. The OAIS (2002) model (see section 2.2.2.2) relies on a DIKW compliant definition of information: information is "any type of knowledge that can be exchanged" (p. 1-10), adding that "in an exchange, it is represented by data" (p. 1-10). Some authors proposed to add a fourth level, namely, wisdom[42].

On this basis, several authors (see Frické, 2008; Jennex, 2009) have criticised the model, pointing, for instance, at the fundamental reduction system of the model (Ma, 2012a).

[41] There are many variations on these definitions in the context of the DIKW model (see Zins, 2007b, 2007a; Bates, 2005). Nevertheless, all of them stick to the added value paradigm and tend to consider information as a mediator between data and knowledge.

[42] Wisdom would be, from this perspective, "as an organisation of knowledge that maximises success" (Houston & Harmon, 2002). Frické (2008) notes that, "while wisdom is traditionally taken to be a layer in the hierarchy, few authors discuss it or use it" (p. 133).

> Although few people will argue that knowledge can ever be reduced to data, the two terms are unwittingly brought into a forced marriage by having the term information act as an informal go-between. (Boisot & Canals, 2004, p. 44)

According to Frické (2008, p. 134), the intellectual background for the DIKW model is, in particular, positivism.

2.3.1.2 Information and processes

Machlup (1983) also criticises the DIKW model, pointing out that "an attempt to read and interpret it [an inscription] is part of the process of information. Information takes at least two persons: one who tells (by speaking, writing, imprinting, pointing, signaling) and one who listens, reads, watches" (p. 645), a position that relates to Capurro's (1991) definition of the *source channel-receiver paradigm*. In this context, information is a syntactic arrangement of signs that are transmitted and received according to common coding-decoding schemes. This paradigm is closely related to Shannon's (1948) information theory and therefore closer to computer science's view on information[43]. It does not specify its relation to knowledge[44]. Nonaka, for example, relies on the famous platonic definition of 'justified true belief'[45]. Boisot and MacMillan (2004) subscribe to a different perspective. They argue that "different mindsets will emphasise different combinations of

[43] Insterestingly, Moles (1966) famously applied information theory together with gestalt principles to the music context; and Schaeffer (1971) claims he initiated Moles to *musique concrète*. Holmes (2002) states: "a research assistant named Abraham A. Moles also joined the group [Groupe de Recherches Musicales] in 1951. Schaeffer and Moles developed one of the first formal aesthetic handbooks for electronic music. In it, they catalogued sounds, described the various tape-editing techniques that formed the basis of musique concrète, and tried to establish a philosophical basis for the new medium" (p. 95).

[44] We note that for Bachimont (2004), "une connaissance est la capacité d'exercer une action pour atteindre un but" (p. 65). Knowledge is therefore ideal and implies repetition: "l'idéalité de la connaissance se traduit également par le fait que la capacité de réaliser une action renvoie à la possibilité de répéter cette action" (Bachimont, 2004, p.66). From this perspective, it relates to Markus' (2001) study about situations and factors for knowledge re-use, but Markus does not provide an ontological and epistemological ground for the characterisation of knowledge.

[45] A definition also famously criticised by Gettier (1963). For a review of further critics see Kakabadse, Kakabadse, & Kouzmin, 2003. Nonaka and von Krogh (2009) will later revise this position: "however, because individuals may not be able to articulate all their beliefs and justify them (tacit knowledge), it seems not all knowledge is justified true belief" (p. 637).

the components 'belief', 'truth' and 'justification' " (p. 507). Boisot and Canals' (2004) view on knowledge is grounded in Shannon's entropy, but they state that information theory "concerns itself primarily with the challenge of information transmission rather than with problems of information content or meaning" (p. 51)[46]. They propose to define three levels of entropy for this concern; the one related to knowledge is the 'cognitive entropy' level.

Whether in the view of Nonaka or Boisot, their move away from the DIKW model enables them to include a distinction between tacit and explicit knowledge[47], a distinction grounded in Polanyi's (1962) conceptualisation of the difference.

2.3.1.3 Tacit knowledge

Tacit knowledge, first introduced by Polanyi (1962), became central in knowledge management in the 1990s. Martin (2008) describes the explicit knowledge as "formal, identifiable, easy to capture and transmit" (p. 372), while tacit knowledge is "informal, tied to the senses and innate personal skills, not always possible to articulate" (p. 372)[48]. Nonaka (1998) further describes these concepts :

> Explicit knowledge can be expressed in words and numbers and shared in the form of data, scientific formulae, specifications, manuals, and the like. This kind of knowledge can be readily transmitted between individuals formally and systematically. (p. 42)

[46] Meunier (2002) also emphasises the need to put meaning back into information theory through representation. Bennet and Bennet (2004), for their part, try to incorporate tacit knowledge in this paradigm: "we choose to consider knowledge as composed of two parts: knowledge (informing) and knowledge (proceeding). This builds on the distinction made by Ryle (1949) between "knowing that" and "knowing how". Knowledge (informing), or KnI, is the information part of knowledge; it could be implicit, explicit, tacit or any combination of these. KnI represents insights, meaning, understanding, expectations, theories and principles that support or lead to effective action" (p. 407).

[47] Another distinction which partially converges is the one provided by Russell (1912) between knowledge by acquaintance and knowledge by description.

[48] Nonaka and von Krogh (2009) state that tacit knowledge is "tied to the senses, tactile experiences, movement skills, intuition, unarticulated mental models, or implicit rules of thumb" (p. 636).

On the other hand, tacit knowledge gets more complex:

> There are two dimensions to tacit knowledge. The first is the technical dimension, which encompasses the kind of informal personal skills or crafts often referred to as "know-how." The second is the cognitive dimension. It consists of beliefs, ideals, values, schemata, and mental models which are deeply ingrained in us and which we often take for granted. While difficult to articulate, this cognitive dimension of tacit knowledge shapes the way we perceive the world. (p. 42)

But this distinction was contested on the basis that "tacit knowledge thus has come to signify an absolute type, namely: 'not codified knowledge' " (Cowan, David, & Foray, 2000, p. 212). Cowan, David, and Foray (2000), then, propose a distinction between codified knowledge and unarticulated knowledge which could have no 'codebook' or a 'displaced codebook'[49]. Cowan, David, and Foray (2000), in turn, have been criticised by Johnson, Lorenz, and Lundvall (2002) on the grounds that "any body of knowledge might be codified *to a certain extent*, while it is very seldom that a body of knowledge can be completely transformed into codified form without losing some of its original characteristics." (p. 146).

Several authors refer to this notion of dimension in tacit knowledge, rather than categories, using mathematics as a paradigmatic example. Feldman states than even mathematics are not pure logic and integrate some intuitive support[50]. The argument of Feldman can

[49]Martin refers to intrinsic knowledge, that is "knowledge that, although similar to tacit in that it is not explicit, nonetheless can be articulated" (p. 372). For Teece (1981) it is rather a question of economics: "uncodified or tacit knowledge, on the other hand, is slow and costly to transmit" (p. 83).

[50]"Ainsi revient le sujet qui avait été refoulé. La science n'est en effet pas pure logique, objectivité totale. On sait que les démonstrations de mathématiques ne peuvent éviter le langage commun. En principe, il serait possible de le supprimer totalement et de faire d'un texte mathématique un texte uniquement logique. Or, le résultat s'avère impossible à lire : la logique n'est pas la mathématique qui, alors même qu'elle s'occupe d'objets parfaitement définis, a besoin d'une certaine dose d'aération, d'un peu de support intuitif" (Feldman, 2002, p. 96)

be traced back to Poincaré's famous critique of Russell[51]. From this perspective, Bachimont considers that the process of explicitation is a looping process[52] that cannot end[53].

This idea of continuum between tacit and explicit that is present in the knowledge management literature (Martin, 2008), has also practical and methodological implications:, operationalisation in specific domains is more flexible because it does not have to deal with *a priori* categories.

2.3.2 Knowledge and management

2.3.2.1 Shifting paradigms

Knowledge management is a rather young discipline that originated as a concept in the late 1980s (Koenig & Neveroski, 2008). Nevertheless it has produced several models which have been variously reviewed and categorised (Earl, 2001; Koenig, 2002; McAdam & McCreedy, 1999). Koenig, as reported by Martin (2008), defined three ages for knowledge management, technology for knowledge sharing, the emphasis on cultural factors, and content manage-

[51] According to Poincaré (1905), "Une démonstration vraiment fondée sur les principes de la Logique Analytique se composera d'une suite de propositions ; les unes, qui serviront de prémisses, seront des identités ou des définitions ; les autres se déduiront des premières de proche en proche ; mais bien que le lien entre chaque proposition et la suivante s'aperçoive immédiatement, on ne verra pas du premier coup comment on a pu passer de la première à la dernière, que l'on pourra être tenté de regarder comme une vérité nouvelle. Mais si l'on remplace successivement les diverses expressions qui y figurent par leur définition et si l'on poursuit cette opération aussi loin qu'on le peut, il ne restera plus à la fin que des identités, de sorte que tout se réduira à une immense tautologie. La Logique reste donc stérile, à moins d'être fécondée par l'intuition".

[52] An extreme view of this argument leads to the conceptualisation of Tsoukas, who states that "tacit and explicit knowledge are not the two ends of a continuum but the two sides of the same coin: even the most explicit kind of knowledge is underlain by tacit knowledge. Tacit knowledge consists of a set of particulars of which we are subsidiarily aware as we focus on something else".

[53] "L'explicitation correspond par définition à la mise en oeuvre de connaissance théorique, qui par défaut sont tacites. Si elles deviennent explicites, c'est qu'elles font l'objet de connaissances théoriques autres, mises en oeuvre par ailleurs, et qui sont elles-mêmes tacites. Et ainsi de suite. L'explicitation conduit donc à une régression à l'infini. Puisque l'infini ne nous est pas accessible, il reste donc toujours des connaissances théoriques tacites" (Bachimont, 2004, p. 69-70). Similarly, Nonaka and von Krogh (2009) state that "the alternation between the intuitive and the formal depends on tacit affirmations, both at the beginning and at the end of each chain of formal reasoning." p.131

ment. Koenig and Neveroski (Koenig & Neveroski, 2008) subsequently added a fourth age, the extranet stage focussed on context, globalisation, and competitive intelligence.

The first paradigm relates to Earl's definition of the technocratic school (Earl, 2001), to Firestone and McElroy's definition of a first generation (Firestone & McElroy, 2003), and what McAdam and McCreedy refer to as intellectual capital models, "Intellectual capital models are mechanistic in nature, and assume that knowledge can be treated as an asset, similar to other assets" (McAdam & McCreedy, 1999, p. 97). This first generation of model "operates around capture, codification, and re-use, with knowledge management perceived as comprising efforts at sharing already existing knowledge" (Martin, 2008, p. 389).

The second paradigm, according to Koenig, emphasises human and cultural aspects. This second paradigm fits Nonaka and Takeuchi's succesful SECI model (Nonaka & Takeuchi, 1995). This paradigm has also been labelled by McAdam and McCreedy as a knowledge categories model (McAdam & McCreedy, 1999). It belongs to Firestone and McElroy's definition of the second generation of knowledge management models, which Martin (Martin, 2008) considers to be the state of the art for this discipline.

According to Martin (2008), the third paradigm[54] relates to a focus that shifted from the management of knowledge to the management of ecologies of knowledge.

2.3.2.2 Knowledge Management Models

The SECI model The SECI model is the most successful model of the second age. It emphasises Polanyi's (1962) distinction between tacit, that is, non-verbalised, intuitive and unarticulated knowledge (Martin, 2008), and explicit knowledge. The model describes a life-cycle of knowledge creation through four phases establishing all combinations between these two kinds of knowledge (Nonaka & Takeuchi, 1995; Nonaka, 1994):

1. Socialisation describes social interactions leading to tacit knowledge acquisition

[54] According to Firestone and McElroy (2003), it still belongs to the second generation of knowledge management , but Snowden (2002) considers it belongs to a third one.

2. Externalisation relates to the action of making this tacit knowledge explicit
3. Combination refers to the creation of new explicit knowledge by processing several explicit sources
4. Internalisation describes the action of appropriation of this explicit knowledge into new tacit knowledge

The model is a reference in knowledge management and its principles can be found in other models. Choo's model (1996, 1998), for example, grounds the knowledge creation entity with the Nonaka and Takeuchi's model. He further adds two entities, namely, sense-making, and decision-making. Sense-making supports knowledge creation, which supports decision-making followed by organisational action.

While popular, Nonaka and Takeuchi's approach has been criticised because of the assumption of a possible segregation into categories (McAdam & McCreedy, 1999; Snowden, 2002).

> The model may also have contributed to an oversimplification of differences that, rather than being absolute, represent movement along a continuum between explicit and tacit (Choo, 1998; Küpers, 2005; Stacey, 2001; Stenmark, 2000, 2001; Styhre, 2003, 2004; Tsoukas, 1997). (Martin, 2008, p. 372)

The information space model This vision of a continuum is one of the main characteristics of Boisot's information space model (1995). Boisot's model belongs to the same category as the SECI model; in fact they share many concepts (McAdam & McCreedy, 1999) as they are based on a life-cycle view involving both tacit and explicit knowledge. Nevertheless Boisot states that the information space model tries to be more generic towards knowledge:

> In contrast to most models in knowledge management that start from what managers and workers in an organisation actually do (Nonaka and Takeuchi

> 1995), the I-Space adopts a more abstract point of departure, namely, the nature of information and knowledge flows in any system. Recasting Polanyi's well-known distinction (1958) between tacit and explicit knowledge in information theoretic terms, the I-Space exploits the idea that knowledge that can be articulated will diffuse more speedily and extensively within a given population of agents than knowledge that cannot be so articulated. (Boisot, MacMillan, & Han, 2007, p. 6-7)

The continuum paradigm in Boisot's model is manifested in the mode of characterisation of knowledge, that is to say in dimensions rather than categories. These dimensions are codification, abstraction, and diffusion. Codification measures "the speed and ease with which a phenomenon or object of experience can be unambiguously assigned to given perceptual or conceptual categories" (Boisot & Cox, 1999, p. 528). Abstraction measures "the number of perceptual and conceptual categories required to capture a phenomenon" (Boisot & Cox, 1999, p. 528). Diffusion measures "the percentage of a given population of data processing agents—the individuals, groups, firms, etc.—for whom an item of information has relevance that can gain access to an information event in a given time period" (Boisot & Cox, 1999, p. 528). The goal of the model is to describe different strategies for the management of complexity, that is to say reduction and absorption (Boisot & Child, 1999). The former implies reducing the quantity of data, the latter implies reducing the number of categories.

Using these dimensions, Boisot defines a life-cycle, the Social Learning Cycle (SLC). The model is based on Kolb's (1978) learning cycle, which pictures skills that are required for an individual to master learning, namely concrete experience, reflective observation, abstract conceptualisation, active experimentation (Boisot, 1995, p. 75). Based on this, Boisot develops his lifecyle in six phases (see figure 2.3):

1. *Scanning*, which aims at "identifying threats and opportunities in generally available but often fuzzy data—i.e., weak signals. Scanning patterns of such data into unique or idiosyncratic insights that then become the possession of individuals or small groups" (Boisot & Cox, 1999, p. 531).

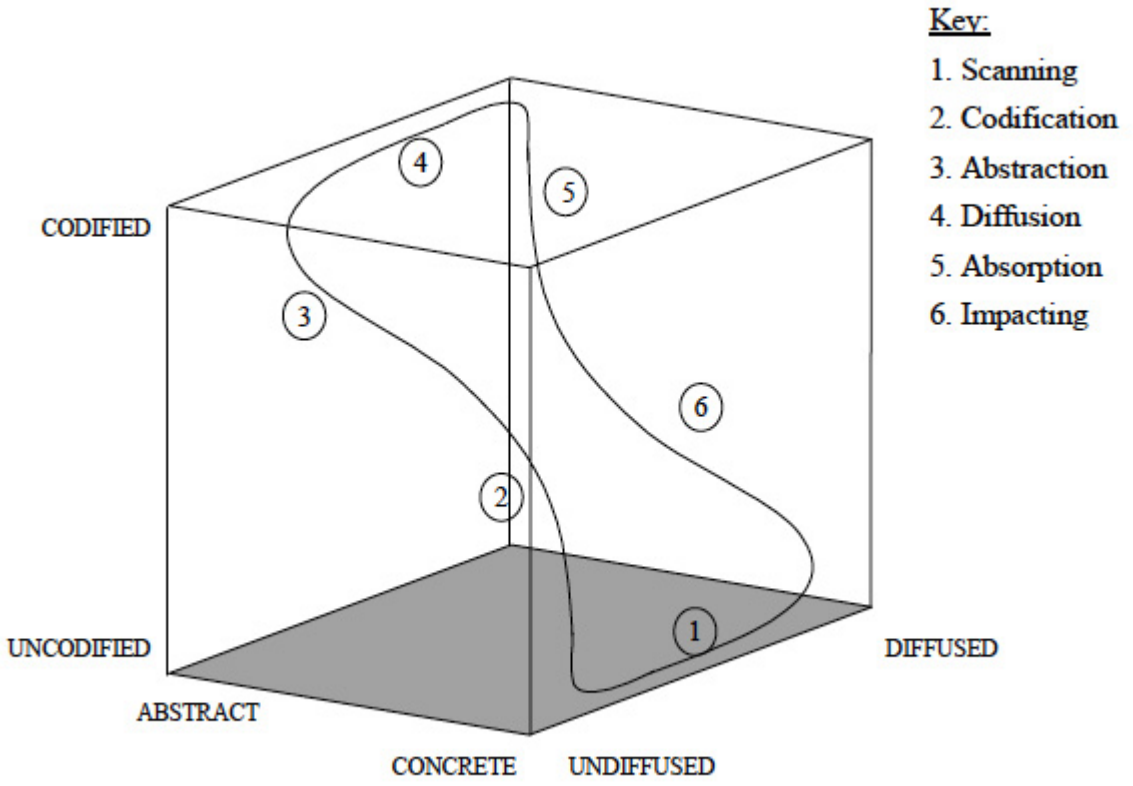

Figure 2.3 The Social Learning Cycle. Adapted from Boisot, Canals, & MacMillan, 2004, p. 9.

2. *Problem-solving*, that is to say "the process of giving structure and coherence to such insights—i.e., codifying them" (Boisot & Cox, 1999, p. 531).

3. *Abstraction*, which relates to "generalising the application of newly codified insights to a wider range of situations. This involves reducing them to their most essential features—i.e., conceptualising them" (Boisot & Cox, 1999, p. 531)

4. *Diffusion*, that is to say "sharing the newly created insights with a target population" (Boisot & Cox, 1999, p. 531)

5. *Absorption*, which consists in "applying the new codified insights to different situations in a 'learning by doing' or a 'learning by using' fashion" (Boisot & Cox, 1999, p. 531)

6. *Impacting*, which pictures "the embedding of abstract knowledge in concrete practices. The embedding can take place in artifacts, technical or organisational rules, or in behavioural practices" (Boisot & Cox, 1999, p. 531).

These phases define a cyclical movement of knowledge similar to Nonaka and Takeuchi's SECI model, with transfer from more tacit to more explicit forms of knowlege (D. Griffiths, Boisot, & Mole, 1998).

Because of its dimensional quality, Boisot's model is clearly operationalisable and has been used in several domains: business management (Boisot & Child, 1999), economics (Boisot & Li, 2006), computer science (Boisot & Cox, 1999) and biology (Daizadeh, 2006). Still, it has never been applied to an artistic or cultural context (M. H. Boisot, personal communication, April 15, 2010).

The Cynefin model Snowden's Cynefin model (2002) belongs to the third category. This model is influenced by complexity theory and therefore distinguishes between complex and complicated. Complicated implies a system where cause and effect can be separated. On the contrary complex systems are holistic. The second distinction is between complex and chaotic, chaotic systems showing no traces of any pattern. The model then defines four domains forming a cycle: complex, chaos, knowable and known. Snowden then emphasises the need to go from knowable to chaotic, an action he calls disruption. He states that "if the disruption is cyclical and expected, then we are closer to a learning ecology, we have also to some degree immunised the group in respect of involuntary moves into the chaotic space" (Snowden, 2002, p. 110). This model focusses on a prescriptive view of knowledge management, fostering cyclical disruption for knowledge emergence.

2.3.2.3 Categorisation

Knowledge management models are numerous because they address multiple issues. Several characteristics emerge from this review that may be used to classify these models (table 2.1) in the context of our research, that is to say the identification of a model that responds

to our knowledge management needs (see chapter 5). They may be classified, first in terms of operationalisation (for example, Boisot's model is dimensional while Nonaka and Takeuchi's, and Snowden's models are categorical), second in terms of distinction between prescription and description, and third in terms of reliance on the explicit/tacit distinction.

Model	Tacit/Explicit	Structure	Use
Nonaka & Takeuchi, 1995	Yes	Discrete	Descriptive
Boisot, 1995	Yes	Continuous	Descriptive
Snowden, 2002	No	Discrete	Prescriptive

Table 2.1: Review of Knowledge Management models

2.3.3 Knowledge and technology: a sociological account

2.3.3.1 The emergence of a social concern for knowledge and technology

The debate about the boundaries between epistemology and the sociology of science stems back to the 1930s with Merton's first external/internal distinction (Shapin, 1992)[55]. Bloor (1999) further states: "Merton felt that sociological enquiry into the nature of knowledge was bound to be of a limited character. It was confined to offering a description of the conditions encouraging or inhibiting the growth of science" (p. 22)[56]. In Merton's view, sociology does not account for the content of science (Ragouet, 2002).

[55]Shapin (1992) states: "I think Merton's early work is the first site in which the internal and external were systematically invoked as gestures towards theories (albeit informal ones) of social and cultural change in science: these aspects of scientific change were due to external/extrinsic factors, those to internal/intrinsic." (p. 337).

[56]This is what Bloor (1999) calls the weak programme: "the traditional stance towards the sociology of knowledge can be called the 'weak' programme. This involves the idea that socio-psychological causes need

By the early 1960s, the internal/external discourse became institutionalised, and according to Shapin (1992), "in 1962, Kuhn's Structure of scientific revolutions implicitly offered a scheme by which external social influences might work to transform anomaly into conceptual crisis, or might operate early in the development of a new field and then be progressively excluded by processes of institutionalisation" (Shapin, 1992, p. 341)[57]

The *strong programme* refused the distinction internal/external[58], applying Bloor's principle of symmetry. As Pestre (2007) puts it, ambiguity is part of science.

> The influential 'strong programme' of SSK insists that such explanation, to avoid teleology and judging veracity in terms of what is currently accepted as true, must be impartial to the truth or falsity of the beliefs under investigation; it must treat all knowledge claims symmetrically, explaining their creation or acceptance in social terms, rather than by reference to the natural world (Bloor 1973, 1976). (Williams & Edge, 1996, p. 6)

The analysis of scientific controversies is critical within social studies of science[59]. They also reflect the political position of the discipline. According to Pestre (2007, p. 38-39), in the 1970s it aimed at undermining the position of the authority of science in society[60], but

only be sought for error, irrationality and deviation from the proper norms and methodological precepts of science" (p. 81).

[57]Dubois (2002, p. 187) takes the example of Kuhn's paradigm to describe the different interpretation of a concept in different branches of the sociology of science: for some authors close to Merton's ideas, it is an internal social structure and for some others, it is an interdependence between social and cognitive factors; for some authors close to the strong programme, it is a fundamentally-social property of scientific activity.

[58]According to Briatte (2007), "refusant la césure internaliste/externaliste qui relègue ces derniers au domaine de l'erreur, David Bloor étend leur capacité explicative à toute proposition scientifique, sans considération pour son exactitude" (p. 208). Dubois (2002) further states that "le causalisme symétrique du programme fort repose bel et bien sur l'idée selon laquelle les structures explicatives de la philosophie et de la sociologie sont 'mutuellement exclusives'. Sa radicalité repose tout entière sur cette clause qui implique qu'à un phénomène unique ne peut correspondre simultanément une justification rationnelle et un enracinement social" (p. 191).

[59]According to Pestre (2007), "l'analyse de controverses dans les science studies est donc construite à la rencontre d'un projet intellectuel qui vise à dés-essentialiser les sciences en les replaçant dans la complexité de leurs actes et dans leur temps" (p. 30).

[60]See, for example, Lynch & Cole, 2005: "currently , social studies of science scholars do not put forward a definitive version of what science is, is not, or should be. Instead, they examine rival claims to scientific

in the 1990s the focus of scientific controversies turned to a broader context: socio-technical controversies [61]. Williams and Edge (1996) argue that "a variety of scholars, with differing concerns and intellectual traditions, find a meeting point in the SST project. They are united by an insistence that the 'black-box' of technology must be opened, to allow the socio-economic patterns embedded in both the content of technologies and the processes of innovation to be exposed and analysed (MacKenzie and Wajcman 1985, Bijker and Law 1992)" (p. 1-2)[62]. The analysis of controversies is common to multiple tendencies in SST but the theoretical background developed by Callon and Latour "turned its attention to the network linkage between human beings and technical objects" (Thévenot, 1995).

2.3.3.2 Technologies and agents

Latour's actor network theory (2005) refutes the notion of social inertia, and, with some influences stemming from interactionism and ethnomethodology (Coenen-Huther, 2002) (see also chapter 4), reconsiders the object of research:

> Social aggregates are not the object of an ostensive definition [...] but only of a performative definition. (Latour, 2005, p. 34)

In this context, as Callon puts it, technology can no longer be defined as a passive intermediary[63]. On the same grounds, we cannot reduce objects to properties, denying actions

status in historical and contemporary settings (including the courts)" (p. 279). See also Seguin, 1996, on the relationship between science and politics, in a context where "la circulation des objets ou thèmes du discours scientifique crée de nouveaux enjeux politiques" (p. 188). We note that, according to Kaufmann, Perret, Bordogna Petriccione, Audétat, and Joseph (2004), in the 1970s emerged the notion of major technological risk.

[61] Such as genetically modified organism (GMO).

[62] Similarly, Pestre (2007) states: "les analyses de controverses étant toujours des études de cas précises et détaillées, et la variété interprétative pouvant toujours être documentée, leur caractère démonstratif est très fort : par l'analyse de controverses, il est toujours possible de réouvrir les 'boîtes noires' et certitudes trop grandes des sciences sur leur mode de production et le caractère intangible de leurs énoncés" (p. 31).

[63] "Si ces classifications sont à la fois inutilisables par les observateurs et indispensables aux acteurs, c'est qu'elles désignent pour ces derniers une réalité cruciale, celle des stratégies complexes et des actions ininterrompues par lesquelles ils définissent et négocient leur identité et les relations qu'ils établissent entre eux" (Callon, 1981, p. 388).

and uses (Thévenot, 1993)[64]. Latour (2005) states that intermediaries are "what transports meaning or force without transformation: defining its inputs is enough to define its outputs. For all practical purposes, an intermediary can be taken not only as a black box, but also as black box counting for one, for nothing, for several, even if if it is internally made of many parts" (p. 39). On the contrary, he proposes to describe technological agents as mediators, whose inputs are never a good predictor of their output[65] and whose "specificity has to be taken into account every time. Mediators transform, translate, distort, and modify the meaning or the elements they are supposed to carry" (p. 39).

A strong debate broke out between Latour's Actor Network Theory and, in particular, Bloor's Strong Programme. "Latour rightly points out that what counts as 'science' and what as 'society' are the results of trials of strength" (Shapin, 1992, p. 355). Consequently, "we have to free the matters of fact from their reduction by 'Nature' exactly as much as we should liberate objects and things from their 'explanation' by society" (Latour, 2005, p. 109). The rejection of the opposition between nature and society led Bloor (1999) to declare that "his [Latour's] idea is that we must not try to explain nature in terms of society, or society in terms of nature, nor should we explain knowledge as a mixture: we must explain both society and nature, at once, in terms of a third thing or process. Society and nature are, as he puts it, 'coproduced"' (p. 84), which for Bloor was a criticism. But according to Latour (1999a), this is indeed a question of ontology: "If scientists insist over and over that they make no durable distinction between nature and beliefs about nature, if their whole work is directed to make sure that their beliefs are not representation, but deal also with ontology, we don't have, it's true, the courage to break what they say in two and then look for a glue to bring their interviews back together" (p. 123).

[64] Thévenot (1993) acknowledges the limits of "un traitement des choses qui vise à les réduire à des propriétés essentielles, générales et transportables, et qui ne permet pas d'intégrer leur engagement dans l'action et dans l'usage" (p. 95).

[65] As Vinck (1999) puts it, "ces objets sont si investis par les acteurs que nous faisons l'hypothèse qu'ils ne sont ni les supports arbitraires de l'action ou du jeu social, ni les simples et fidèles véhicules de ce qui leur est imputé. Si les acteurs s'acharnent tant à les discipliner c'est, justement, parce qu'ils risquent toujours de leur échapper et d'introduire dans l'action quelque chose qui n'était pas souhaité" (p. 408).

Latour has been accused of reverting to the position of Merton (Bloor, 1999) and of relativism (Gingras, 1995)[66], an accusation Latour answered in elaborating his theory (Latour, 2005): " 'constructivism' should not be confused with 'social constructivism'. When we say that a fact is constructed, we simply mean that we account for the solid objective reality by mobilising various entities whose assemblage could fail; 'social constructivism' means, on the other hand, that we replace what this reality is made of with some other stuff, the social in which it is 'really' built. [...] Since it was obvious to us that 'social construction' meant a renewed attention to the number of heterogeneous realities entering into the fabrication of some state of affairs, it took years for us to react in a balanced way to the absurd theories with which we appeared to be associated" (p. 91-92).

2.3.4 Conclusion

In this section, we have focussed on two specific research areas that have an impact on our research design, in terms of models and in terms of methodology. In our claim to address the intelligibility of digital artifacts, we have proposed on one hand to focus on tacit knowledge, and on the other hand, on the social context of the performance involving digital technologies, that is to say, the role of agents, both human and technological[67]. First, we proposed a categorisation of knowledge management models that may inform our research design. Second, we proposed a review of the theoretical frameworks in the sociology of science and technology that may impact the ontological and epistemological directions of our research. The potential relation between these two points will be discussed in chapter 4.

[66] According to Gingras (1995), "la stratégie qui consiste à nier la position relativiste (perçue comme devenue dominante) afin de présenter une position 'nouvelle' a simplement eu l'effet inattendu de retourner à la position réaliste d'abord décriée par les relativistes : après tout, une double négation est une affirmation qui ramène à la position initiale" (p. 7).

[67] For the record, Teubner (2006) includes animals within non human agents. He states that "from the ninth century to the nineteenth, in Western Europe, there are over two hundred well-recorded cases of trials of animals. [...] The animals did not always win their case. [...] In medieval and Renaissance Europe and also in other cultures, the world of law was populated with non-human beings, [...]" (p. 498).

2.4 Music research and the creative process

2.4.1 Creative paradigms

The analysis of electroacoustic and mixed music leads to several categorisations related to the axis of research and the topics of interest. Frengel (2010) proposes a complex categorisation framework for mixed music works in the specific context of the conjunction of instrumental music and tape music. He defines nine axes[68] complemented with sub-categories. A more global approach is that of Tiffon (2005), which encompasses the compositional paradigm theorised by Frengel. His categorisation proposes three paradigms which relate directly to the use of electronics in mixed music: non real time electronics (labelled C+, which corresponds to the original, historical definition of mixed music (Tiffon, 2005, p. 25), and Frengel's domain of conceptualisation), electronics answering in real time to instruments (labelled C*), and finally the combination of both (pragmatically labelled C+*). Tiffon theorises interaction in the scope of his framework as an axis of evolution[69] from C+ to C*. While Interaction is not part of his categorisation, Tiffon (2005, p. 31) considers it to have become a central question in mixed music. On the contrary, Ungeheuer (in press)' proposes a framework which theorises the modes of connection between both worlds, human and technological, taking special care to include not only the theoretical position of composers, but also the other positions of all agents involved in the creative process. The three concepts belonging to this theoretical framework are the human/machine opposition, the spatial/temporal transgression of the instrument, and interaction. They are conceptually separated, although they may technologically co-exist in a specific work (Ungeheuer, in press). From this point of view, Tiffon's framework is historically and technologically focussed, whereas Ungeheuer's framework is centred on

[68] Namely "segregational, proportional, temporal, timbral, behavioural, functional, spatial, discursive and pragmatic" (Frengel, 2010, p. 96).

[69] "L'évolution de la musique mixte (C+) vers l'électronique temps réel (C*) suit deux axes en étroite relation qui sont, par ordre chronologique d' apparition, l'échantillonneur numérique et l'interaction instrument/machine. Il est symptomatique de relever que ces deux axes se fondent sur des critères esthétiques propres aux musiques mixtes ; l'échantillon sonore est l'héritier de l'esthétique du collage, telle qu'elle apparaît dans les oeuvres électroacoustiques et les oeuvres mixtes originelles (C+) [...] ; l' interaction instrument(s)/machine est une nouvelle expression de l'esthétique du dialogue, l'une des toutes premières dialectiques du genre mixte (C+)" (Tiffon, 2005, p. 27).

compositional paradigms, and therefore is broader, if also more abstract. Still, both frameworks converge on specific topics. For example, Tiffon's (2005) C+, that is, instrumental music associated with tape music, is emblematic of Ungeheuer's (in press) first paradigm, that is the human/machine opposition. As far as preservation issues are concerned, the challenges of fixed media are quite different from those of live electronics. The former have been much discussed in literature[70] (see, for example, Canazza & Orcalli, 2001; Canazza & Vidolin, 2001; H. Davies, 2001; Zattra, De Poli, & Vidolin, 2001; Zattra, 2006. In terms of curation, see, for example, Calas & Fontaine, 1996.); we will discuss the subsequent paradigms in relation to our research.

2.4.1.1 Spatialisation

The second paradigm, that is the spatial/temporal transgression of the instrument, relates, in particular, to the idea of augmented instruments[71], which, in terms of human computer interaction, relates to a supervisory control model. This supervisory control model "applies to situations where a person allocates his attention among various graphical or alphanumeric displays and intermittently communicates new programs to a computer which itself is in continuous direct control of a physical process" (Sheridan, 1976, p. 271). While the graphical display is not critical in the musical context, the model relates, generally speaking, to the control of "a semi-autonomous system through the intermediary of a computer. The computer receives information from sensing devices, makes decisions according to its stored programs, and issues commands to effector mechanisms. The human supervisor performs upper level goal-oriented functions" (Sheridan & Johannsen, 1976, p. 506). From this point of view, the technology becomes a critical part of the preservation issues. Still, the model is hierarchical, the human agent acts as an upper level controller, as a guide for computerised technological systems (Johannsen & Poli, 2002).

[70] These challenges have been also the focus of several projects such as PrestoPrime (2009-2012).

[71] See section 1.2.2.1. See also Manoury, 2007 for a review of multiple relationships between acoustic instruments and electronics in the context of his musical works, in relation to his concept of virtual score: "une partition virtuelle est une organisation musicale dans laquelle on connaît la nature des paramètres qui vont être traités, mais pas toujours la valeur exacte qu'ils vont recevoir le moment voulu" (p. 8).

Ungeheuer exemplifies this paradigm with the question of spatialisation[72]. Approaches to spatialisation are multiple, whether they relate to a perceptive focus or a compositional focus[73]. As Harley (1994) puts it, "the task of classifying all possible spatial designs in music is [...] daunting" (p. 207)[74]. Nevertheless, she provides a five axis theoretical categorisation of spatial designs based on a thorough literature review: *acoustic environments*; *sound-space types*; *categories: static or mobile performers and/or audience*; *selected designs in real sound-space*; and *selected designs in virtual sound-space*. On technological grounds, according to Stroppa (2011), two positions can be defended: either the speakers create a virtual space or they act as a manifestation of the space[75]. While Harley grounds her categorisation in instrumental music and mixed music, the question of spatialisation is also central to electroacoustic music. Normandeau (2009), for example, describes his concept of *timbre spatialization*, that is to say that "the entire spectrum of a sound is recombined only virtually in the space of the concert hall. Each point represents only a part of the ensemble. It is not a conception of space that is added at the end of the composition process – an approach frequently seen, especially today with multitrack software – but a truly composed spatialisation. It is a musical parameter that is exclusive to acousmatic music" (p. 278)[76]. From an empirical point of view, Peters, Marentakis, and McAdams, conducted a survey of compositional as well as practical practices in terms of spatialisation [77].

[72]Specifically, with Luigi Nono's 1981-1985 *Prometeo* in which spatialisation relied on the Halaphon created by Hans Peter Haller et Peter Lawo: the Ha(ller)-La(wo)-phon (see the booklet of the *25 Experimentalstudio Freiburg* compact disc release).

[73]That is to say, following Nattiez's (1998) theory of musical analysis, on the 'aesthesic' side or the 'poietic' side.

[74]Merlier (2006) collected 350 words and 1200 definitions related to spatialisation. On more focussed grounds, several authors address specific spatialisation ideas in relation to specific composers. For example, Albèra (2003) states about composer Emmanuel Nuñes, "chez [...] Emmanuel Nunes, l'idée de la spatialisation du son, centrale dans son esthétique, dérive de l'expérience de la forme ouverte dans ses premières œuvres" (p.241).

[75]Stroppa (2011) states: "du point de vue strictement technologique, deux conceptions de l'espace sont à disposition du compositeur. [...] La première est d'imaginer un espace continu qui se manifeste à travers un certain nombre de haut-parleurs agissant comme des fenêtres sur cet espace, la continuité étant reconstruite par l'auditeur. [...] La deuxième conception est d'utiliser le haut-parleur non pas comme le support d'un espace continu, mais comme la manifestation de cet espace: le haut-parleur devient une source autonome, presque comme un instrumentiste, il est présent, visible sur scène" (p. 173-174).

[76]Similarly, Smalley (2007) argues that "acousmatic music is the only sonic medium that concentrates on space and spatial experience as aesthetically central" (p. 35). Nevertheless, the idea that spatialisation may be a compositional parameter is not limited to electroacoustic music; see, for example, Schumacher and Bresson (2010).

[77]See also Baalman (2010), for a review of spatialisation techniques.

Our goal is not to provide an account of all spatialisation techniques, in theoretical or practical terms, but to present them in relation to Ungeheuer's classification, since this may have some impact on our research design.

2.4.1.2 Gesture following

Ungeheuer's (in press) third paradigm describes interaction as a quintessential paradigm of mixed music, where human agents and technological agents seem like equal partners. Rowe (1993) classifies the relationship between the performer and digital processing instruments in two paradigms: the instrumental paradigm and the player paradigm. According to Rowe (1993), "instrument paradigm systems are concerned with constructing an extended musical instrument: performance gestures from a human player are analysed by the computer and guide an elaborated output exceeding normal instrumental response" (p. 8). Thus we can see that this paradigm relates directly to Ungeheuer's (Ungeheuer, in press) second compositional paradigm, that is the spatial/temporal transgression of the instrument. On the other hand, "systems following the player paradigm try to construct an artificial player, a musical presence with a personality and behavior of its own, though it may vary in the degree to which it follows the lead of human partner. A player paradigm system played by a single human would produce an output like a duet" (Rowe, 1993, p. 8). These systems refer to Ungeheuer's (in press) interaction paradigm where the computer develops an autonomous behaviour, which she relates to the 'synthetic-performer mode' as described by Dodge and Jerse (1997). In terms of human machine interaction it relates to multi-agent systems. In a multi-agent system, each agent has incomplete information, a limited viewpoint, and there is no global system control (Jennings, Sycara, & Wooldridge, 1998). As a consequence, this paradigm involves complex contexts of creation (see Zattra, 2006; Delalande, 2009), which Gurevich and Treviño (2007) oppose to the text/action paradigm (as exemplified by the score).

According to Magnusson (2009), the electroacoustic instrument, as opposed to the acoustic instrument, introduces a critical cognitive transformation. Whereas in the acoustic context, "the instrument becomes an extension of the body, where trained musicians are able to express themselves through incorporated knowledge that is primarily noncon-

ceptual and tacit" (p. 168), the electroacoustic instrument on the other hand "is not an extension of the body, but rather a tool external to the body whose information we have to interpret (thus hermeneutic)" (p. 168). This transformation is directly related to the absence of any natural mapping between gesture and sound production as compared with the acoustic context[78]. Consequently the cognitive transformation, which Magnusson talks about, as well as the social context of the creation of these new instruments and interfaces has an impact on documention. This impact on documention is critical since the strategies of appropriation as well as the agents involved may have subsequently diverged and expanded.

Bevilacqua, Rasamimanana et Schnell (2006) consider that these new approaches, focussed on interaction, imply a greater role for gesture. From this perspective, gesture constitutes one of the central aspects of interaction. 'Gesture following' is therefore a relevant example of the interaction paradigm, which may be considered in the course of our research design.

2.4.2 Music and stakeholders

Authenticity in the context of music can be traced back to eighteenth century aesthetics, as reported by Desroches and Guertin (2005). They observe that authenticity is polysemic and ambiguous[79]. In cultural heritage, Muñoz-Viñas (2005) has emphasised the need to integrate, for conservation issues, all stakeholders in the mediation process, which he defines as the passing from the expert's zone to the trading zone.

[78] Typically, the mapping is defined as "the liaison or correspondence between control parameters (derived from performer actions) and sound synthesis parameters" (Hunt, Wanderley, & Kirk, 2000). These authors consider mapping as a part of the instrument and not just as a composition feature.

[79] Desroches and Guertin (2005) state that "à l'instar de l'identité, l'authenticité demeure une réalité mouvante puisqu'elle est construite sur la base de choix, de sélections, de lieux de mémoire et de cadres de référence. Esthétique et ethnomusicologie conduisent en définitive à reconnaître le caractère polysémique et ambigu du concept d'authenticité" (p. 753). Interestingly, Roeder (2009) remarks that during all interviews conducted by Jill Teasley during InterPARES II with composers and computer music designers, interviewees never use words such as 'authentic', or 'reliable'.

> The people for whom a heritage object is meaningful, have been called *stakeholders* by several authors (Avrami *et al.*, 2000; Cameron *et al.*), a term which is especially appropriate: stakeholders own a tiny part of something larger; as such, they are affected by the decisions that are taken regarding it, and they have the right to have a say in relation to it. People's right to impose their views is proportional to their involvement with the object. (Muñoz-Viñas, 2005, p. 161)

As with cultural heritage—see, for example, the opposing approaches to conservation, during the nineteenth century, from Ruskin (1855) and Viollet-le-Duc (1867)[80], the former emphasising the need for preservation and the latter restoration[81]— debates on authenticity are notorious in the musical context. A striking example is the debate over baroque music that Hennion (1993)[82] has quite elegantly described and analysed. According to Hennion, the case of baroque music provides us with a comparison between two ways of transmission: the transmission through practice[83]; and the transmission through objects[84]. The specificity of the baroque controversy is that there was a double interruption in the transmission, namely on the human side and on the material side (Hennion, 1993). The general premise to these debates, as long as a score is involved[85], is that "because any musical notation under-determines the sound of a faithful performance, different-sounding

[80]Proust (1913) pictured this debate in his work: "Mais ma rêverie (semblable à ces architectes élèves de Viollet-le-Duc, qui, croyant retrouver sous un jubé Renaissance et un autel du XVIIe siècle les traces d'un chœur roman, remettent tout l'édifice dans l'état où il devait être au XIIe siècle) ne laisse pas une pierre du bâtiment nouveau, reperce et 'restitue' la rue des Perchamps" (p.165-166).

[81]In this context, we refer to the museological terms, which describe conservation as the sum of possibilities coming from preservation and restoration (Muñoz-Viñas, 2005).

[82]See also, in particular, Sherman, 1998 and Nattiez, 2004a, for different analyses.

[83]"[La] transmission par la pratique [...], sujette à une trahison continue, mais 'vivante' " (p. 31), which emphasises the preservation of intelligibility. We may, analogically, relate this point to this statement of Bachimont and Blanchette (2006): "while preservation deals with the problem of transmitting *physical objects* through time, access deals with the problem of transmitting the *cultural competence* necessary to 'read' the physical objects, so that they are intelligible".

[84]"[La] transmission directe par les choses, une re-production archéologique, discontinue, authentique mais 'morte', à partir du décodage savant" (p. 31), which involves, in particular, a philological approach to preservation, see Zattra (2007)."

[85]Desroches and Guertin (2005) state: "le discours sur l'authenticité d'une interprétation musicale ne porte pas seulement sur les paramètres d'un objet, mais aussi sur les sujets en relation avec cet objet, au niveau de la création, de l'interprétation ou de l'écoute" (p. 744). They consider that the question of authenticity in ethnomusicology is quite recent (that is to say, the 1960s). See also Nattiez, 2005.

performances may be equally and ideally authentic" (S. Davies, 1988, p. 223). According to Ravet (2005), as soon we consider the interpretation as a performance, music research has to deal with sociology[86].

Electroacoustic and mixed music is a particularly relevant domain of investigation, for it involves multiple agents, both human and non-human. Zattra (2006) identifies six stakeholders: (1) composers, (2) listeners, (3) musical assistants (also known as computer music engineers), (4) performers, (5) performance devices, and (6) instruments for sound generation (see figure 2.4). She further emphasises "the problem of authorship of pieces which, beyond the creative process of composition, involves a large quantity of technological competence which invades the compositional dimension" (p. 114). This consideration was developed and theorised, in the context of specific creative practices, by Gurevich and Treviño (2007), who introduce flexibility to positions. They state:

> As an alternative to the traditional model of composer, performer and listener as monolithic individuals, each inhabiting a predefined context, an ecological approach to musical creation focusses on the relationships between composers, performers and listeners as a part of a system that includes external factors such as genre, historical reception, sonic context and performance scenario. (Gurevich & Treviño, 2007, p. 108)

In terms of human agents, Benghozi (1995) states that artistic creative processes challenge the specification of precise roles[87]. Specifically, Menger and Cullinane (Menger & Cullinane, 1989) emphasise the relationship between the computer music designer and the

[86]The original phrasing is: "dès lors que l'on considère l'interprétation comme performance, souligne Ravet, c'est-à-dire comme processus de (re)création en acte porté/initié/conduit par des corps musiciens, il semble nécessaire d'associer les perspectives sociologique et musicologique. C'est en effet, analyser non seulement le travail de l'interprétation comme une activité de travail artistique, mais aussi sa contribution à l'élaboration de 'l'œuvre elle-même' pour reprendre les termes de Howard S. Becker" (Ravet, 2005, p. 5).

[87]For example, Zattra, Burleigh, and Sallis (2011) remind us that, in the context of Luigi Nono's 1985 *A Pierre. Dell'azzurro silenzio, inquietum*, "the group evolved over time and consisted of numerous musicians (Roberto Fabbriciani, flute; Ciro Scarponi, clarinet; Giancarlo Schiaffini, tuba; Susanne Otto, contralto; among others), sound engineers (Hans Peter Haller, Alvise Vidolin, Rudolf Strauss) and technicians (Bernd Noll, Andreas Breitscheid). Certain key collaborators, such as André Richard, were so embedded in numerous aspects of the compositional projects as to defy easy classification." (p. 411).

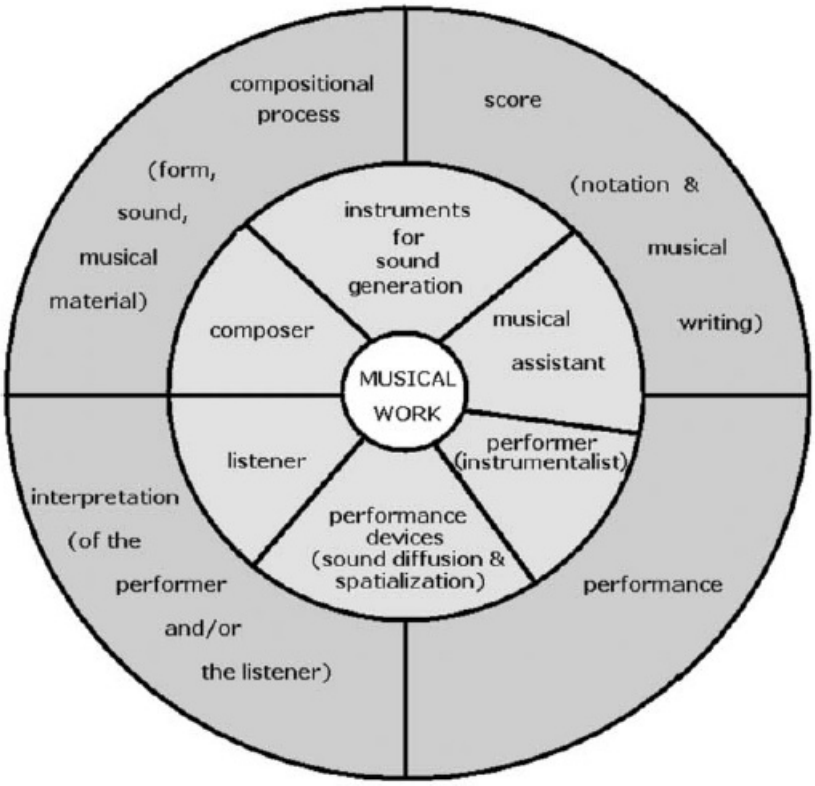

Figure 2.4 Agents and processes in electroacoustic music production. Adapted from Zattra, 2006, p. 115.

composer whose success "depends on the full and entire cooperation of the assistant" (p. 99). Whereas Boulez (1986) considers that "research/invention individual/collective, the multiple resources of this double dialectic are capable of engendering infinite possibilities" (p. 494), composer Marco Stroppa specifies that interactions between composers and researchers occur in several ways: the composer as the absolute master (exemplified by Pierre Boulez); the composer as a "super-consultant" acknowledging the potential musical use of technology; and finally, composers and researchers as partners (Stroppa et al., 2011). In a similar vein, Delalande (2009) suggests investigating social practices during the production and reception[88] of electroacoustic music for analytical purposes[89]. In terms of production,

[88]The investigation of reception has been emphasised also in the domain of new media arts, see Edmonds, Muller, & Turnbull, 2006.

[89]Delalande (2009) states: "les objets musicaux considérés sont le support d'un échange entre producteurs et récepteurs, et c'est en tant que tels qu'ils intéressent ce qu'il est convenu d'appeler l'analyse musicale. On les décrit seulement comme résultat d'une production donnant lieu à une réception. Mais production

while teamwork in an artistic context has been considered in terms of human agents (see, for example, Rouse & Rouse, 2004), Born (2005) wants to "consider the distribution of creative agency between different producers, as in collaborative forms of musical authorship; and between subjects and objects, human and non-human agents" (p. 25), and focusses "on the way that electronic and digital technologies afford and enhance a dispersed and collaborative creativity" (p. 25). While the role of performers in mixed music[90] has been described as critical[91], according to Lemouton (Lemouton, 2009), in electronic music, according to Stroppa (1984), "the role of interpreter has far from disappeared: it is absorbed within the act of composition" (p. 178). This statement, which exemplifies a process of mediation in the sense of Hennion (1993), converges with Stiegler's (2003) description of the social complexity produced by the organological transformation of live electronics. It emphasises the need for an investigation of the creative process that accounts for multiple agents, both human and technological.

The fact that Hennion (1993) illustrates his sociology of mediation[92] with a controversy, namely the baroque controversy, is not a coincidence. His work is grounded in different

de qui? (Traditionnellement du compositeur seul, mais est-il légitime d'oublier un éventuel assistant et/ou les concepteurs de logiciels?) Réception par qui, dans quelles conditions? Les réponses résulteront d'une études des pratiques sociales" (p.151).

[90] See also Féron & Boutard, submitted, on the appropriation strategies that relate to the relation between performers and electronics.

[91] Performance is also investigated in the domain of performance studies. See also, for theoretical investigation, Frangne, 2009.

[92] For Hennion (1993), "c'est cela traiter de la médiation : ne plus, théoriquement, annuler comme des signes ou admettre comme des choses les objets rencontrés, mais montrer en œuvre dans la pratique la plus constante des acteurs ce double travail pour mettre en cause leurs objets (les naturaliser, en faire des choses, dotées de leur force, et faire de même avec les sujets qui leur font face), et les remettre en cause (contester leur force, montrer d'où elle leur vient, mobiliser les intérêts qui les tiennent, les socialiser)" (p. 266).

sociological approaches, in particular the work of Latour[93] on controversies[94]. His account for 'objects' is therefore significantly different from a position such as that of Becker (1982), who states: "because equipment comes to embody one set of conventions in such a coercive way, artists frequently exercise their creativity by trying to make equipment and materials do things their makers never intended" (p. 58). From this perspective, the technology is passive in the mediation process and only human agents make a difference, whether it is the maker or the artist. The equipment and the materials are intermediaries, not mediators, according to Latour's definitions (see section 2.3.3). Becker's depiction of the use of equipment would change substantially, if we consider that, within the new agency created by artists and equipment, "nonhumans also act, displace goals, and contribute to their redefinition" (Latour, 1994, p. 38). From this point of view, they account for a more active mediation[95].

[93]But also Boltanski and Thévenot's (1991) sociology of critical capacity. In fact, Hennion states: "nous pensons, comme B. Latour [1990] ou L. Boltanski [1990], que seule une conversion, avec les deuils qu'elle suppose, rendra à la sociologie sa capacité, d'un coté à voir les objets (c'est la piste ouverte par la sociologie des techniques du premier), de l'autre à reconnaître le savoir des acteurs (à commencer par la faculté critique, et c'est la piste ouverte par la sociologie de la justification du second)" (p. 263). The impact of the sociology of science and technology, as proposed by Latour (2005), on other domains of sociological enquiry, such as arts, is that "la comparaison systématique entre le régime de médiation des objets d'art et des objets de science permettra d'extraire un certain nombre de propriétés caractéristiques, rendant possible un traitement différencié — différenciation qui était impossible auparavant, puisque l'objet de science et lui seul échappait à l'analyse" (Hennion & Latour, 1993).

[94]Therefore in Hennion's (1993) work, "le jeu des controverses musicales passe par la remise en cause du statut des médiateurs : le serviteur est devenu le maître, l'instrument nécessaire des uns est pour les autres le moyen d'asservir la musique à d'autres intérêts — le marché, la technique, le spectacle, la consommation. Chaque musique se présente ainsi comme une valeur propre, plus ou moins trahie par ses moyens ; elle est naturalisante pour elle-même ; mais elle devient excellente sociologue pour les autres, qu'elle réduit volontiers aux intérêts de leur producteurs, aux procédés de leur production, aux illusions de leurs fidèles ou au fétichisme de leur acheteurs. La polémique revient toujours à rapporter la musique à un autre type de représentation qu'à celui qu'elle reconnaît" (p. 301).

[95]Hennion (1993), on the basis of his depiction of the work of Durkheim, provides an active view of material intermediaries, "ils ne prêtent pas seulement leur matière pour servir de support à une autre réalité qui cherche à s'écrire, par une opération purement intellectuelle de mise en forme croisée, ils la réalisent, cette réalité, ils permettent une action qui n'aurait pas existé sans eux" (p. 247).

2.4.3 Music and creative processes

In addition to agencies, or rather together with agencies[96], the notion of creative process was investigated by researchers in different domains, for "each art or musical work constructs connections to both prior and future or prospective works" (Born, 2005, p. 23). This statement relates to the notion of *situated composition*, conceptualised by Donin and Theureau (2007):

> These characteristics of composer's cognition demonstrate that it must be considered not only as situated in the strong sense, but also as situated in a specific sense. With regards to the notion of situated action as it has been proposed by Suchman (1987), the particularity of situated music composition is that many important elements of the composition situation have been constructed in the past by the composer himself. This explains the essential role of memorisation, inscription, and re-reading and their corresponding techniques, which participate in the construction of an ensemble of which the realised work is only one of its most obvious manifestations. (p. 236)

Born (2005) advocates for the extension of the notion of mediation to a greater time-scale:

> "I have argued that music's ontology and its mediation must be grasped as historical. Although musical mediation takes place in specific, often local settings, it takes a number of characteristic historical forms. In this context, accounts of mediation need to address technological, social and cultural changes heralded early in the twentieth century and now sweeping across the production and reception of art and popular musics, developments that signal a new ontology of the provisional work. Probing the mutual construction of music and time, I have suggested that theories of mediation should move beyond the sphere of micro-social interactions and trace the historical trajectories of musical assem-

[96] Since "all cultural production constructs and engages relations not only between persons, but also between persons and things, and it does so across both space and time" (Born, 2005, p. 16)

> blages, reconnecting them to analyses of the macro-dynamics of cultural history and technological change." (p. 33-34)

The methodological consequences of this emphasis on the creative process are numerous. Donin and Theureau (2007) propose a methodology for the investigation of the creative process, which they labelled the 'interview within situation simulation through material traces' (Donin & Theureau, 2006). They question the various temporalities of the creative process, "what are these types of relationships and how are they constituted and how do they evolve over the course of the composition?" (Donin & Theureau, 2007, p. 240). They define different levels of relevance: inside a part of the work, during the whole work, and then consider a phenomenon of procedures whose emergence affects future compositions by the same composer. Donin (2008) will further apply this framework to electronic parts of the compositional process. On a different theoretical ground and musical context, Zattra, De Poli, and Vidolin (2001) and Bari, Canazza, De Poli, and Mian (2001), place the production of a work within a philological approach involving "analysis of the sources; comparison among them; and comparison with external testimonies" (Zattra, 2007, p. 48). Zattra (2007) considers that without the composer's "comments, recollections, feedback, and supervision, this research [the analysis of the creative process of John Chowning's work *Stria*] could often have encountered a 'dead end"' (p. 39). Saaze (2011) emphasises that installation art cannot be understood separately from actors and museum practices, and advocates for an ethnographic approach to curation. In the context of the preservation of video games, Winget (2011) considers that "each piece of hardware and software has a history of creation of its own, as does the design of the game as a whole" (p. 1879) and also advocates for ethnographic studies of stakeholders involved in creation and use.

2.4.4 Creative processes and documentation

Stockhausen (1978) stated that "the highest obligation of our time is to preserve as many musical forms and performance styles as possible" (p. 2). The preservation of musical works involving electroacoustic technologies requires preserving the means to re-perform the work. As Bernardini and Vidolin (2005) stated, "live electro–acoustic music currently

possesses notational conventions and practices that can be compared at best to [medieval] tablatures"[97]. In this context, the relationship between the preservation of musical works involving electroacoustic technologies and their documentation has long been established (e.g., Battier & Landy, 2004; Bernardini & Vidolin, 2005; Wetzel, 2006). But on the basis of which documentation should we address their preservation? A posteriori documentation is a standard process for institutions dealing with music archives (e.g., the archive database at the Institut de Recherche et Coordination Acoustique/Musique [IRCAM] in Paris), but it may be insufficient for preservation purposes. Indeed, "[software] programs are often developed over time through the collaborative imaginative labor of several authors. Because of this inherent temporal and social mediation, the resultant baroque totality is extremely difficult to decode after the event and is thus opaque to the reconstruction of its total logic—the necessary prerequisite for documenting it" (Born, 1995, p. 276). Born refers primarily to IRCAM's specific artistic production, but the importance of the process of artistic creation has also been emphasised in other contexts, such as the ones we reviewed in this chapter. As a consequence, we argue that preservation of musical works involving electroacoustic technologies should be grounded in a thorough documentation of creative processes[98].

Theoretically, the relationship between technology and the processes of its creation is a critical axis of research in science and technology studies (see section 2.3.3), since "technology does not develop according to an inner technical logic but is instead a social product, patterned by the conditions of its creation and use" (Williams & Edge, 1996, p. 2). This social process is further emphasised by the context of the preservation of electroacoustic technologies, whose best practice relies on a constant effort of migration (Polfreman et al., 2006; Yong, 2006). Specifically, the black-boxing process, i.e., "a process that makes the joint production of actors and artefacts entirely opaque" (Latour, 1999b,

[97] Similarly, Manoury (1999) states that "l'écriture est née en Mésopotamie, environ trois mille ans avant Jésus-Christ et je vois un parallèle entre la naissance des premières écritures et la situation musicale dans laquelle nous vivons actuellement" (p. 205). Zattra (2004) is a little more generous: "it could be said that computer score notation is at the same stage that tablature notation was at in the sixteenth and seventeenth centuries" (p. 45).

[98] On a larger scale, "l'enjeu de sa conservation dépasse amplement celui des oeuvres considérées de façon isolée, et concerne davantage une mémoire collective qu'il devient urgent, à mesure que le temps s'écoule, de préserver" (Baudouin, 2011).

p. 183), is relevant to preservation issues of art installations (Saaze, 2009), and we submit that it is also relevant for preserving musical works involving electroacoustic technologies.

2.4.5 Conclusion

The investigation of mediations, as presented in this section, transforms the notion of stakeholders that is found in literature to include a wider range of agents. From this point of view we see a parallel between our concern for the preservation of the intelligibility of the repertoire of contemporary works with live electronics and Lynch and Cole's (2005) statement in the context of judicial practice: "an equally persuasive argument can be made that if some kind of boundary work is a necessary precondition for making policy decisions or dispensing justice, then STS [Science and Technology Studies] scholars have a duty to help legal and regulatory actors improve their art" (p. 297). In a similar way, if archival practitioners have to specify policies for appraisal[99], they have to define, *a priori*, the boundaries of the objects they manage.

The growing complexity of compositional paradigms in terms of interaction and situation (in the sense that Donin and Theureau gave to the term) in contemporary works with live electronics provides simultaneously an expansion of mediations and a potential for their study. Indeed, the creative process which involves numerous agents, both human and non human, bring these interactions into light and provide us with an opportunity for field research. We propose to ground our research in these compositional paradigms in order to investigate the consequences of creative processes, on different levels of complexity, for the intelligibility of contemporary works with live electronics.

[99] In terms of acquisition and selection (see Millar, 2010).

Chapter 3

Research questions

3.1 Introduction

This chapter provides a synthesis of the literature review (see section 3.2) and specifies the resulting research questions and hypotheses (see section 3.3).

3.2 Synthesis of the literature

The preservation of contemporary music works with live electronics requires preserving the means to re-perform the work. In the context of the performance of this repertoire, the addition of live electronics and live interaction to acoustic instruments has consequences that bring to light the critical issue of intelligibility in the digital archival world. It is no coincidence that several international projects have focussed on this repertoire to exemplify issues of digital curation and digital archiving. We have argued that the notion of

performance[1], which comes from the research community of the Australian digital archives, needs to be considered in light of the social status attributed to technological agents and the notion of technological mediation.

Because the digital world implies the absence of semantics for digital objects, the question of the re-performance of digital records needs to be integrated into the proposed investigation of the extension of the concerns about readability and authenticity of digital archives to concerns about their intelligibility.

We propose to investigate the intelligibility of digital archives in the context of contemporary music with live electronics, in relation to two complementary research areas:

1. The integration of tacit knowledge documentation concerns within the scope of the specification of intelligibility preservation frameworks for digital archives. The need and the feasibility of involving knowledge management concerns in preservation methodologies is evident from the literature review. Specifically, we propose to extend *significant properties* taking the tacit/explicit knowledge dimension into account. This *significant knowledge* contrasts to the proposal for *transformational information property* from the OAIS (2009), taking the full measure of the debate between the OAIS' *represention information* and *significant properties*. Research on the specification of which knowledge management model is suitable relies on the literature. The specifications in the context of performing arts are three-fold: 1) a model emphasising tacit and explicit knowledge. According to the literature, the significance of the former stands out during creative processes; 2) a non-intervention policy toward knowledge producers, as far as the archivist is concerned, which consequently requires a descriptive model (as opposed to prescriptive); and 3) a potential for operationalisation. In light of these requirements we have chosen to use Boisot's three dimensional model, which fits the description, in the context of our research.

2. The investigation of creative process involving multiple agents, both human and non human. In this context, we intend to broaden the scope of the specification of the stakeholders in the preservation of contemporary works with live electronics. Dif-

[1] As well as the notion of allographic digital records.

ferent compositional paradigms imply different levels of complexity and intricacy. The interaction paradigm proposes a level of social intricacy which is relevant to our research focus, we deduce from our literature review. The first study relies on electroacoustic music production in the context of spatialised music, the second focusses on the study of a creative process centred on the production life-cycle of a gesture following implementation.

We further propose to analyse and model the impact of the outcomes of these investigations (that is to say *significant knowledge* and creative processes life-cycles) within models for the management of digital archives, and specifically within the OAIS (Open Archival Information System).

3.3 Questions and Hypotheses

- Question 1: Does Boisot's model adequately describe the knowledge involved during the creation of a spatialised work?
    - Hypothesis 1.1: Boisot's model is suitable for segregating knowledge descriptions.
    - Hypothesis 1.2: The classification of the knowledge involved is independent from the orchestration/style of the composition.
- Question 2: How do multiple agents, both human and non-human, interact and produce knowledge during the creative process of contemporary work with live electronics?
    - Hypothesis 2.1: The knowledge production during creative processes impacts the documentation methodologies.
- Question 3: Which implications came out of our previous studies for digital archives models?

- Hypothesis 3.1: *significant knowledge* may be integrated with the OAIS' ingest entity.
- Hypothesis 3.2: The grounds for the specification of ingestion policies may be integrated in the OAIS, with a focus on the production lifecycles of the creative processes.

Chapter 4

Methodology

4.1 Introduction

In this chapter, we present our methodological framework for the three studies. Because the epistemological and methodological frameworks of each study are multiple, we present them separately for each study: the first study is presented in section 4.2; the second study is presented in section 4.3; and the third study is presented in section 4.4. Each study is directly related to a research question (see research questions and hypotheses in section 3.3): the first study (see chapter 5) relates to the first research question; the second study (see chapter 6) relates to the second research question; and the third study (see chapter 7) relates to the third research question. The presentation of the third study in section 4.4, which proposes to integrate the outcomes of both previous studies, epitomises the interdisciplinary approach of this research. Consequently, we will discuss the challenges of mixed methods, in the specific context of integration, in section 4.4.

4.2 First study

4.2.1 Sampling

We conducted a survey among composers of electroacoustic and mixed music. Thus the unit of analysis was the composer. The target population was the population composed of electroacoustic and mixed music composers registered at the online popular electroacoustic and mixed music organisations. Thus the sampling frame was the list of composers registered at these institutions. It must be reported that the size of this population is difficult to evaluate. We relied on the most popular international and national organisations (while national at the organisation level, the membership is international) such as the International Computer Music Association (ICMA), the Australasian Computer Music Association (ACMA), and the Canadian Electroacoustic Community (CEC). These organisations have a world-wide range of subscribers including world-renowned composers. These composers represent a full range of styles within the scope of electroacoustic and mixed music as described in chapter 1.

4.2.2 Questionnaire Design

Boisot's model is composed of three dimensions: abstraction, codification and diffusion. We operationalised these three dimensions with relevant conceptual frameworks coming from music research, information studies, and knowledge management (see chapter 5 for details about operationalisation). The methodology was adapted from a previous study in the field of contemporary music with spatialisation techniques by Peters, Marentakis, and MacAdams (2011). Peters et al. (2011) proposed a survey aiming at understanding "how they [composers] use spatialisation, what spatial aspects are essential, and what functionalities spatial audio systems should strive to include or improve" (p. 10). Their survey was sent to similar online associations of composers. The design was composed of Likert scales, multiple-choice questions, and open-ended questions. Our survey targeted the same population with an interdisciplinary framework aiming at providing grounds for the preservation of the repertoire. The questionnaire was composed of Likert scales and open-

ended questions (see Appendix A). Control variables included experience as a composer, and orchestration/style of composition.

For the purposes of internal and construct validity, the questionnaire was elaborated based on prior face-to-face interviews with composers from the target population[1]. Participants were selected according to purposive sampling and had more than five years experience in composition using spatialisation[2]. These interviews were conducted in collaboration with Montreal's main composition institutions at McGill University, the Université de Montréal, and the Québec Conservatoire de musique.

4.2.3 Data collection and analysis

Following Peters et al. (2011), this study was implemented as a web survey to reach an international sample of respondents. We expected a similar response rate to that of the previous study on spatialisation techniques (that is, about fifty completed surveys). In order to maximise the response rate, the study relied on contact steps defined by the 'Tailored Design Method' (Dillman, Smyth, & Christian, 2009), when applicable. Respondants were provided with a consent form before proceeding with the questionnaire. For the preliminary interviews, selected composers received twenty Canadian dollars each for their participation and were required to sign a consent form. Ethics certification was provided by McGill University.

Because of the ordinal level of measurement of all data related to the classification of knowledge within our proposed operationalisation of the model, we used non-parametric statistics for the data analysis (see Sprent & Smeeton, 2007 for the use of non-parametric statistics and Göb, McCollin, & Ramalhoto, 2007 for the specific application to Likert scale

[1] See Kvale and Brinkmann (2009) for a description of methods and epistemological grounds for interviews. See also Georgiou, 2001, p. 19 for a description of interview conducting.

[2] That is to say, an experience level that is higher than Peters et al.'s (2011) first category. Peters et al. defined three experience categories: "'beginners' (under 5 years), 'intermediate' (5–10 years), and 'advanced' (more than 10 years)" (p. 11).

data[3].). We used Goodman and Kruskal's Gamma statistic, a non-parametric measure of association, for the test of association between both intra- and extra-dimensional levels of operationalisation. We performed a Kruskal-Wallis test, a non-parametric equivalent to an ANOVA[4], to evaluate the effect of the spatialisation experience as well as orchestration/style within the model. To measure associations between categorical variables we used Cramer's V statistic.

4.3 Second study

4.3.1 Introduction

The second study aims at providing a grounded conceptual framework for the description of agents interactions including both human and non-human agents and the knowledge production during creative processes in the context of contemporary works with live electronics. The IRCAM (Institut de Recherche et Coordination Acoustique Musique), was created by Pierre Boulez in 1977. It is one of the most important institutes for research and production in the domain of contemporary music with live electronics (Born, 1997). Its expertise in gesture following has been acknowledged in the literature and by the contemporary music community, and this study is grounded in IRCAM's paradigmatic music production. Our study aimed to include all potential agents of the creative process of contemporary works with live electronics. For this repertoire, we proposed to study the creative process in the context of work with a specific interest in interactivity, which involves performers, as well as other agents. Specifically, we focussed on gesture following, because it epitomises interactivity in the creation of electroacoustic and mixed music (Bevilacqua, Rasamimanana, & Schnell, 2006). Following the creative process of a work that focusses on gesture following provided us with a situation in which the level of complexity is well suited to our concerns about preservation and our goal to inform documentation frameworks.

[3]Some authors have argued that parametric statistics can be used also with ordinal data such as Likert scale. See, for example, Norman, 2010, who focusses on the robustness of a statistic, that is to say "the extent to which the test will give the right answer even when assumptions are violated".

[4]Siegel and Castellan (1988) state that "the Kruskal-Wallis one-way analysis of variance by ranks is an extremely useful test for deciding whether k independent samples are from different populations" (p. 206).

4.3.2 Data collection and Analysis

This study relies on a case study using secondary data analysis. We contacted the specific IRCAM research team that collected these data: Analyse des Pratiques Musicales (APM), headed by Nicolas Donin, to obtain access to the data. These data consist of a collection of video recordings of the production process of a String Quartet involving gesture following, as well as subsequent interviews (see chapter 6 for details). These data have been used in a previous study by Donin, Goldszmith, and Theureau (2009). No consent form had been used during the original study by the APM team (in the context of French research policies); however, we provided a consent form to all participants involved in the data we analysed. Ethics certification was provided by McGill university.

4.3.3 Methodology and epistemology: a background

Ravet (2005) states that studying performance requires an interdisciplinary research framework including music research and sociology. Donin and Chouvel (2005) propose a broader disciplinary framework involving sociology, ethnology, psychology, history, and so on[5]. The situation, which we described in the literature review, is quite similar to the context of creative processes.

Nevertheless, our research goal was not one of social anthropology, as was, to a certain extent, the work of Donin and Theureau (2007), based on ethnographic work, whose thickness is directly related to the longitudinal dimension[6]. Nor was our goal a sociology of music[7] from the perspective of constructivism following the work of Becker (1982), or the work of Menger (2009) on creative work ('travail créateur'). Nor was it an integration of different perspectives, sociological, historical, and aesthetical, following Hennion's (1993) sociology of mediation, even though his work, oriented toward the ability to account for objects, informs our research.

[5]"il semble difficile de parler d'un sujet comme celui-là sans faire appel à des compétences touchant aux diverses sciences humaines (sociologie, ethnologie, psychologie, histoire...) ainsi qu'à l'informatique musicale" (Donin & Chouvel, 2005, p. 4).

[6]See the pioneering work of Geertz (1973) for a description of ethnographic work.

[7]See Ravet (2005) for a review of different approaches.

Hennion's (1993) integration and Ravet's (2005) 'crossed questioning'[8] propose an interdisciplinary research axis which informs our research on the potential convergence of archival studies and music research regarding the specific question of the preservation of digital objects. Specifically, the epistemological questions that they bring to light require that we position our own research in order to analyse our object of research: contemporary works with live electronics; objects that are never stabilised in a unique form, but always performed within temporary agencies.

According to Georgiou (2001), Glaser and Strauss' (1967) grounded theory relies on a contextualist epistemology that presupposes that the data collected is part of an organised social interaction structure. The process of conceptualisation using the grounded theory requires the study of actions/interactions in context[9]. Nevertheless, grounded theory is not limited to an ethnographic data collection. Glaser (1978) reminds us that "though uniquely suited to field work and qualitative data, [grounded theory] can be easily used as a general method of analysis with any form of data collection : survey experiment, case study. [...] It transcends specific data collection methods" (p. 6). Georgiou (2001) declares that grounded theory is grounded in Mead's (1934) and Blumer's (1969) symbolic interactionism[10]. We may measure this statement against the later divergence of both authors on the ontological and epistemological background of the theory. Glaser will head toward what Henwood and

[8] That is, 'les interrogations croisées'.

[9] "Employer la méthode de grounded theory, c'est donc s'engager à étudier les processus d'action et d'interaction d'acteurs dans leur contexte, dans le double but d'identifier et de conceptualiser les conditions et les conséquences de cette action/interaction. [...] L'épistémologie à laquelle ils [Glaser et Strauss] adhèrent les situe dans le cadre du contextualisme [...]" (Georgiou, 2001, p. 25-27).

[10] Symbolic interactionism, together with other sociological theories such as Garfinkel's (1967) ethnomethodology, belongs to the Chicago school (Rouan & Pédinielli, 2001). It developed in opposition to behaviorism (Georgiou, 2001) and proposes a ground in empirical research with qualitative methods (observation and interviews) and in a rejection of determinism (Rouan & Pédinielli, 2001). According to Heath and Cowley (2004), in symbolic interactionism, "social interactions create meaning and shaping of society via shared meaning predominate over the effect of society on individuals". For Blumer (1969), "there is no empirically observable activity in a human society that does not spring from some acting unit. [...] action takes place in and with regard to a situation" (p. 85). On a side note, Vannini et Waskul (2006) argue that "as some sociologists have noted (e.g., Brown 1977; Fine 1996; Nisbet 1976), the difficulty of studying esthetics from a sociological perspective is both ontological and epistemological. Most commonly in sociology, esthetics is reduced to linguistic discourse and practice, thus losing immediate, somatic, and esthetic qualities—which is, incidentally, the very reason esthetics is of any significance whatsoever" (p. 7-8). They subsequently propose to ground the analytical framework of symbolic interactionism in the metaphor of 'life as music'.

Pidgeon (1992) call 'inductivist positivism'[11]. Heath and Cowley (2004) state that, for Glaser, "induction is viewed as the key process, with the researcher moving from the data to empirical generalisation and on to theory (Bulmer, 1979)" (p. 144). Following Glaser, Charmaz (2006, p. 48) emphasises the need to keep initial coding open-ended but still she acknowledges that researchers hold prior ideas and skills. In this way, Charmaz converges with Strauss' position. While Glaser does not deny prior ideas, he considers that "learning not to know is crucial to maintaining sensitivity to data" (Heath & Cowley, 2004, p. 143). Strauss and Corbin (1998) acknowledge these elements: "we recognise the human element in analysis and the potential for possible distortion of meaning. That is why we feel it is important that analyst validate his or her interpretations through constantly comparing one piece of data to another" (p. 137). But they also claim them as an integral part of grounded theory (2002) through the inductive as well as the deductive process of theory construction.

> We are deducing what is going on based on data but also based on our reading of that data along with our assumptions about the nature of life, the literature that we carry in our heads, and the discussions that we have with colleagues. (Strauss & Corbin, 1998, p. 136-137)

The specification of the role of previous literature is critical in the difference of position between Glaser and Strauss. Heath and Cowley (2004) acknowledge that, for Strauss, "both use of self and the literature are early influences and, while diffuse understandings provide sensitivity, both specific understandings from past experience and literature may be used to stimulate theoretical sensitivity and generate hypotheses" (p. 143). Mills, Bonner et Francis (2006) remind us of Strauss and Corbin's ontological standing.

> Strauss and Corbin (1994) have clearly stated that they do not believe in the existence of a 'pre-existing reality 'out there.' To think otherwise is to take a positivistic position that [...] we reject [...] Our position is that truth is enacted' (p. 279). This is a relativist ontological position that leaves behind the traditional grounded theorists' subscription to the discovery of truth that

[11] As opposed to positivist experimental designs with hypothetico-deductive methods.

> emerges from data representative of a 'real' reality (Glaser, 1978). (Mills et al., 2006, p. 27)

Strauss diverges from the essentialist position (that is, realist) and instead takes a nominalist position[12]. He states that "the nature or essence of an object does not reside mysteriously within the object itself but is dependent upon how it is defined" (Strauss, 1969, p. 20).

Bryant reminds us that, since its inception, grounded theory has avoided acknowledging the theory's epistemological position. Still, Bryant traces back Strauss' relationship, as a member of the school of Chicago, to pragmatism and symbolic interactionism[13]. This relationship to pragmatism[14], is Bryant's ground for a constructivist understanding of grounded theory. Consequently, it should be noted that some extensions of grounded theory modified its epistemological background. Clarke's (2005) situational analysis proposes a post-modern turn; Georgiou (2001) identifies in Costain Schou and Hewison's (1998) work a shift from a contextualist epistemology to a constructivist epistemology, providing a ground for post-structuralist approaches; Mills, Bonner and Francis (2006) stress that Charmaz was first to present her research as constructivist grounded theory. In this context, Bryant highlights the critical role of abduction in regard to Glaser and Strauss' positions on induction and deduction.

[12]Nominalism, as well as conceptualism, rejects the idea of universals as things. Ockham states: "I maintain that a universal is not something real that exists in a subject [of inference], either inside or outside the mind, but that it has being only as a thought-object in the mind. It is a kind of a mental picture which as a thought-object has a being similar to that which the thing outside the mind has in its real existence" (Ockham, 1967, p. 41). See Chak Tornay (1936) for a discussion of William of Ockham's nominalism.

[13]Bryant (2009) states that "this evasion or prevarication may well have contributed to the rising popularity of GTM [Grounded Theory Method (1967)], since it appeared to avoid all the epistemological pitfalls that seemed to befall other methods—particularly qualitative ones. [...] Those well versed in the relevant history and literature can point to Strauss' role as a key figure linking Pragmatism and Symbolic Interactionism, acting as a conduit for the ideas of Dewey and Mead".

[14]"For Pragmatists knowledge exists in the form of statements or theories which are best seen as instruments or tools; coping mechanisms, not once-and-for-all-time truths. Consequently we must always allow that all and any of our current tools may be surpassed in the future—this is what is meant by the term fallibilism. [...] hence no universal and context-free claims to truth. All knowledge is provisional, and has to be judged in terms of its usefulness within some set of confines" (Bryant, 2009).

4.3.4 Methodology and epistemology: a position

Following Latour's denial of a constructivist position in his theory, we grounded our research in a contextualist epistemological background, which therefore relied on Strauss and Corbin's (1998) view on grounded theory. In this context we studied our object of research, that is the knowledge involved in the creative process of contemporary works with live electronics and interactions between agents, both human and non-human. Consistent with this, we acknowledge the use of the literature for the generation of the theory, especially the impact of the notion of technological mediation (Latour, 1994) on the consideration of agencies.

4.3.5 Grounded theory in practice

Maintaining a qualitative approach, grounded theory enables one to "generate a rich, deep and well integrated conceptual system, organised at various levels of theoretical abstraction all of which in some way articulate with the data" (Henwood & Pidgeon, 1992, p. 104). As Strauss and Corbin (1998) put it, "if our concepts are abstract enough, then they are likely to occur in similar or variant forms [...]" p. 284. Thus there is a direct relationship between the level of abstraction of the concepts generated and their transferability[15] to similar situations, which determines the relevance of this 'rich conceptual system'.

Grounded theory relies on several operations—not strictly sequential—of data coding, which form the constant comparison method (Glaser & Strauss, 1967). According to Strauss and Corbin (1998), coding steps are: open coding, which enables the identification of concepts, their properties, and their dimensions; axial coding, which links categories according to properties and dimensions; selective coding, which ensures the process of integration and the improvement of generated theory. Two further concepts complete this method: theoretical sampling, which describes a sampling method based on the emerging theory in order to maximise variations; and theoretical saturation, which specifies the process of

[15] See Guba (1981) about the analogical link between the external validity criterion of positivist research and that of transferability proposed for qualitative research.

closure through the saturation of categories (that is, the categories do not develop further despite data collection).

Glaser and Strauss (1967) define two levels of theory: substantive theory and formal theory. While "Glaser and Strauss (1967, p. 32f) emphasise that both types of theory are 'middle range' in Merton's sense" (Mjøset, 2009, p. 54), there is a substantive difference between them. Substantive theory is grounded in research on one particular area but it is a strategic link in the formulation and generation of grounded formal theory" (Glaser & Strauss, 1967, p. 79). Nevertheless, according to Glaser (1978), "we are far more humble when it comes to generating formal theory. We remain convinced that it should be grounded, but are not sure yet, as with grounded substantive theory, of the resolutions to many specific problems of generation" (p. 142). Consequently, in our research, we focussed on the substantive theory level.

The transferability[16] relates to the level of abstraction of emerged categories. Guba (1981) relates transferability to theoretical sampling, which "is intended to maximise the range of information uncovered" (p. 86), and the collection of 'thick' descriptive data. For credibility, we relied on member check, "whereby data and interpretations are continuously tested as they are derived with members of the various audiences and groups from which data are solicited. The process of member checks is the single most important action inquirers can take, for it goes to the heart of the credibility criterion" (Guba, 1981, p. 85). We further relied on member checks after analysis, "that is, testing the overall report or case study with source groups before casting it into final form. These checks are like those already described, but are carried out after completion of the study rather than during it" (p. 86). These actions impact also the dependability, according to Lincoln et Guba (1986)[17].

[16] Lincoln et Guba (1986) state: "we have suggested credibility as analog to internal validity, transferability as an analog to external validity, dependability as an analog to reliability, and confirmability as an analog to objectivity. We shall refer to these criteria of trustworthiness (itself a parallel to the term rigor)" (p. 76-77).

[17] Specifically, Lincoln and Guba (1986) stress the need for "an external audit requiring both the establishment of an audit trail and the carrying out of an audit by a competent external, disinterested auditor (the process is described in detail in Lincoln and Cuba, 1985a). That part of the audit that examines the process results in a dependability judgment, while that part concerned with the product (data and reconstructions) results in a confirmability judgment" (p. 77).

4.4 Third study

4.4.1 Introduction

The third study integrated the outcomes of both the previous studies, in digital archives' best practices. Thus we analysed the impact of previous outcomes according to current standards. For this study we focussed on the OAIS (*Reference Model OAIS*, 2002). With this study, we provide a framework for best practices in archiving contemporay works with live electronics. As a follow-up to our literature review, the integration of the previous studies provides a theoretical and practical framework for the preservation of the intelligibility of digital records in direct relation with their allographic status. Our goals were thus:

1. To specify the integration of the *significant knowledge* framework in relation to the notion of *representation information* that is provided by the OAIS.

2. To specify the impact of the documentation of the creative process on the management of the OAIS' Archival Information Packages.

No further data collection was carried out for this study. We defined the necessary modifications and extensions to current models. With these modifications and extensions we provide a ground for establishing ingestion policies between data producers and digital archives. The design of the model relied on standard engineering design practices (see, for example, Gamma, Helm, Johnson, & Vlissides, 1994; Pressman, 2004). The implementation of the logical solution relied on the UML (Unified Modeling Language). The choice of UML is directly related to standard design practice. UML is also the modelling language chosen for the design of the OAIS.

4.4.2 Integration

The OAIS relies on the DIKW (Data Information Knowledge Wisdom) view of knowledge (see section 2.3.1.1). This research does not reconsider every ontological and epistemological consideration of the model. Rather, we provide a way to broaden the scope of the model and pose the limitations to the potentiel integration. As Ma (2012b) puts it, "one critical issue in MMR [mixed methods research] is the reconciliation of the polarised views of reality in qualitative and quantitative research. Greene (2006) has suggested that the clarification of philosophical assumptions is necessary for constituting a methodology in social inquiry, arguing that 'assumptions about the nature of social world (ontology) and about the nature of warranted social knowledge (epistemology)' as well as issues such as 'objectivity and subjectivity, the role of context and contingency in social knowing, and the relationship between the knower and the known' (p. 93) should be clarified" (p. 1859).

As far as knowledge management is concerned, while some authors posit their epistemological position (see, for example, Boisot & MacMillan, 2004), the ontological ground of their theories is rarely discussed. The fact that several authors, such as Nonaka (but also Boisot (Boisot & Canals, 2004) as a base for further elaboration) have followed the platonic definition of knowledge tends to position them in a realist view of universals. Boisot and Canals (2004) conclude their criticism of the DIKW model with a statement about the three propositions that their position implies:

1. Information is physical (Landauer, 1999). It is a constituent element of all physical processes and hence cannot treated as something epiphenomenal to the economic process. It must be engaged in on its own terms. (p. 62)
2. Economic agents subject to the principles of least action and to the effects of the second law of thermodynamics aim to economise on their consumption of both physical and data resources by deploying effective cognitive and behavioral strategies. (p. 62)
3. Effective cognitive strategies extract information from data and then convert it into knowledge. Effective cognitive and behavioral strategies vary

> from agent to agent as a function of their situation, of their prior individual knowledge, of their values, and of their emotional dispositions. (p. 62)

While critical of the relation between data, information, and knowledge, Boisot is also grounded in a realist position. From this perspective, there is an implicit connection between our *significant knowledge* theoretical framework and the OAIS. Nevertheless the integration of *significant knowledge* to our concern about the intelligibility of digital records, especially in the case of contemporary works with live electronics, can only be managed at the metadata level rather than being the ground for specifying the different life-cycles of the creative process (see chapter 6). *Significant knowledge* is therefore used to enable the definition of future ingestion policies and to relate these policies to different relevant *performance information* (see chapter 7), which document the different life-cycles that the second study defines. In this context, it enables the hermeneutical process (see Bachimont & Blanchette, 2006) that is concomitant with the performance of digital records. Thus *significant knowledge* is not intended as a quality of the digital record or its consequent *performance information*, but as a quality of the process of data collection in terms of management, that is, in relation to the potential ingestion policy[18].

[18] On the other hand, the data collection of the *performance information* may involve some qualitative methods that relate to our position. For example, the work of Clot and Faïta (2000), which accounts for a view on activity not limited to what is done: "l'activité n'est plus limitée à ce qui se fait. Ce qui ne s'est pas fait, ce qu'on voudrait faire, ce qu'il faudrait faire, ce qu'on aurait pu faire, ce qui est à refaire et même ce qu'on fait sans vouloir le faire est accueilli dans l'analyse de l'activité en éclairant ses conflits" (p. 35).

Chapter 5

Study 1: *Significant knowledge* for mixed and electroacoustic music

5.1 Significant knowledge

According to Rothenberg (2000) the goal of preservation is "to allow future users to retrieve, access, decipher, view, interpret, understand, and experience documents, data, and records in meaningful and valid (that is, authentic) ways" (p. 54). This approach to the concept of meaningful usability (Rothenberg, 2000)[1] converges with the definition of *significant properties*, as it emerged from the CEDARS (1998-2002) project and is now part of the PREMIS Data Dictionary for Preservation Metadata (Xie et al., 2008), namely "those properties of digital objects that affect their quality, usability, rendering, and behaviour" (Hedstrom & Lee, 2002, p. 218) (see section 2.2.4 for further details). In our literature review, we have stressed the need to address the intelligibility of digital artefacts in the context of their performance (see section 2.2.5 for a specification of the context for the performance of digital archives) in light of the knowledge involved in the creative process (see section 2.3.4).

As a consequence, we have proposed in section 3.2, to address the preservation of the intelligibility of musical works with technological components using a knowledge management framework. This knowledge management framework will provide a mean to specify the *significant knowledge* associated with the creative process. In this context, we proposed to extend the framework of *significant properties* into a framework which accounts for the tacit dimension of knowledge (see section 3.2). We further proposed to label this conceptual framework: *significant knowledge*.

This *significant knowledge* is involved in the creation of technological artefacts designed specifically for electroacoustic and mixed music works; these artefacts are the black boxes (Latour, 1994) we are trying to preserve. Documenting this *significant knowledge* aims at providing meaningful usability for these specific technological artefacts. It will provide an archiving framework that will subsequently inform different user communities, those concerned either with use, migration, or, arguably, analysis.

[1] We have argued in section 2.2.4, that this concept is close to the notion of intelligibility, that is, "the ability to understand the meaning of the preserved file" (B. Lee, 2000, p. 201).

5.2 The knowledge conceptual framework

We propose to identify and operationalise a knowledge management model suited to the specific issues of electroacoustic and mixed music preservation and recent conceptualisations for digital archives. We base our choice on the review of knowledge management presented in section 2.3.2 and summarised in table 2.1. This categorisation supports our selection process for a knowledge management model relevant to electroacoustic and mixed music preservation.

A conceptual framework for knowledge management in the context of electroacoustic and mixed music has to meet several requirements. First the creative process involves a large part of tacit knowledge, since "mental texts (of composers, technicians, etc.) are important to the preservation and analysis of musical works" (Zattra, 2007, p. 38). Second a framework for knowledge management in an artistic context ought to be descriptive rather than prescriptive, in order not to intrude into the creative process. Indeed interfering with the creative process is unlikely to be allowed or desired in an artistic production context and Menger (1993) emphasises that the collective action of artistic creation cannot be reduced to functionalism. Last, the framework has to be operationalisable. The models mentioned above can be classified according to these characteristics (see Table 2.1). Consequently, we selected Boisot's Information Space model, a descriptive knowledge management model that emphasises the distinction between tacit and explicit knowledge with a strong operationalisation potential (Dalkir, 2005) given its structure along continuous dimensions. The Information Space model has three dimensions, namely: abstraction; codification; and diffusion (see Figure 5.1). Abstraction relates to a process that reduces the quantity of categories (Boisot & Child, 1999), while codification "involves the assignment of data to categories, thus giving them form" (Boisot & Child, 1999, p. 237). Abstraction is synthetical whereas codification is analytical; nevertheless Boisot (1995) stressed their dependency and therefore the need to consider both of them since altogether they account for the potential tacit dimension of the knowledge involved (Boisot & Li, 2006). Diffusion measures the relevance to a given population (Boisot & Cox, 1999), it allows to "capture relational complexity" (Boisot & Child, 1999, p. 241). Initially Boisot's model was used as a conceptual framework in the domain of organisation science (Boisot & Child, 1999) and

economics (Boisot & Child, 1999). The model was then used as a conceptual framework for computer architecture evolution studies (Boisot & Li, 2006), and proposed for biological data repositories evaluation (Daizadeh, 2006). The model was also part of a framework for indigenous knowledge transmission research (Lwoga, 2011). Our research extends the use of this model to an artistic context with electroacoustic and mixed works creation. The operationalisation will rely on frameworks derived from information science, music research, and knowledge management.

In 2009, Knight and Pennock proposed to use Functional Requirements for Bibliographic Records (IFLA, 1998) to define abstraction levels within the framework provided by significant properties. The concept of significant properties is closely related to Rothenberg's (2000) proposal to preserve meaningful attributes. Furthermore FRBRoo (Aalberg et al., 2010), FRBR object-oriented version, has broadened the scope of FRBR to museology. Indeed, there is a strong potential to use FRBR outside of its initial application domain, namely library science. Specifically we propose to operationalise Boisot's abstraction dimension with the FRBR model. Therefore we propose to divide the abstraction dimension into the four levels of FRBR (IFLA, 1998): Work, Expression, Manifestation, and Item. The work is the most abstract entity; it is "a distinct intellectual or artistic creation" (p. 16). The expression is a "specific intellectual or artistic form" (p. 18), while the manifestation is the physical embodiment of this expression and the item, a single exemplar. Following Boisot (1995), we associate codification with formalisation, that is to say the ability to formalise a specific knowledge. Boisot (1995) states that "language becomes the filter through which all created knowledge is required to pass and it occupies a specific region along the codification dimension" (p.169), he adds that 'valid' knowledge "typically moves from a linguistic to a more highly codified formulation further up the codification dimension" (p.169). The link between codification and formalisation is also present in the knowledge transfer literature. Zander and Kogut (1995) define 'codifiability' as the ability to "capture the extent to which the knowledge could be articulated in documents and software." (p. 81). This articulation in documents and software is especially relevant in our research context.

Finally, diffusion relates to the ability of specific knowledge to be relevant within a broader context. Consequently we propose to operationalise this dimension with cate-

gories derived from Donin and Theureau's (2007) conceptualisation of different temporalities within the creative process. Donin and Theureau's cognitive approach consider the instrumental as much as electroacoustic aspect of composition, they state that "musical 'ideas' exist [...] which are destined to an operationalisation in the form of libraries of patches; from the beginning, they are planned to be concretised on the scale of several compositional projects, and their effects are felt on the scale of several works" (p.247). Specifically they consider four levels since "just as the creative instant counts, so does the composition of some meaningful part of the work, as well as the composition of the entire work, and even more, its place as part of the composition of a set of works, or as part of the composer's intervention in the artistic debates of the time-period" (p. 233). This operationalisation is proposed as the backbone for our study on preservation of electroacoustic and mixed music.

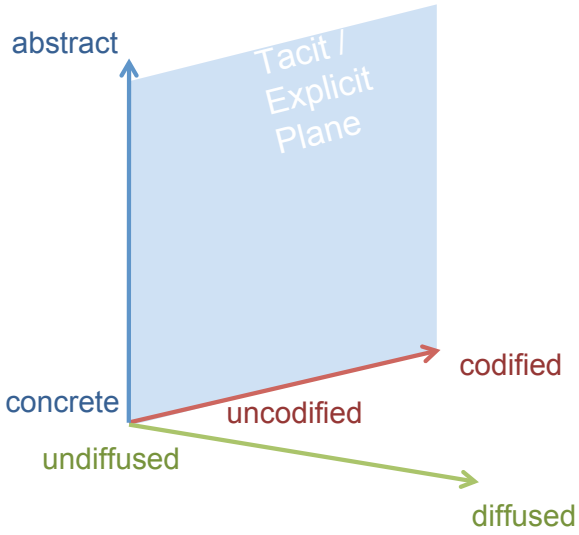

Figure 5.1 The three dimensions of Boisot's (1995) Information Space model: abstraction, codification and diffusion

5.3 Design

In order to study the knowledge involved in the creation process, we decided to focus on one specific compositional paradigm. Spatialisation relates to the "musical utilisation of

the physical-acoustical-perceptual spatiality of sound [...]. The presence of spatialisation can be recognised in every situation in which spatial extensions, positions (directions and distances) of the sound sources as well as the acoustic quality of the performance space are given compositional significance." (Harley, 1994, p. 4). Because spatialisation of sound has been a primary concern for electroacoustic and mixed music since their inception, it was chosen as our compositional case study. As composers are geographically distributed worldwide and difficult to reach we opted for a web survey. Our target population is therefore electroacoustic and mixed music composers registered in composers online associations, specifically at the International Computer Music Association (ICMA), the Australasian Computer Music Association (ACMA), Canadian Electroacoustic Community (CEC), several online forums, and a few personal invitations.

Using the tailored design method (Dillman et al., 2009), the design of the questionnaire was based on a series of interviews. We conducted seven semi-structured interviews with composers from different compositional background within the electroacoustic and mixed music domain. Composers were francophone, mainly based in Montreal and selected by purposive sampling. Selected for coding ability purposes, these composers have worldwide recognition. These interviews provided feedback on the construct validity of the questionnaire. It provided a list of potential phases of the creative process of electroacoustic and mixed works. Furthermore we identified an issue in the abstraction description as regards the lowest level of FRBR: item. Indeed this level proved to be a source of misunderstandings with composers. They did not establish a link with this level when describing the creative process. Another issue was the link to external sources of knowledge. When asked about other contributors to knowledge production and use, our interviewees provided inconsistent answers, so we decided to exclude this aspect from our survey. Further analyses of the interviews were presented in Boutard and Guastavino (2011). Based on this analysis, we derived a questionnaire for the online survey. The questionnaire was translated into English with a composer from our target population. The final English version was pre-tested with one potential respondent. No changes were suggested.

The questionnaire combines open-ended and closed-ended questions. The first question was open-ended in order not to confine respondents' responses into predefined categories. We asked respondents to describe the knowledge involved in the creative process using their

own words. To facilitate their recollection, we asked them to refer to their last work with spatialisation. Respondents were then asked to rate each of the knowledge description they had provided along each of the dimensions of the model using 5-point Likert scales. We operationalised Boisot's model dimension of abstraction using FRBR levels. We adapted these levels to the specific context of spatialisation. The resulting abstraction levels include 1) the work as an abstract entity at a conceptual level, 2) the work as expressed with a specific spatialisation method (e.g.: ambisonics, wfs, 5.1, stereo, etc), 3) the work as realised in software and hardware (e.g. loudspeaker system, Max/MSP patch, etc.), and 4) the work as a specific instance of this realisation in unique objects (e.g. difference between 2 instances of the same speakers or Max/MSP patch). Because the fourth item level proved to be a source of confusion during interviews, we decided to remove it from the questionnaire. This is consistent with Knight and Pennock (2009) who state that "the majority of information provided with an item will have been created for each manifestation and, as a result will not require description at the item level" (p. 170).

Finally, respondents were asked to relate this knowledge to different phases of the creative process. To do so, they had to choose from a list of phases derived from the interviews. The order of presentation of the items in this list was randomised for each knowledge description to nullify order effects.

In addition, we measured control variables related to respondents' expertise level in terms of years of composition with spatialisation, and orchestration/style for the specific work they describe in the questionnaire in keeping with a previous study on spatialisation (Peters et al., 2011). The complete list of questions and response categories is provided in Appendix A.

5.4 Data collection and analysis

5.4.1 Respondents

The survey was available online during the whole month of November 2010. About 90 respondents connected to the online questionnaire and signed the electronic consent form, 32 completed the form describing at least one item of knowledge. These data were combined with data collected during the pre-test since no changes were made at this stage. Consequently we collected data from 33 respondents resulting in 62 specific knowledge descriptions. In terms of expertise we divided the respondent into categories used by Peters, Marentakis, and MacAdams (2011): "beginners" (under 5 years: 8 participants), "intermediate" (5-10 years: 9 respondents), and "advanced" (more than 10 years: 16 respondents). The mean number of years of composition experience was: 25.08 for generic composition and 14.19 for composition with spatialisation. In terms of orchestration/style respondents self-described their work as: fixed media (15 respondents); real-time synthesis (9 respondents); and mixed works (6 respondents). Three respondents did not relate to these choices and specified their own: electronics, installation, and electroacoustic.

5.4.2 The knowledge involved

This section presents the analysis of the free-format responses to Question 5: "Briefly describe the item of knowledge required during the creative process of your work specifically related to spatialisation". The 62 different knowledge descriptions were grouped into five categories emerging from the free-format through axial coding (Glaser & Strauss, 1967). Four knowledge descriptions were removed from the analysis because they were too broad to be categorised. These include "all knowledge", "empirical" (2 occurrences) and "what sounds good" which could not be categorised without contextual information, as it could refer to sound engineering technical knowledge or aesthetic choices.

After initial coding of categories and subcategories by the first author, for inter-coder reliability purposes, the results were cross-validated by three coders with expertise in com-

position, sound engineering, and psychoacoustics respectively. The coders agreed on 82% of the occurrences at the main categories level.

The final categorisation is the following:

Category 1: Technical skills (27 occ.)

- 1.1: Computer skills
- 1.2: Sound engineering skills
- 1.3: Spatialisation skills

Category 2: Mapping strategies (17 occ.)

- 2.1: Control level mappings
- 2.2: Technical level mappings

Category 3: Dependence on performance venue (12 occ.)

- 3.1: Performance venue characteristics
- 3.2: Performance venue technical setup

Category 4: Effects on perception (11 occ.)

- 4.1: Physical features on perception
- 4.2: Compositional features on perception

Category 5: Dependence on compositional specifications (5 occ.)

- 5.1: Hardware specifications
- 5.2: Instrumentation specifications

Category 1: Technical skills. Theses includes computer skills, e.g. Max/MSP patching, that is to say the implementation of the idiosyncratic software part of the work (such as the

audio signal processing) in the software environment provided by Max/MSP; sound engineering skills, e.g. source recording techniques; and technical skills related to spatialisation implementation, e.g. decoding/encoding ambisonic.

Category 2: Mapping strategies. Mapping strategies emerged as a category of knowledge based on arbitrary, non-causal links defined during the creation process. They are typically dependent on composers' conception of spatialisation. Subcategories include control level mapping, e.g. gesture control; and technical level mapping, e.g. patterns between channels and loudspeakers.

Category 3: Dependence on performance venue. Different kinds of contingencies emerged from the data in relation to the performance venue and the technical setup. They include purely technical contingencies, e.g. number of speakers to be provided, number of channels; but also perceptual contingencies, e.g. room acoustics, audience position (the sweet spot was never verbalised directly during the survey but it was during interviews).

Category 4: Effects on perception. This category includes knowledge related to causal relations between space and time but also on the very material used for the composition. Subcategories include: physical features on perception, e.g. proximity, trajectory and speed on perception of sound motion; compositional features on perception, e.g. spatial movement and musical objects significance.

Category 5: Dependence on compositional specifications. Compositional is defined etymologically: to put together. These are specifications that are not related to the performance venue. Although the category only includes 5 knowledge descriptions, we divided it into dependence on hardware specifications, e.g. sensors specifications according to expected data; and dependence on instrumentation specifications, e.g. how many agents (human or technological) interact. It should be noted that none of these categories are exclusive. Every knowledge category shares one part of its membership with one or several categories, and occurrences can relate to two sub-categories inside the same category. Verbalisations used to label the categories are not the one provided by respondents but summaries. An example of actual descriptions is provided for each category in table 5.1.

Interestingly, although the total number of knowledge description is limited to 62, we observed a wide diversity of categories and sub-categories.

	Sample Quotation
Category 1: Technical skills	
1.1: Computer skills	"Max Patching."
1.2: Sound engineering skills	"Knowledge that at its most basic, the sound field should be captured. Therefore, as a bare minimum, stereo imaging and position are vital in both source recording, manipulation and presentation."
1.3: Spatialisation skills	"Decoding first and higher-order ambisonic."
Category 2: Mapping strategies	
2.1: Control level mappings	"Manipulation of transfer functions to distribute and move FFT [Fast Fourier Transform] bins in space was an integral part of the composition."
2.2: Technical level mappings	"Although there were 8 independently spaced tracks/voices, they were considered in pairs which were separated spatially at opposite points on the octagon."
Category 3: Dependence on performance venue	
3.1: Performance venue characteristics	"Different spat in each room and relation between those rooms."
3.2: Performance venue technical setup	"How many discrete channels and speakers would be provided for the performance."
Category 4: Effects on perception	

Continued...

	Sample Quotation
4.1: Physical features on perception	"What physical characteristics of a sound relate to its perceived physical representation."
4.2: Compositional features on perception	"Relation of spatial movement and design to the temporal significance of sonic/musical objects."
Category 5: Dependence on compositional specifications	
5.1: Hardware specifications	"The diffusion pattern of metal sheets with transducers playing sin waves and the resultant enharmonic spectra [...]"
5.2: Instrumentation specifications	"How many sonic agents (musicians, ensembles, loudspeakers) will interact."

Table 5.1: Sample quotations for each sub-category

5.4.3 Spatialisation knowledge rating in terms of abstraction, codification, and diffusion

Respondent were asked to rate each knowledge description they had provided along the different levels of the three dimensions of Boisot's model. For the abstraction dimension, three scales were used to rate the relevance of each knowledge description to 1) the work, 2) the expression and 3) the manifestation, on a five-point Likert scales ranging from not relevant to extremely relevant. For the codification dimension, a single five-point Likert scale was used to indicate the level of formalisation (not formalisable to completely formalisable). Additionally, respondents were asked to specify the formal system that would, in their opinion, best support the formalisation process. They had to choose between several systems (presented in random order across knowledge descriptions): schema; documentation text; mathematics; score; sound processing software (Max/MSP, etc.); and/or could specify another system. For the diffusion dimension, four scales measured the relevance of

the knowledge description to 1) a specific part of the work, 2) the whole work, 3) several works of theirs, 4) other composers' works (see Appendix A for the full questionnaire). Based on these ratings along the three dimensions, each knowledge description can be classified in the model as illustrated in Figure 5.2.

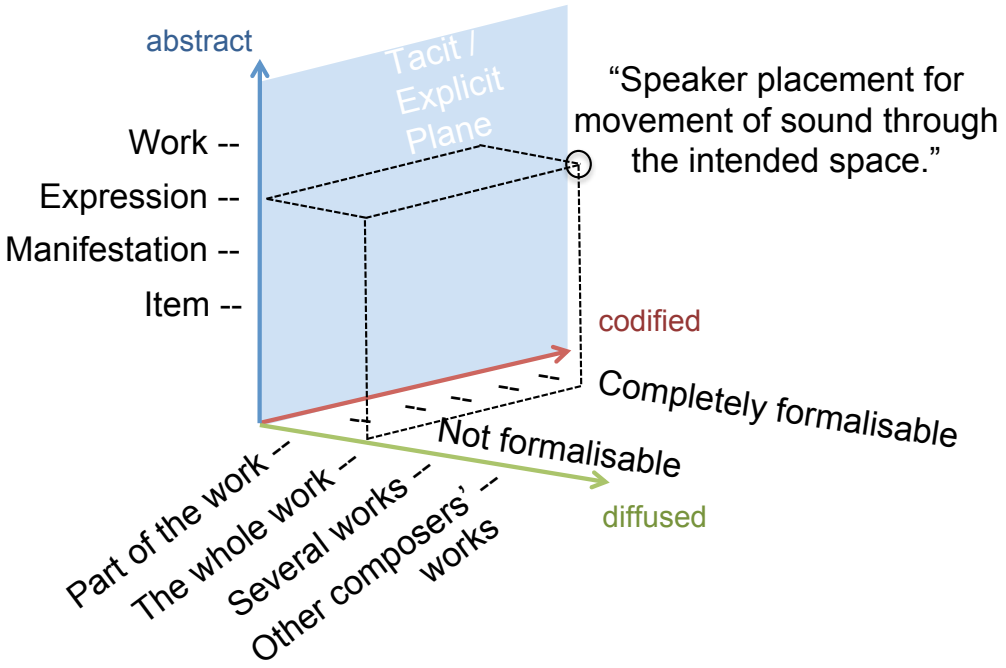

Figure 5.2 Example of the classification of a knowledge described (displayed as a black circle and illustrated with a quote) along the three dimensions of Information Space model using our operationalisation

The measure of association between each level of each dimension is based on the Goodman and Kruskal's Gamma statistic, a non-parametric measure of association recommended in case of numerous ties (Siegel & Castellan, 1988), something likely to occur with five-point Likert scale data. The results of analysis are presented on table 5.2 and detailed in the next section.

In order to match the characteristics of our target population we only selected occurrences belonging to the three pre-selected orchestration/style. This operation reduced the set to 55 occurrences.

	Abstraction			Codification	Diffusion			
	Work	Expression	Manifestation	Formalisation	Part of the work	Whole work	Several works	Other composers' works
Abstraction								
Work	1	0.005	0.132	-0.086	0.488**	0.518**	0.527**	0.327*
Expression		1	0.502**	0.323*	0.075	0.238	0.141	0.184
Manifestation			1	0.134	0.226	0.171	0.206	0.026
Codification								
Formalisation				1	0.164	-0.107	-0.229	0.004
Diffusion								
Part of the work					1	0.629**	0.338*	0.139
Whole work						1	0.817**	0.519**
Several works							1	0.429**
Other composers' works								1

Table 5.2: Goodman and Kruskal's Gamma measure of association. * = significant at the 5% level (2 tailed) for the three dimensions, ** = significant at the 1% level (2 tailed)

5.4.3.1 Intra-dimensional association

Abstraction: The first result is the strong independence from the work level to the lower levels of abstraction, expression and manifestation. This association seems to

indicate that composers did not distinguish between expression and manifestation in the context of music with spatialisation.

Codification: considering every knowledge description, 55 were classified as formalisable to some extent (slightly, fairly, very, or completely formalisable) and linked to the following formal systems: sound processing software [Max/MSP, etc.] (15 occurrences); text (12 occ.); others (9 occ.); score (7 occ.); mathematics (6 occ.); schema (6 occ.). Seven knowledge descriptions were classified as not formalisable and therefore not linked to any formal system. The distribution of formal systems as a function of the level of formalisation is represented in Figure 5.3 with box plot diagrams (the bold line represents the median value, the box represents the interquartile range, points represent outliers, and stars represent extreme outliers). The lack of association between the two measures (formalisation level and appropriate formal system) suggests the need to document both in order to better account for this dimension. Music scores and mathematics are associated with very formalisable knowledge. Schemas are thought of as formal systems likely to be used for knowledge with an average level of formalisation. Sound processing software tends to be selected for higher levels of formalisation and documentation text for lower levels of formalisation. This outcome emphasises the need for preservation policies that go beyond technological means of preservation and consider tacit knowledge involved during the creation process. Another interesting result is the popularity of sound processing software (15 occ.) compared to score (7 occ.) as a chosen embedment for relevant knowledge. This seems to stress the difficulty producing a score in electroacoustic paradigms, as already reported by Bossis (2006), and the associated ever-growing organology (Stiegler, 2003). Composers embed a lot of knowledge in software, a knowledge that spreads down to the lowest level of formalisation. Furthermore, nine knowledge descriptions were linked to other formal system, such as perception, collaboration, Csound (another signal processing software), and so on. The wide variety of potential systems for knowledge capture stresses the inherent difficulty of digital curation.

Diffusion: The analysis of diffusion ratings revealed a high level of association between the levels of diffusion. Specifically, what was rated relevant to a specific part of the work, was also rated as relevant to the work as a whole and relevant to several works, but not necessarily relevant to other composers' works. This result, together with feedback

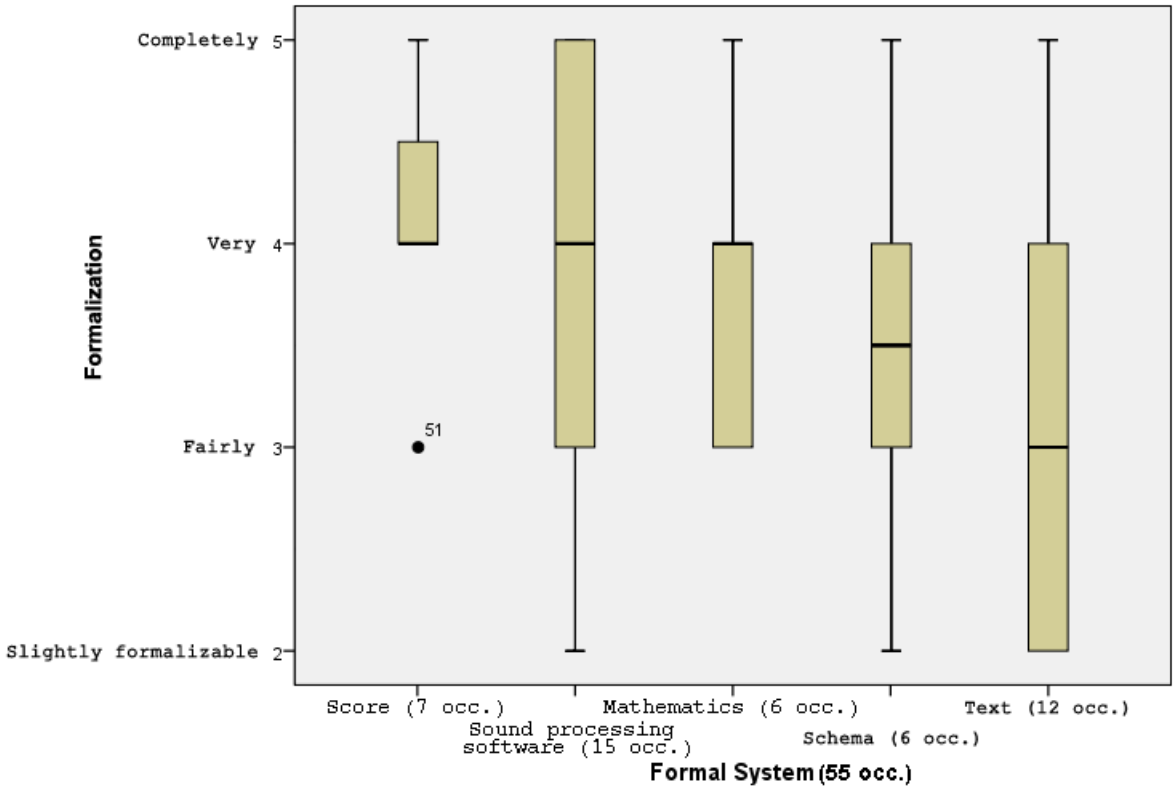

Figure 5.3 Box plot for formal system and formalisation (see Appendix A – questions 7 and 8)

from interviews and pilot study, seems to indicate that respondents considered this dimension to be cumulative instead of thinking about mutually exclusive response categories. From this perspective, the knowledge relevant to the whole work would be automatically relevant to a specific part of the work. This makes the analysis of this level more difficult but not deprived of interest.

We performed a Kruskal-Wallis test, a non-parametric equivalent to the ANOVA, to evaluate the effect of spatialisation experience over the model. The only significant measures of association were the one with the diffusion dimension, specifically at both levels the work as a whole (statistic: 7.32, significant at the 5% level) and several works of yours (statistic: 6.15, significant at the 5% level). More experienced composers can indeed best describe the larger diffusion potential of their own work than less experienced composers. This suggests that experienced composers have a broader vision of the impact of specific knowledge.

5.4.3.2 Inter-dimensional association

Codification vs. Abstraction and Diffusion: The codification dimension shows a strong independence from the other two dimensions. The only significant association observed is at the expression level. The strong independence emphasises the potential benefit of this specific part of the model for archival purposes since the codification information is not accounted for by the abstraction or diffusion dimensions. Specifically it provides information that is independent from abstraction levels operationalised through FRBR. This result highlights the potential for an extension of significant properties to a framework that considers the knowledge involved in the creation process be it tacit or explicit knowledge. Abstraction vs. Diffusion: The relationship between abstraction and diffusion is complex. Indeed, although no significant association was found between diffusion levels and the abstraction levels expression and manifestation, the association to the highest level of abstraction: work, is strong (statistic spanning from 0.327 to 0.527 for several works, significant at the 1% level). In terms of Boisot's model, this association highlights the fact that more abstract knowledge would tend to be easier to diffuse. Interestingly, this seems to go in the direction of Boisot's prediction in its original domain of application, namely management (Boisot & Child, 1999).

5.4.4 Spatialisation knowledge according to context

As Peters et al. (2011) did, we asked respondents to identify the orchestration/style of the work they referred to during the survey. The answers were distributed as follows: fixed media (28 occ.), mixed works (16 occ.), real time synthesis (12 occ.), other self-described styles (6 occ. including installation; electronics; and electroacoustic). We used a Kruskal-Wallis test to investigate the impact of orchestration/style on the classification along Boisot's model dimensions. We removed knowledge descriptions associated with a self-described orchestration/style that was not provided a priori, in order to remove potential noise. This resulted in a set of 55 knowledge descriptions. The analysis revealed no significant difference ($p>0.5$) between styles for each dimension in the model. This result suggests that this model is appropriate for different creative styles. In order to test potential associations

between orchestration/style and lifecycle phases we performed a Cramer's V test between these two measures. We removed occurrences associated with other phases and orchestration/style than those provided a priori. This resulted in a set of 52 knowledge descriptions. The test revealed a two-tailed significant association ($V=0.436$; $p<0.05$) between orchestration/style and lifecycle phases. Specifically, for real-time synthesis, the preeminent phase is spatialisation system implementation while mixed works emphasises the conception phase, and fixed media works spread over several phases including mixing and conception (see Figure 5.4).

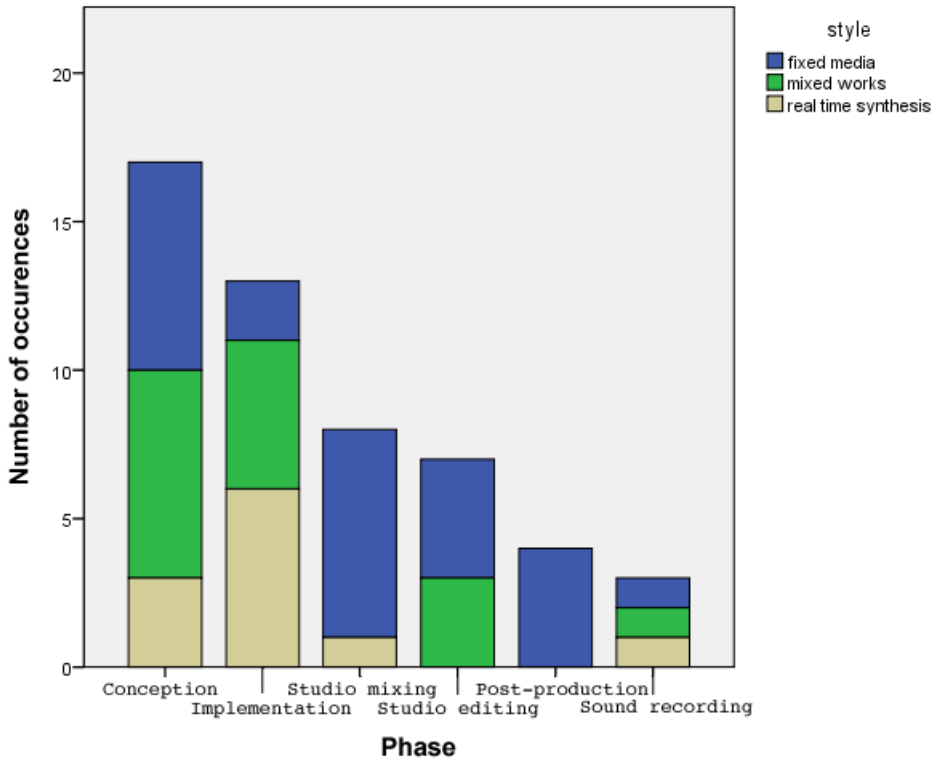

Figure 5.4 Knowledge descriptions occurrences for each of the creative phases grouped by orchestration/style (see Appendix A – questions 4 and 10)

Consequently, while phases are significantly different across orchestration/style, there is no significant difference between styles in terms of the model. The mapping between knowledge description and creative phases does not account for an idiosyncratic and complex creative process likely to be different for each composer and work. Nevertheless, it highlights significant differences between broad categories of orchestration/style that may

have impact on preservation methodologies. These results suggest the potential use of Boisot's model in different artistic contexts. Considering the recent use of similar technologies in various domains such as theatre, dance, installation art, this result is likely to be of interest to the artistic community at large.

5.4.5 The knowledge lifecycle

The distribution of knowledge descriptions in terms of creation phases is the following: Conception (18 occ.); Spatialisation system implementation (14 occ.); Studio mixing (8 occ.); Studio editing (7 occ.); Post-production (4 occ.); Sound recording (4 occ.); others (4 occ.); Rehearsal (2 occ.). We analysed only the most populated phases (4 occ. and fewer were excluded from the analysis).

The most selected phases exhibit interesting features (see Figure 5.5). Conception (see Figure 5.5.a) emphasises higher level of abstraction, mid level of formalisation, and lower levels of diffusion, that is to say a knowledge that is more relevant to a specific part of the work as opposed to a knowledge that is more relevant to several works or even to other composers' works. Interestingly this tendency is reversed compared to Boisot's model prediction of higher diffusion for more abstract knowledge (Boisot et al., 2007), but the lower level of codification could account for this tendency. In contrast to this, studio mixing (see Figure 5.5.c) emphasises higher levels of diffusion and lower levels of abstraction. Similarly the second most selected phase spatialisation system implementation relates to lower levels of abstraction and does not emphasise any specific level of diffusion. Considering the cumulative use of the diffusion levels noted above, this accounts for a higher diffusion tendency. Contrary to studio mixing however, the spatialisation systems implementation phase (see Figure 5.5.b) shows high codification potential. Sound editing (see Figure 5.5.d) seems to exhibit the same tendencies as spatialisation system implementation except for the possibility of extending to the highest level of diffusion, which indicates the need for this particular level of specification. In view of the model, though interquartile ranges are important, we see specific distinctions between creation phases (see Table 5.3). In terms of abstraction we may distinguish between higher abstraction level phases with conception, middle range abstraction level like spatialisation system implementation, and lower

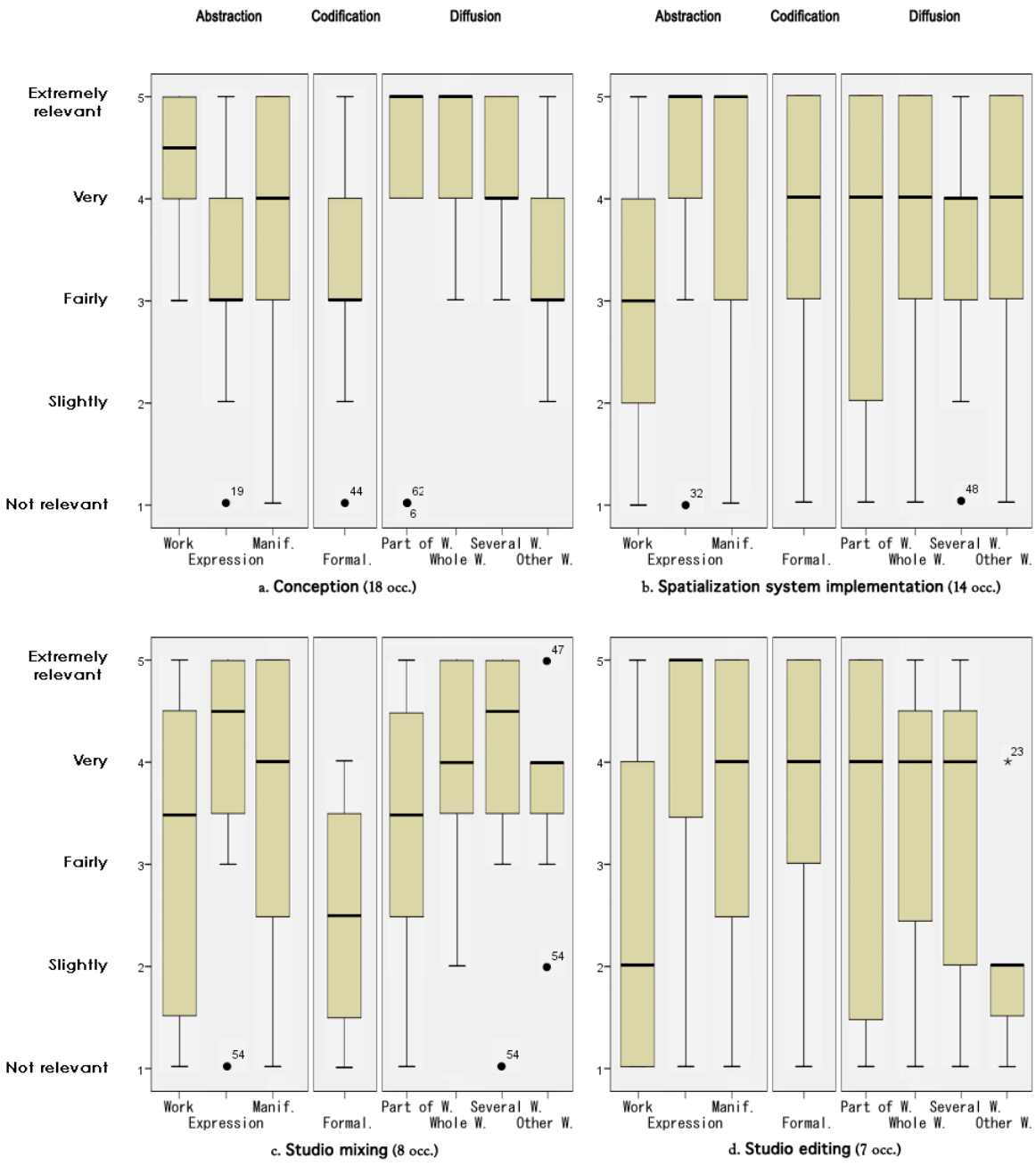

Figure 5.5 Ordinal ranking of creation phases according to the knowledge model operationalisation (see Appendix A – questions 6, 7, and 9)

abstraction level phases such as sound editing. In terms of codification, we may distinguish between higher levels for spatialisation system implementation and sound editing, middle range codification for conception, and an unexpected, puzzling though interesting, low level for studio mixing. Descriptions at the diffusion dimension levels are not straightforward because of the possible cumulative effect mentioned previously. There is also a potential bias regarding relevance to other composers' work due to the competition in terms of creativeness that might exist within the artistic domain. In terms of tendencies, while studio mixing tends towards higher levels of diffusion, conception tends to go in the opposite direction, that is to say towards lower levels of diffusion. Spatialisation system implementation seems to stand rather flat at a higher level of diffusion while studio editing shows a similar but wider distribution.

	Low level	Medium level	High level
Abstraction	Conception	Spatialisation system implementation	Sound editing
Codification	Spatialisation system implementation; Sound editing	Conception	Studio mixing
Diffusion	Conception	-	Studio mixing

Table 5.3: Creative process phases, classification summary

5.5 Discussion

Operationalisations of Boisot's model are sparse. Despite the acknowledged potential of Boisot's model for operationalisation (Dalkir, 2005), empirical studies using these operationalisations are even sparser. This observation applies more generally to the field of

knowledge management; according to Boisot, Canals, and MacMillan (2004), knowledge management theories are "often too general or abstract to be easily testable" (p. 3). Our contribution here is to 1) propose an operationalisation of Boisot's Information Space model (1995) in the context of electroacoustic and mixed music creation and 2) use the resulting questionnaire for an online survey with composers. We were able to validate the use of Boisot's model in an artistic context and to identify limitations in terms of what respondents were able to relate to for the abstraction and diffusion dimensions. Regarding abstraction, the survey results revealed a significant association between the FRBR levels of expression and manifestation. The relevance of the diffusion dimension was first noted in preliminary interviews (Boutard & Guastavino, 2011), as composers proved to be very aware of these different levels as regards their work. In the survey, we observed a strong association between the first three levels of diffusion: namely part of the work; the whole work; and several works. This significant measure of association is consistent with feedback from the interviews and the pilot, during which composers reported a cumulative understanding of these three levels: in their view, if knowledge is relevant to several works it is also relevant to the whole work, and part of the work. Furthermore, in terms of association between dimensions, the lack of independence across dimensions highlights the non-orthogonality of our operationalisation. This result is in line with Boisot's (1995) description of the information space, which includes a systematic relationship between diffusion and codification, as well as between diffusion and abstraction. Considering this non-orthogonality, our operationalisation enabled us to characterise knowledge descriptions along the three dimensions of the model. Regarding codification, our findings highlight a wide range of potential for formalisation, as well as diversity of foreseen formal systems. While this measure represents a subjective measure of respondents, our findings have two consequences on archival practices in terms of data collection methodologies and management of diversity. Specifically the first outcome, that is to say the various degrees of potential formalisation of specific knowledge involved in the creative process, urges to reconsider, or complement, purely formal approaches to preservation of electroacoustic and mixed music works such as technological approaches through virtualisation of technologies (Ciavarella et al., 2009), or approaches in terms of textual documentation (Duranti & Thibodeau, 2006). Subsequently the lack of foreseen potential for formalisation has implications in terms of data collection methodologies. Specifically it questions the suitability of externalisation (Nonaka & Takeuchi, 1995), that is to say the conversion of tacit into explicit knowledge, as the

most relevant strategy for documentation of all knowledge involved during the creative process of electroacoustic and mixed music works with spatialisation. In this regard, according to Cowan et al. (2000), a standard economic view is to consider that the cost of making this knowledge explicit may be too high. As regards knowledge descriptions, respondents described a broad set of knowledge related to spatialisation, which emphasised the great richness of this concept both in electroacoustic and mixed music. In a similar vein, Merlier (2006) listed 350 words in his taxonomy of spatialisation in electroacoustic music. While knowledge is diverse, with respondents covering the whole range of electroacoustic and mixed music, and while composers' approach to sound spatialisation may be idiosyncratic and in some cases of electroacoustic music strictly related to performance, our operationalisation of Boisot's (1995) model proved to be globally consistent with Boisot's initial description of the information space in the context of organisation science and economics. Similarly the ratings proved to span the entire range of the three dimensions, which accounts for the relevance of the model in the context of the creative process of electroacoustic and mixed music. Furthermore the classification of knowledge inside the model proved to be independent of the creation lifecycle. Consequently there is a strong potential to use this model in other contexts. This is of interest to the artistic community at large since theatre, dance, and arts installations currently use these digital processing technologies. Since time-based media installations have been considered an allographic art (Laurenson, 2006), that is to say an art that is performed, it may be useful to consider convergent preservation methodologies.

5.6 Conclusion

We propose a conceptual interdisciplinary framework derived from previous research in information science, knowledge management, and music research. This framework relies on the operationalisation of Boisot's information space model and aims at providing a meaningful usability for electroacoustic and mixed music digital artefacts. Specifically this operationalisation is proposed as a characterisation of what we called significant knowledge. In this context significant knowledge may be considered an extension of significant properties that emphasises the role of tacit knowledge during creation processes. It is specified

through our model's operationalisation as regards its three dimensions: abstraction; codification; and diffusion. This framework first provides support for specifications in terms of relevant data collection methodologies according to the classification of knowledge inside this framework and the specific aspects of the domain it addresses, with the purpose of preserving through adequate archival practice. Second, it provides support for integration of tacit knowledge concerns inside digital archives models. Indeed, the significant knowledge framework is relevant to the preservation of every digital objet that involves tacit knowledge during its creation process, a situation likely to be entrenched in other contexts. On practical grounds, this framework addresses the sustainability of the repertoire of electroacoustic and mixed music. Because our operationalisation does not depend on the orchestration/style and encompasses different creation lifecycle, its relevance to broader domains should be investigated. Indeed these digital artefacts have been recently pervading domains such as contemporary art practices in the field of theatre as well as dance. The description of the creation lifecycle in terms of list of phases derived from the interviews allowed us to provide a framework relevant to archival practices in terms of ingestion framework. But in order to address the inherent complexity and variety of creative processes, future research is needed to extend this research to specific cases of artistic creation involving multiple agents. Using ethnographic data, we plan to document a multi-agent creation process involving both human (e.g. composers, engineers, performers) and non-human agents (e.g. software, interfaces) in terms of interaction processes and knowledge lifecycle. Together, these findings will inform documentation and preservation frameworks for artistic works with technological components.

Chapter 6

Study 2: Grounding the documentation of creative processes of contemporary works with live electronics

6.1 A creative process involving Gesture Following: Florence Baschet's *StreicherKreis*

The present study investigates the multi-agent creative process of a mixed music work in order to provide new insights for documentation practice. This research departs from a strictly formal and technological approach to technology preservation, broadening the scope by offering a sociological approach where technology is just one agent among others (see further details in section 2.4).

In this context of multi-agent creative processes, we focus on an interactive composition involving gesture following (see section 2.4.1.2), which was the object of an ethnographic data collection. In 2006 Donin, Goldszmidt, and Theureau started a study at IRCAM on the creative process of Florence Baschet's string quartet augmented with electroacoustic processes, *StreicherKreis*. Their goal was to inform cognitive ergonomics as well as music research with a focus on creative processes (Donin et al., 2009). Our study will rely on a formal analysis of the data set they collected between 2006 and 2008, but our aim is to inform documentation practices.

During the research phase (six work sessions in the studio, from February 2007 to July 2007), Donin and colleagues collected ethnographic data about experiments and gesture-control technological system development with one or several performers. During the production phase (five work sessions in the studio, from September 2007 to October 2008) they collected further ethnographic data about the process of music creation. Both phases involved the composer, as well as the computer music designer (a.k.a. musical assistant), the scientific team and its leader, and different engineering teams (sound and electronics). This augmented string quartet project built upon a previous project on gesture following with the same composer: *Bogenlied*, a composition by Florence Baschet for augmented violin (Bevilacqua, Rasamimanana, Fléty, et al., 2006). For *StreicherKreis*, the gesture-following technological environment is composed, in particular, of the IRCAM Max/MSP library MnM and a module combining a three-axis accelerometer (Analog Device ADXL335) and a dual-axis gyroscope (InvenSense IDG500) (Bevilacqua, Baschet, & Lemouton, 2012).

During the project's presentation meeting, on 6 February 2007, Florence Baschet stated, "this quartet is a real challenge, I would like it to really be 'augmented.' When I got involved with the gesture working group [at IRCAM], when I composed *Bogenlied*, I already had in mind the idea of this quartet, but it was not possible to start before we validated the possibility of using gesture as a real compositional parameter" (our translation; see Appendix B, row 1). Based on this statement, we first note that the collaboration between Florence Baschet and the scientific team started as a super-consultant relationship during *Bogenlied* and later evolved into a planned true partnership for the quartet (to use the classification of Stroppa et al., 2011). Second, interactivity in *StreicherKreis* fits Rowe's player paradigm as well as his instrumental paradigm, a goal presented by the scientific team leader, who stated at an early stage of the research phase, "the electronic part will emerge as a fifth performer" (our translation; see Appendix B, row 2). As a consequence, this creation process provides us with a unique opportunity to analyse interactions between all agents involved in a context relevant to the preservation of musical works dealing with electroacoustic technologies.

	Work sessions		Debriefing sessions		Interviews	
	Video (mn)	Transcriptions (words)	Video (mn)	Transcriptions (words)	Video (mn)	Transcriptions (words)
Project's presentation meeting (06/02/07)			150	9457		
Research phase (02/07 to 07/07)	1130	13511	321	11089	175	9859
Production phase (09/07 to 10/08)	1710	60994	70	4981	544	20087
Final debriefing (19/11/08)			136	9088		
Total	2840	74505	677	34984	719	29946

Table 6.1: Video Data Captured During Work Sessions, Debriefings, and Interviews

6.2 Methodology

In this section, we present the data set and the challenges of its methodological analysis.

6.2.1 Data Review

Our large data set consists of video recordings of all work sessions (involving all participants) and debriefing sessions (with all participants but the performers) over two years, as well as video interviews (with several participants including the composer, the computer music designer, and the scientific team leader), scores, software, emails, notes, and reports (Donin et al., 2009). We were also provided with transcriptions of video recordings. Table 6.1 summarises the data set recorded during work sessions, debriefing sessions, and interviews, in terms of video duration and transcription length.

6.2.2 Secondary Data Analysis

Our analysis relies on grounded theory, an inductive method of theory development (Glaser & Strauss, 1967), i.e., a way of producing a theory that is grounded in data, in contrast to the typical approach of starting from a hypothesis. Grounded theory consists of: (1) a method of formalisation based on constant comparison at every level of analysis; (2) a specific sampling method; and (3) a specification of the saturation point, named theoretical saturation. The process is summarised by Strauss and Corbin (Strauss & Corbin, 1998) as "data gathering driven by concepts derived from the evolving theory and based on the concept of 'making comparisons,' whose purpose is to go to places, people, or events that will maximise opportunities to discover variations among concepts and to densify categories in terms of their properties and dimensions" (p. 201). Grounded theory was developed for qualitative data and fieldwork but applies to different data-collection techniques (Glaser,

1978). Strauss and Corbin (1998) consider that "researchers should approach already collected data and secondary or archival materials exactly as they would their own data" (p. 281). Szabo and Strang (1997) emphasise the need for large data sets for secondary data analysis. In our data set, we focussed on data relevant to the documentation process of the technological part of the composition. We first reviewed the entire data set, with the support of a data index provided by IRCAM's Analyse des Pratiques Musicales (APM) team, in order to implement a strategy based on grounded theory's theoretical sampling, i.e., the way the analyst "decides what data to collect next and where to find them, in order to develop [her or] his theory as it emerges" (Glaser & Strauss, 1967, p. 45). Consequently we started our analysis with data out of the project's presentation meeting, together with studio sessions and debriefing from the research phase. During the analysis we established relationships between statements from the debriefing sessions and corresponding work sessions. Then we extended the analysis to work sessions and interviews of the production phase, until we reached theoretical saturation (25,000 words out of a transcription corpus of about 140,000 words).

Not included in the analysis are interviews and work sessions that focussed on instrumental practice or composition per se (with no link to electroacoustic aspects), or any discussions outside of the project context. We coded verbal data transcribed from the videos or written material (notes, reports, and emails), but not nonverbal information (such as behavior or facial expressions). Because transcriptions were often incomplete or sketchy, we reviewed all videos and completed the transcriptions for relevant incidents, i.e., the unit of analysis in grounded theory.

6.3 Analysis

We analysed about 650 incidents (with 38 words per incident on average) using grounded theory's constant comparison analysis. Each incident could be classified into one or more categories.

Four main categories emerged from the data analysis: *organological specifications*, *knowledge lifecycle*, *production process lifecycle*, and *electroacoustic composition*, each one of them leading to a hierarchical structure of sub-categories. The inductive analysis principle of grounded theory tends to generate categories starting from low levels to reach, a posteriori, more abstract categories. But for the sake of argumentation we will instead discuss these categories from the more generic to the more specific. In this article's four figures, each of which depicts a categorisation scheme, the most generic categories are displayed on the left side and the most specific sub-categories are displayed on the right. The following scheme is used for differentiation purposes: first-level categories are formatted in **CAPITAL LETTERS AND BOLD STYLE**; second-level categories in *CAPITAL LETTERS AND ITALIC STYLE*; third-level categories in ***bold and italic style***; and subsequent categories in *italic style*. The quotations in Tables 2, 3, 4, and 5 are our translations; please refer to the Appendix B for the original quotations. The composer is referred to as COM, the computer music designer as CMD, and the scientific team leader as STL.

6.3.1 ORGANOLOGICAL SPECIFICATIONS

ORGANOLOGICAL SPECIFICATIONS (see Figure 6.1) refer to statements that define the project's specific organological setup. Organology is not restricted here to the musical instrument taxonomy but also includes computers, software, sensors, etc. (Stiegler, 2003). It can be divided into two subcategories: *LOGICAL FUNCTIONALITIES* and *SYSTEMIC DEPENDENCIES*.

LOGICAL FUNCTIONALITIES describe the technological system in terms of logical entities involved in the specific goal of the project, namely (in the case of *StreicherKreis*), to produce an electroacoustic processing in relation to gesture. Three entities emerged from the analysis: ***data production***, ***data pre-processing***, and ***data processing***. Interestingly, this categorisation can be related to Rowe's (Rowe, 1993) theorisation of the processing stages of interactive computer music systems: "the first is the sensing stage, when data is collected from controllers reading gestural information from the human performers on stage. Second is the processing stage, in which a computer reads and interprets

ORGANOLOGICAL SPECIFICATIONS	LOGICAL FUNCTIONALITIES	***Data production***	*Typological specifications*	
			Contextualization	
		Data pre-processing	*Calibration*	
			Modification	
		Data processing	*Modeling*	*Extraction principles and procedures*
				Differentiation and segmentation principles
			Operationalizing	*Comparison and recognition principles*
				Comparison procedures
			Mapping	*Mapping principles*
				Entities
	SYSTEMIC DEPENDENCIES	***Reliability / Adaptability***	*To compositional properties and variations*	
			To organological properties and variations	
			To intra/inter-individual characteristics and differences	
			To performance context properties and variations	
		Engineering	*Architecture*	
			Libraries and versions	

Figure 6.1 Organological specifications

information coming from the sensors and prepares data for the third, or response stage, when the computer and some collection of sound-producing devices share in realising a musical output" (p. 9). Our analysis, however, revealed an additional ***data pre-processing*** category, referring to issues of data *calibration* (see Table 6.2, quotation 6) and *modification* (see Table 6.2, quotation 7) mentioned recurrently throughout the whole creative process. *Modification* refers to various processes of data cleaning.

Within ***data production*** we distinguish between *typological specifications* and *contextualisation*. *Typological specifications* refer to data-production systems' specifications that are not context-related. For example, the kind of measurements provided by sensors (see Table 6.2, quotation 3), characteristics of the signal (seeTable 6.2, quotation 4), and data formats. *Contextualisation* provides the link between the data production system and its organological context (see Table 6.2, quotation 5).

data processing may be considered the core issue of the organological specification framework. It is a major goal of the project (see Table 6.2, quotation 8), specifically for the scientific team, whose leader is involved in other projects involving gesture following (Donin

et al., 2009). The relevance of this involvement relates to the link discussed later between **PRODUCTION PROCESS LIFECYCLE** and *KNOWLEDGE RANGE*. ***data processing*** emerged as a threefold categorisation that is not function-related and therefore is less work-specific. It describes broader concepts that refer to logical entities. This is not surprising, because the process of categorisation tends to move toward greater levels of abstraction. For example, a distinction between gesture following and gesture recognition could account for more concrete levels of explanation, but this proved less relevant according to the method of analysis.

Modeling refers to the part of the process that builds up models needed for performance. On one side, this *modelling* activity is defined by *extraction principles and procedures*, i.e., theories and implementations that relate models' specifications to the signal (see Table 6.2, quotation 9), and, on the other side, by *differentiation and segmentation principles*, i.e., specification processes for models' boundaries (see Table 6.2, quotation 10).

Operationalising is about using modelling outcomes within the real-time framework. It directly relates to performance. Within *operationalising*, we distinguish *comparison and recognition principles*—that is to say, principles that relate the performance data to models—from *comparison procedures* that refer to actual processes. For instance, the composer at the beginning of the project emphasises a non- Boolean comparison method (see Table 6.2, quotation 11) whereas the scientific team leader emphasises a specific procedure (see Table 6.2, quotation 12).

Mapping, finally, is the arbitrary setting of relationships, *mapping principles* (see Table 6.2, quotation 13), between two *entities* (see Table 6.2, quotation 14). In our context, it refers predominantly to the relationship between the outcomes of the comparison, such as the one previously described, and electroacoustic transformations (a filter, a reverb, etc.).

id	date	session	agent	translated quote
3	2/6/07	Project's Presentation Meeting	STL	"the sensor, which is a three-axis accelerometer and a two-axis gyroscope. So the accelerometer measures accelerations according to three potential axes and the gyroscope measures angular velocity according to two axes"
4	2/6/07	Project's Presentation Meeting	STL	"in a way it means that the work could be reperformed with something else. It could be reperformed with something other than accelerometers if we are ever able to provide the same kind of information"
5	9/19/07	Interview COM+CMD	COM	"there is a small ring that goes in [...], which adapts to each bow since each bow is different"
6	3/6/07	Interview COM	COM	"sensor number two is poorly calibrated, it may provide more significant information in the future"
7	2/6/08	Work Session (afternoon)	STL	"we should use a gate on sound again [...]"
8	9/19/07	Interview COM+CMD	COM	"[...] gesture following, since it is ... one of the main electroacoustic goals of this work, that is to say on the software side"
9	2/6/07	Project's Presentation Meeting	STL	"we try to extract parameters by comparing these different [signal] units"
10	5/22/07	Interview STL	STL	"what we do actually is listen to the whole work and specify 'here we switch to the next model'. For example there is this part where 'écrasé' bow strokes chain up very fast with 'martelés' bow strokes; we may even consider this a whole section"

Continued...

id	date	session	agent	translated quote
11	2/6/07	Project's Presentation Meeting	COM	"and the third interesting point is to recognise it [gesture] in context, out of context, played by a performer in two different ways, but also to be able to assess these differences between the way it was defined and the way it is performed. This is more interesting than simply saying 'I recognised it, I won', which is poor"
12	5/22/07	Interview STL	STL	"if this is the referenced played and if this is what is realigned with a margin of error, we draw a function between this and this to obtain that, then we calculate the slope, and it provide us with the difference mean"
13	11/19/08	Project's Debriefing Meeting	CMD	"[...] at witch point are there too many of them [sensors], When is it not worth it anymore since we cannot perceive anything? Indeed when each performer simultaneously controls only one synthesis parameter, [...], it works [...]"
14	4/2/07	Work Session	COM	"I'd like to map his gesture on electroacoustic transformations, I receive very little gesture signal and I'd like to map it to bass frequency density"
15	3/6/07	Interview COM	COM	"transposing up a sixth is no problem for gesture recognition"
16	1/15/08	Work Session	CMD	"we have to adjust pressure a little bit, we changed potentiometers, now they are easier to calibrate"
17	5/22/07	Interview STL	STL	"It is going to work better because there will be less variation in the way they play"

Continued...

id	date	session	agent	translated quote
18	11/19/08	Project's Debriefing Meeting	CMD	"whenever you play [...] in different concert halls [...], you need a fast adaptive system, you cannot do everything all over again each time. Now that is what you've got: a fast adaptive system"
19	9/19/07	Interview COM+CMD	CMD	"you know it's not stable, even between a dress rehearsal and a concert. The follower has to have the widest possible variety, from almost good to not good at all."
20	9/26/07	Interview STL	STL	"one machine will carry out everything sound processing related and another one will carry out the analysis"
21	10/30/07	Work Session	COM	"B : and it's lib and...? A : lib, snd, and FTM [...] B : ok and witch patch? A : october 30th 2001"

Table 6.2: Translated Quotations in the Category **ORGANOLOGICAL SPECIFICATIONS**

SYSTEMIC DEPENDENCIES are twofold, either dealingwith ***reliability and adaptability*** of the technological system, or with ***engineering*** dependencies. Within the category of ***reliability and adaptability*** we refer to four topics: *Compositional properties and variations* (see Table 6.2, quotation 15), *organological properties and variations* that describe the system's own capability to address variability (see Table 6.2, quotation 16), *intra-/inter-individual characteristics and differences* (see Table 6.2, quotation 17), and *performance context properties and variations*, a broad sub-category that relates to different kinds of performance context (see Table 6.2, quotation 18), as well as different kinds of performances (see Table 6.2, quotation 19).

On the other hand, ***engineering*** dependencies relate to usual technological dependencies in terms of *architecture* (see Table 6.2, quotation 20), and *libraries and versions* (see Table 6.2, quotation 21).

6.3.2 KNOWLEDGE LIFECYCLE

The **KNOWLEDGE LIFECYCLE** category (see Figure 6.2), which emerged from analysis, is a specific topic of interest for our research, as it relates to the notion of black-boxed instruments (Magnusson, 2009).

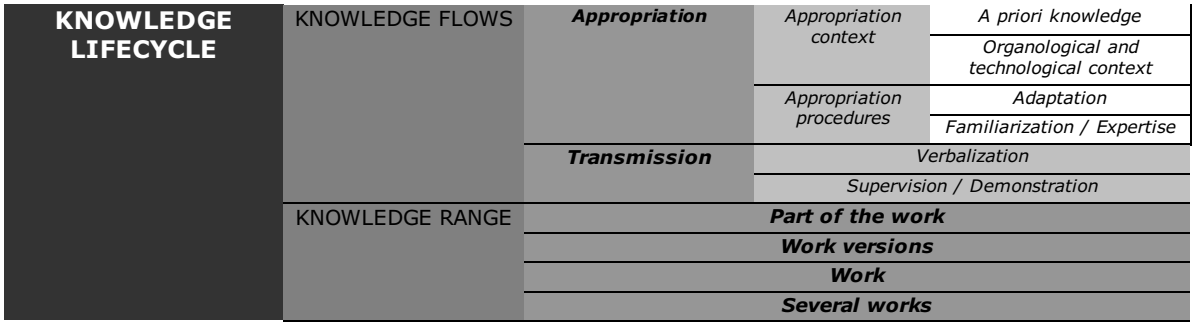

Figure 6.2 Knowledge lifecycle

KNOWLEDGE FLOWS is the first sub-category of **KNOWLEDGE LIFECYCLE**. It describes knowledge processes involved in the creative process through two different types of process: ***appropriation*** and ***transmission***.

Appropriation is a complex process. As we will see, it involves far more agents than anticipated and is not limited to embodiment issues by performers. It can be divided into *appropriation context* and *appropriation procedures*. *Appropriation context* refers to external factors affecting the appropriation process. It involves both a priori knowledge (see Table 6.3, quotation 22), a broad category that also involves ***transmission*** between actors (see Table 6.3, quotation 23), and organological and technological context, which often refers to constraints imposed by the system (see Table 6.3, quotation 24). Generally

speaking, this category is in direct relationship with **ORGANOLOGICAL SPECIFICATIONS** but also with other constraints such as the recurring discussion during the creative process about sound feedback for performers (Donin et al., 2009). On the other hand, *appropriation procedures* refer to *adaptation* (i.e., practice modification for this specific project; see Table 6.3, quotation 25), and *familiarisation / expertise* (i.e., appropriation procedures which do not imply any specific prerequisites). These procedures are not limited to performers. Indeed, the computer music designer as much as the scientific team is involved in *appropriation procedures*, especially within *familiarisation / expertise* procedures (see Table 6.3, quotation 26).

Transmission, on the other hand, is purposive, in the sense that it is a knowledge flow whose goal can be articulated but whose process is more or less tacit. It emerged through two sub-categories, namely, *verbalisation*, which can be affirmative (see Table 6.3, quotation 27) or interrogative (see Table 6.3, quotation 28), and *supervision / demonstration*, which differs from *verbalisation* because it implies more-tacit modes of transmission (see Table 6.3, quotation 29).

KNOWLEDGE RANGE, the second sub-category of **KNOWLEDGE LIFECYCLE**, places knowledge significance within a context. It answers the question, "What does it apply to?" The analysis revealed four contexts. ***Part of the work*** refers to knowledge that is related to a specific part of the composition (see Table 6.3, quotation 30). ***Work versions*** emerged from the analysis of the project debriefing session on 19 November 2008 (see Table 6.3, quotation 31). ***Work*** is about knowledge impacting the whole work (see Table 6.3, quotation 32). Because the work is the scope of this case study, these kinds of incidents are likely not to occur in the verbal data. Finally, ***several works*** refers to knowledge that is relevant to multiple compositions, either from the same composer, for instance, *Bogenlied* (see Table 6.3, quotation 33), or other composers.

id	date	session	agent	translated quote
22	2/6/07	Project's Presentation Meeting	COM	"it implies instrumental practice because she worked her gesture eight hours a day at the conservatory, the repertoire, it implies to be used to contemporary music [...] and then it implies note accuracy in a specific situation that relates to the instrument... and then it implies oral tradition [...]"
23	10/30/07	Work Session	COM	"[Performer] and how do we know... or is this not important? [Composer] yes, you know it, [...]. So the one with the lead has the frequency shifter control with the pressure sensor. So actually you'll hear that these events work, [...]"
24	2/6/07	Project's Presentation Meeting	CMD	"[...] we abandoned [the sensor's position] since it was too constraining"
25	4/2/07	Work Session	COM	"to adapt his technique to this, we felt he had to play flautendos for a longer time so that it works"
26	2/6/07	Project's Presentation Meeting	STL	"if something is not working and we clearly see why, [...] and the system reacts as expected because of this error, it still makes us move forward because we get familiar with the system [...]"
27	1/15/08	Debriefing Session	COM	"I explained electroacoustic to them, what I wanted to do here and there"
28	2/12/07	E-mail	COM	"1 I need details about the flautendo capture. 2 Does the accelerometer operate in 3D? [...]"

Continued...

id	date	session	agent	translated quote
29	10/30/07	Work Session	COM	"for example here it the violin 1 that... wait, I transfer it [sound effect] to violin 2, go ahead, play whatever you want and you will hear the frequency shifter that..."
30	9/19/07	Interview COM+CMD	CMD	"in the first section there are comparisons between individual or inter-individual models, but it is not necessarily a conscious gesture control"
31	11/19/08	Project's Debriefing Meeting	STL	"basically, if we were to perform it again in a month, I think I would move a marker to the beginning of a section and eventually restart the training of one section, or nothing... "
32	2/21/08	Interview COM+CMD	CMD	"she used this experiment's outcomes again and it's true, since there is no need to do it all over again, and now you know what works and what doesn't work"
33	2/21/08	Interview COM+CMD	CMD	"the granular synthesis, which is the same as the one in Bogenlied"

Table 6.3: Translated Quotations in the Category **KNOWLEDGE LIFECYCLE**

6.3.3 PRODUCTION PROCESS LIFECYCLE

The **PRODUCTION PROCESS LIFECYCLE** (see Figure 6.3) specifies the project framework in terms of *PRODUCTION STEPS* and *WORKFLOWS*. It addresses critical aspects of the creative process.

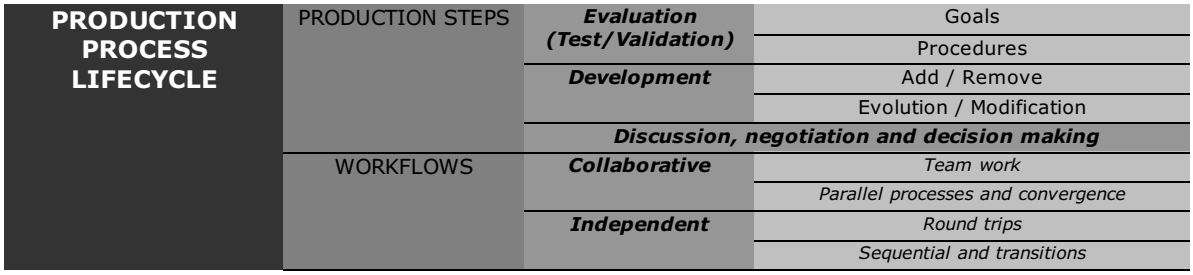

Figure 6.3 Production process lifecycle

PRODUCTION STEPS is a category that emerged from three sub-categories, namely, ***evaluation (test / validation)***; ***development***; and ***discussion, negotiation, and decision-making***.

Evaluation (test / validation) is a category often referred to because the whole creative process is punctuated by these processes. It is characterised by its goals (see Table 6.4, quotation 34) and its procedures (see Table 6.4, quotation 35).

Development is the logical counterpart of ***evaluation (test / validation)***. It relates to both software and hardware, and accounts for standard engineering practices in terms of features. It divides into *add / remove* (see Table 6.4, quotation 36) and *evolution / modification* (see Table 6.4, quotation 37).

Discussion, negotiation, and decision-making, the last category within *PRODUCTION STEPS*, relates to events that are usually of a shorter time span. Decision-making reflects the evolution of the global project, and may provide accounts for critical steps of the process (see Table 6.4, quotation 38).

WORKFLOWS refer to project management practices. It involves agents and the different ways they work together within the project framework, either in a direct ***collaborative*** way or in an ***independent*** way.

Collaborative processes emerged in two different ways: strict *teamwork*, which refers to the work conducted by several agents (usually at the same time and place; see Table 6.4, quotation 39) and *parallel processes and convergence* (see Table 6.4, quotation 40).

Independent, on the other hand, relates to processes that are, broadly speaking, sequential, either *round trips* (see Table 6.4, quotation 41) or in a strict *sequential and transitions* way, which describes sequential work but also the way an activity follows a previous one (see Table 6.4, quotation 42).

id	date	session	agent	translated quote
34	11/19/08	Project's Debriefing Meeting	CMD	"we tested it, and we understood that the speed parameter wasn't doing anything"
35	9/26/07	Interview STL	STL	"Florence usually started with Plot [...] we can view the data, we can see differences to some extent [...] and then we check how the system analyses... and we go back to Plot when things surprised us; when we can't recognise or follow something, we go back to Plot and carefully look at the details [...]."
36	4/12/08	Interview COM	COM	"I removed some modules and work only on harmoniser, granular synthesis, frequency shifter, distortion, reverberation [...]"
37	9/26/07	Interview STL	STL	"Things will change over here. Here we selected only one instrument and this is going to disappear... instead we will be able to select a group of sensors from any instrument"

Continued...

id	date	session	agent	translated quote
38	11/19/08	Project's Debriefing Meeting	COM	"then we fiercely negotiated with [the computer music designer], he told me that we wouldn't come back to real-time mode if ever we did that, we would stay in fake real-time mode. I said 'no way, we stay in fake real-time mode as long as the system is down and then we come back to real time mode"
39	11/19/08	Project's Debriefing Meeting	COM	"We did a fine job with [the sound engineer], we played it in full, he listened to it, he understood perfectly, he took notes, etc."
40	2/21/08	Interview COM+CMD	CMD	"I think Florence should work on events [Florence Baschet agrees], I should move forward too, and then converge before... in fifteen days [...]"
41	2/6/07	Project's Presentation Meeting	STL	"there were many round trips, you [Florence Baschet] were bringing parts of the score, and we would tell whether or not it was likely to work"
42	2/6/07	Project's Presentation Meeting	STL	"for the time being we do things in batches [...] We are going to record all these phrases and then we'll check the system's behaviour"

Table 6.4: Translated Quotations in the Category **PRODUCTION PROCESS LIFECYCLE**

6.3.4 ELECTROACOUSTIC COMPOSITION

The last broad category, **ELECTROACOUSTIC COMPOSITION** (see Figure 6.4) may stand on the fringes of our research focus, namely, the inscription of knowledge in electroacoustic technologies. Indeed, this categorisation is the most work-related and therefore the least likely to be transferable to other creative contexts. Still, compositionrelated statements were included whenever they referred to electroacoustic aspects. The **ELECTROACOUSTIC COMPOSITION** category is not a theorisation of what electroacoustic composition is or should be. It is an account, grounded in data, of relationships between compositional questions related to electroacoustic concerns either theoretical or organological. In this sense, this category is relevant to our research. Indeed, there is a close relationship between sub-categories from **ELECTROACOUSTIC COMPOSITION** and categories previously described. It is composed of two subcategories: *COMPOSITIONAL POSSIBILITIES AND INFLUENCE OF ORGANOLOGY* and *COMPOSITIONAL CHOICES* AND *SPECIFICATIONS*.

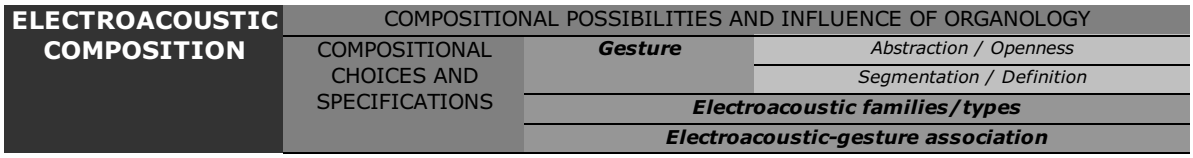

Figure 6.4 Electroacoustic composition

COMPOSITIONAL POSSIBILITIES AND INFLUENCE OF ORGANOLOGY. This category is, in the first place, a counterpart of the **ORGANOLOGICAL SPECIFICATIONS**' ***reliability / adaptability***, specifically the subcategory *compositional properties and variations*, from the composition point of view. An example is the use of technology to register events that constitute a kind of score (see Table 6.5, quotation 43). This specific point refers to what Schnell and Battier (2002) call a "composed instrument"; it "underlines the fact that computer systems used in musical performance carry as much the notion of an instrument as that of a score, in the sense of determining various aspects of a musical work." Furthermore, statements about the specific influence of organology on composition are included in this category. For example, the composer emphasises a specific sensor prop-

erty that appeals to her in relation to the compositional process (see Table 6.5, quotation 44). This is also a natural complement to *appropriation procedures* (Figure 6.2) on the part of the composer, for instance when the composer uses new software for compositional purposes, which implies *familiarisation / expertise* (see Table 6.5, quotation 45).

COMPOSITIONAL CHOICES AND *SPECIFICATIONS* relates to the process of building a compositional discourse about gesture and its relationship to electroacoustic sounds. It is a compositional counterpart of *LOGICAL FUNCTIONALITIES*, especially ***data processing*** (Figure 6.1). It can be divided into ***gesture***, ***electroacoustic families/types***, and ***electroacoustic-gesture association***.

Gesture contains two sub-categories: *abstraction/ openness*, which refers to the level of specification of gesture from a compositional perspective (see Table 6.5, quotation 46), and the *segmentation / definition of gesture*, e.g., the different schemes defined and displayed with pictograms (see Table 6.5, quotation 47). ***Electroacoustic families/types*** refer to the compositional specification of electroacoustic aspects as regards the current musical work, e.g., the definition of different spaces by the composer (see Table 6.5, quotation 48). ***Electroacoustic-gesture association*** refers to compositional aspects of the established relation between electroacoustic aspects and gesture (see for instance Table 6.5, quotation 49).

id	date	session	agent	translated quote
43	2/21/08	Interview COM+CMD	CMD	"the part we didn't talk about is the way we store events. So we are using Patter, and everything is here [pointing at the array of data], so this is the score"
44	10/30/07	Interview COM+STL	COM	"the gyroscope 1 [first axis] is pretty interesting, I personally look a lot at gyroscope 1"
45	9/26/07	Interview STL	STL	"[the Plot software] was very useful to Florence [...] she built up a representation, an intuition about the musical outcome of the sensors."

Continued...

id	date	session	agent	translated quote
46	2/6/07	Project's Presentation Meeting	COM	"I thought about [...] having another pentagram below the score and write exactly... I didn't do it [...] because I wanted the performer to be involved in gesture [...]"
47	7/9/07	Debriefing Session	COM	"[points at the crenel] these are trajectories, I switch between the violin and the cello. [...] [points at the diamond] these are complex forms made out of several gestures"
48	4/12/08	Interview COM	COM	"And in terms of space, I conceived five different spaces."
49	7/11/08	Interview COM	COM	"I tried this writing 2 by 2, with these thirty-second notes, really thinking about an electroaocustic transformation [. . .]"

Table 6.5: Translated Quotations in the Category **ELECTROACOUSTIC COMPOSITION**

6.4 Documentation Relevance

The outcome of our analysis is a complex categorisation that portrays a creative process from four perspectives, each one of them bringing up relevant documentation issues. Considering the state of the art of documentation for musical works dealing with electroacoustic technologies, we are able to provide improvements in terms of the documentation of the knowledge involved in the creative process, its inscription within technological agents, and the ways nonhuman agents interact with human agents. Each of our four broader categories is of potential interest for future documentation frameworks and will be discussed independently.

ORGANOLOGICAL SPECIFICATIONS (see Figure 6.1) are typically addressed by existing documentation frameworks; still, our analysis revealed the importance of topics that are not traditionally covered. First, the significance of ***data pre-processing***, especially *calibration* processes, should be addressed. Indeed, any documentation framework relying on Rowe's (1993) classification might have overlooked this category that proved to be relevant in the analysis. Second, the network of *SYSTEMIC DEPENDENCIES* is of particular interest. As much as *LOGICAL FUNCTIONALITIES* deal with lists of features, characteristics, etc.—that is, the kind of data structure that documentation traditionally deals with—*SYSTEMIC DEPENDENCIES* relate to maps and networks. Indeed, this category portrays a complex network of relationships. If ***engineering*** seems straightforward, and potentially accessible through reverse engineering, the complex set of ***reliability and adaptability*** relationships appears to be a critical documentation issue for future performance (especially for *performance context properties and variations* and *intra-/inter-individual characteristics and differences*) and migration purposes (especially for *organological properties and variations*).

KNOWLEDGE LIFECYCLE (see Figure 6.2) is of specific interest to the question of nonhuman agents' involvement in the process of interaction. *KNOWLEDGE RANGE* relates to issues of cognitive relevance studied by Donin and Theureau (2007). On the other hand, *KNOWLEDGE FLOWS* points at essential documentation issues. First, ***appropriation*** should be documented both in terms of *appropriation context* and in terms of *appropriation procedures*. It is relevant for performers, therefore important for preservation for reuse, ensuring the sustainability of the repertoire. The scientific team leader provides us with a striking example of *appropriation procedures* on the performers' side: "I like the fact that they overplayed with the system [. . .] they get familiar with what is possible, before working in a more subtle way" (our translation; see Appendix B, row 50). Furthermore, the analysis indicates that this category is also relevant for other agents, namely, for the engineers and researchers, therefore relevant for migration purposes. It also applies to composers and therefore is potentially interesting for music research; a shining example of appropriation by the composer is the use of Plot, a very generic plotting software provided but not used by the scientific team, which the composer used in order to visually evaluate the compositional potential of gestural data in terms of data curves and their relationship to the electroacoustic composition (see Table 6.5, quotation 46). ***Transmission*** involves

issues of tacit knowledge flows, an issue also relevant to ***appropriation***. If *verbalisation* refers to knowledge made explicit, *supervision / demonstration* leans toward more tacit communication modes, which suggest that specific methodologies of data collection should be proposed for *KNOWLEDGE FLOWS*.

The category **PRODUCTION PROCESS LIFECYCLE** (see Figure 6.3) may at first sound irrelevant to documentation frameworks, but we argue quite the contrary. Creation is a process, and our analysis shows that all categories previously described are embedded in a temporal framework. First, categories within *PRODUCTION STEPS*, such as ***evaluation (test / validation)*** and ***development***, support **ORGANOLOGICAL *SPECIFICATIONS*** (see Figure 6.1), especially the ***engineering*** sub-category but also ***data processing***, whose principles and procedures evolved during the project. Second, the general lifecycle described with *WORKFLOWS* supports the **KNOWLEDGE LIFECYCLE** (see Figure 6.2) and accounts for the diversity and variability of roles (Benghozi, 1995) within the creative process. Evolutions are critical. ***Reliability / adaptability***, for instance, changed over the lifetime of the project, and so did *appropriation procedures*. **PRODUCTION PROCESS LIFECYCLE** (see Figure 6.3) together with *KNOWLEDGE RANGE* account for interconnections of different lifecycles. As an example, the scientific team has its own agenda and produces knowledge that may be relevant for ***several works***, independently of the composer, as highlighted in this statement from its leader: "[things] we put aside temporarily . . . may come back later during other projects . . . according to the specific case of each composer" (our translation; see Appendix B, row 51). Together with **KNOWLEDGE LIFECYCLE** (see Figure 6.2), this category questions documentation frameworks. Integrating lifecycles in documentation frameworks is relevant to account for the question of the visibility of the object's action, this is emphasised by Latour (2005) who considers that "when objects have receded into the background for good, it is always possible—but more difficult—to bring them back to light by using archives, documents, memoirs, museum collections, etc., to artificially produce, through historians' accounts, the state of crisis in which machines, devices, and implements were born" (p. 81).

The category **ELECTROACOUSTIC COMPOSITION** (see Figure 6.4), although more idiosyncratic, has close relationships with the other three, specifically with *KNOWLEDGE RANGE*. Furthermore, *COMPOSITIONAL POSSIBILITIES AND INFLUENCE*

OF ORGANOLOGY and abstraction / openness relate to *compositional properties and variations* in ***reliability / adaptability***. *Segmentation / definition* provides a compositional counterpoint to *modelling* in ***data processing***, and ***electroacoustic families/types*** and ***electroacoustic-gesture association*** provide a counterpart to *entities* of *mapping*, as emphasised by composer Florence Baschet: "I prefer to choose it [the transformation type]; this is a compositional choice" (our translation; see Appendix B, row 52).

As a consequence, in comparison to current documentation practice, the outcomes of the analysis provide a theoretical ground for a documentation framework. Each one of the four broad categories brings up a relevant point of view on documentation issues to further address.

6.5 Toward a Documentation Framework

The provision of this conceptual account of creative processes in the context of musical works with electroacoustic technologies aims to provide the basis for an unobtrusive documentation framework, that is to say, a framework that does not enforce a specific context of production. Nevertheless, unobtrusive does not necessarily mean transparent; the level of transparency should be specified whenever defining documentation policies.

Still, the outcomes of the analysis we presented are not documentation guidelines, but rather a conceptual framework grounded in data specifically relevant to preservation issues. Although it is not in the scope of this article to implement a documentation framework informed by this conceptualisation, several paths for future research are presented in order to highlight the impact of this study on documentation practice.

The focus on controversies, an object of study in science and technologies studies, is the first trail we propose to follow. Venturini (2010) states that "controversies begin when actors discover that they cannot ignore each other and controversies end when actors manage to work out a solid compromise to live together. Anything between these two ex-

tremes can be called a controversy" (p. 26). In our conceptual framework the category *PRODUCTION STEPS* and, specifically, the subcategory ***discussion, negotiation, and decision-making***, provide us with the possibility to document the emergence and conclusion of some relevant controversies. A substantial part of this information could be embedded in a more generic software production–tracking tool, which could account for other relevant categories included in the broad category **PRODUCTION PROCESS LIFECYCLE**. Similarly, specific categories such as *LOGICAL FUNCTIONALITIES* can be enforced in a documentation methodology, controlling, for instance, the presence of specific ***data pre-processing*** documentation when an agent provides a technological setup at any point of the creative process. Furthermore, following Callon (1981), who studied the process of generalising a solution to a broader context, this focus on controversies should be related to subcategories of *KNOWLEDGE RANGE* as part of the documentation methodology. That way, we may incorporate a specific subset of the conceptual framework into a documentary framework.

In order to account for knowledge that is more tacit, we can refer to previous methodologies developed in other contexts. Although the current study relied on the analysis of observational data and interviews collected during the creative process, less intrusive methods should be considered in order to minimise potential interferences with the creative process. From this perspective, a potential solution for documentation would be to follow the work of Donin and Theureau (2007), using what they call an *interview within situation simulation through material traces*, that is, by recreating a situation (in their case, the compositional situation) through the use of material traces and interviews. A convergent approach in a different domain, namely, the documentation of computer-mediated activity, is the semi-automatic approach of story-telling presented by Yahiaoui et al. (2011), which is also based on traces of activity. This data collection could take place at any relevant time in the course of the creative process with minimum interference.

Reliability and adaptability concerns should be documented with every version submitted during the process. The responsibility for providing a prototype for documentation at multiple stages of the creative process is delegated to the agents of the creative process. The involvement of human agents in the preservation of their work is necessary,

but with such a documentation framework, the content becomes acknowledgeable, open to validation, and potentially with automated support.

A documentation framework may benefit from other research that specifically focusses on the appropriation of electronics by performers for further elaboration purposes. In a similar vein, Féron and Boutard (2012) conducted semi-structured interviews with performers about context, personal skills, notation of electronics, and collaboration with composers and engineers during the preparation process of mixed music with live electronics. On the basis of the current study, we may want to relate structured interviews in the domain of live electronics to data-collection methodologies proposed in previous research in the domain of video-game archiving, such as the player-produced walkthroughs used by Newman (2011). This approach expands the proposition Canazza and Vidolin advocated for in 2001 for handing down the performance praxis. Overall, interviews with participants, structured according to our findings, should be planned for data collection during relevant steps of the creative process, namely, in association with the **PRODUCTION PROCESS LIFECYCLE**.

Further research is needed to test the impact of such a documentation framework on digital preservation theory and on the preservation of musical works involving electroacoustic technologies. Specifically, different levels of implementation could be compared.

6.6 Discussion

Donin, Goldszmidt, and Theureau (2009) remind us of the fundamental fact that the creative process of *StreicherKreis* is historically situated. It is unlikely to be defined as a paradigmatic creative process that we could generalise to all musical works dealing with electroacoustic technologies. Donin and Theureau (2007) conducted a methodologically similar study on compositional processes with composer Philippe Leroux. Leroux (2010, p. 55), reflecting on this study, stated: “ils ont compris que la création artistique était un phénomène extrêmement riche, et qu’il serait tout à fait inintelligent de chercher à l’enfermer dans quelques lois qui ne pourraient être que réductrices” [they understood the

extreme complexity of the phenomenon of artistic creation, and that any attempt to define it in necessarily simplistic laws would be unreasonable (our translation)]. Therefore, our analysis is in no way an attempt to implement a formal system that would account for creative processes in music, an attempt likely to fail, but rather an attempt to identify abstract principles grounded in specific cases. The more abstract the principles, the greater potential they have to be relevant to other cases (Strauss & Corbin, 1998).

This complexity of the artistic creative process stressed by Leroux was indeed a key component of Florence Baschet's creative process in *StreicherKreis*. Although idiosyncratic, this project, thanks to its extraordinary setup, provides us with a unique situation where interaction processes between agents are emphasised, captured, and therefore made observable. The availability of interactions between all agents of the creative process, along with the complexity and time span of the process, enabled us to zoom in on specific practices while situating them in a larger longitudinal perspective, which is highly relevant to documentation issues.

Although it is likely that some of these issues will not generalise to other, different creative process, a documentation framework should address their potential relevance. In this context, further investigations could enrich the analysis with case studies likely to address specific areas of concern, such as the one discussed in this section.

Regarding the data set, it should be noted that the technical setting varied during the process. Indeed, the video camera setup became complex during the production phase when the data-collection team decided to use three video cameras instead of one. There is a possibility that some data were not captured during the research phase with a single camera. In terms of completeness of the work process, we have to note that the recordings of rehearsals in the performance hall (before the premiere) were limited, because fixed cameras and microphones were unable to capture all interactions. Consequently, transcriptions were incomplete for the last two work sessions, which could account for limited interactions with sound engineers, present at the rehearsals, in our analysis. Lastly, the lack of performers' interviews tends to lessen their point of view in the analysis.

Nevertheless, the categorisation, grounded in data, which emerged from the analysis process is an account of the specific situation of the creative processes under investigation. Its trustworthiness was controlled at different stages of development. The results were presented twice to the participants for validation at different stages of the research— first during the coding process and again at the end of the analysis process. In addition, we circulated a written report to all participants.

6.7 Conclusion

Heydenreich (2011) posits that documentation of installation art "is the basis for developing preservation strategies, planning loans and presentation, [and] determining environmental conditions and risk assessment" (p. 159). We argue that the situation is quite similar for musical works involving electroacoustic technologies. Specifically, documentation policies and preservation strategies are closely related, especially as migration is the current best practice in this field whenever an actual preservation strategy is endorsed.

The documentation basis we advocate for, in order to preserve music works with electroacoustic technologies, is informed by processes and lifecycles. Our analysis reveals the limitations of a posteriori documentation in accounting for the knowledge involved in the creative process of a musical work involving electroacoustic technologies and interaction between agents. It implies that the documentation has to be closely related to the process of developing the musical work. At the same time, the documentation methodology should be implemented in a non-obtrusive way without imposing technological and lifecycle constraints on the artistic workflow.

A documentation framework based on our categorisation implies the need to address the question of data-collection methodologies, which have to reflect tacit knowledge as well as active participation of nonhuman agents, and to define what can be automated and what cannot. In the context of film preservation, Cherchi Usai et al. (2008) noticed that the amount of extra work that documentation policies imply may be too high, because "[articles and essays] assume that an archive would have the time to precisely collect the information

about preservation, in a way which is clearly not applicable to archives that preserve a large amount of films" (p. 166). It is up to institutions (or individuals) to define their policy in terms of completeness of their documentation process. It is a question of negotiation, and from this perspective our study serves as the basis for accountable, informed documentation policies. These policies will have to account for what is and what is not part of their process according to their goals: re-performance, migration, and/or analysis.

Chapter 7

Study 3: Modelling the impact on a digital archives model

7.1 Archiving the creative process

7.1.1 The relevance of the creative process

Digital sound processing artifacts produced during the creative process of musical works involving technological components epitomise complex conditions of creation and use, as well as idiosyncratic and obsolescent technological frameworks. It also epitomises the variability of hierarchies and the organisation of labor, and specifically the creative side of sustaining tasks, that Benghozi (1995) describes. It is no wonder that these digital sound processing artifacts represent a challenge to digital archives theories and models: they are the result of complex knowledge interactions in a creative process involving multiple agents, both human and non-human, that cannot be reduced to the added value paradigm conveyed by concept such as context information and/or, in the OAIS terms, *representation information*. In 2008, Cunningham stated that records "derive their meaning and value from a myriad of contextual relationships surrounding their creation and use—relationships that have to be documented and understood" (p. 532). While this statement relates to the archival lifecycle and to the concept of the records continuum, it is relevant to the creative process as well. It emphasises the fact that a digital object is not merely an isolated object. Indeed, "technology does not develop according to an inner technical logic but is instead a social product, patterned by the conditions of its creation and use" (Williams & Edge, 1996, p. 857). Consequently, the status we grant to digital object has an impact on the way we manage them within theories and models.

The InterPARES I project proposed a specification of the necessary constituent parts of a record (Duranti & Thibodeau, 2006). It consists of the documentary form, which includes intrinsic elements (such as the place of origin and the chronological date) as well as extrinsic elements (such as the overall presentation features), the annotations, the context (that is to say, the juridical-administrative context, the provenancial context, the procedural context, the documentary context, and the technological context), and finally the medium, whose status is undefined and might be part of the technological context, according to Duranti and Thibodeau. If "the medium is not a relevant factor in assessing a record's authenticity" (Duranti & Thibodeau, 2006, p. 18), we argue that it is relevant to its intelligibility,

since the medium allows us to account for the active participation of non-human agents in the interaction process[1]. The creative process leading to the creation of digital signal processing artifacts, involves, notably, processes that Latour (1994) refers to as delegation and blackboxing. The recursive process of blackboxing[2] emphasises the complex relation between human agents and technological agents. Delegation is the technological inscription of a programme of action whose goals are defined by agents, both human and non-human; it emphasises the active role of technological agents. These processes are critical to the intelligibility of these digital artifacts, and consequently to the musical works they are part of. These processes have impact on the potential reuse and migration of digital artefacts. Still, they are difficult to document after the finalisation of the digital artefact[3] that is to become the object of preservation, so that they account for "the state of crisis in which machines, devices, and implements were born" (Latour, 2005, p. 81). If we do want to account for this 'state of crisis', the curation lifecycle should be informed by creative processes.

7.1.2 Documenting the creative process

In our second study, we described the creative process of a musical work involving technological components. We conducted a formal analysis, based on grounded theory (Glaser & Strauss, 1967), of secondary ethnographic data previously collected at IRCAM (Institut de recherche et coordination acoustique/musique) from 2006 to 2008. These data consisted of two years of research and artistic production surrounding the composition of a string quartet with live electronics and a specific focus on interaction. The IRCAM team, APM (Analyse des pratiques musicales), collected video recordings of studio sessions during the entire process, as well as interviews with the main participants: the composer; the scien-

[1] In this sense, the medium relates to the third dimension of Rowe's (1993) classification, which ranges from instrument paradigm systems to player paradigm systems, namely "an artificial player, a musical presence with a personality and behavior of its own [...]. A player paradigm system played by a single human would produce an output like a duet" (p. 8).

[2] Latour (1994) states "each of the parts inside the black box is a black box full of parts. If any part were to break, how many humans would immediately materialise around each?" (p. 37)

[3] According to Latour (2005), "when objects have receded into the background for good, it is always possible – but more difficult – to bring them back to light by using archives, documents, memoirs, museum collections, etc [...]" (p. 81).

tific team leader; and the computer music designer. The team also collected e-mails, notes, scores, and digital artifacts at various stages of technological development. The inductive analysis grounded in the data gave rise to a categorisation scheme (see chapter 6) highly relevant to documentation. The categorisation scheme is composed of four broad categories: **ORGANOLOGICAL SPECIFICATIONS**; **KNOWLEDGE LIFECYCLE**; **PRODUCTION PROCESS LIFECYCLE**; and **ELECTROACOUSTIC COMPOSITION**. The latter category was considered most idiosyncratic.

We consider that each broad category is relevant to documentation. **ORGANOLOGICAL SPECIFICATIONS** document *LOGICAL FUNCTIONALITIES* as well as a network of *SYSTEMIC DEPENDENCIES*, which range from engineering dependencies to issues of adaptability and reliability to various contextual factors. The **KNOWLEDGE LIFECYCLE** involves *KNOWLEDGE FLOWS*, in terms of ***appropriation*** (a category relevant to all human agents of the creative process, on the side of the performer, but also on the side of the composer, the engineers, and the researchers) and in terms of ***transmission***. Subsequently it involves the specification of the *KNOWLEDGE RANGE*, that is to say, the extent to which this knowledge is relevant to a small or large part of the work, but also to other works. *Appropriation procedures* as well as certain types of ***transmission*** highlight the tacit dimension of the knowledge involved in the creative process. In addition, we posit that the broad category of **PRODUCTION PROCESS LIFECYCLE** is the backbone of the documentation of every other broad category that emerged from our analysis. The **PRODUCTION PROCESS LIFECYCLE** describes the lifecycle in terms of *PRODUCTION STEPS* (such as ***development***, ***evaluation***, and ***decision making***) and *WORKFLOWS* that account for ***collaborative*** and ***independent*** work processes. *PRODUCTION STEPS* support **ORGANOLOGICAL SPECIFICATIONS**, since "central to SST [Social Shaping of Technology] is the concept that there are 'choices' (though not necessarily conscious choices) inherent in both the design of individual artifacts and systems [...]" (Williams & Edge, 1996, p. 857). The **PRODUCTION PROCESS LIFECYCLE** also supports the plasticity of *KNOWLEDGE RANGE* since it may account for the generalisation process of a local solution to a broader extent, a process emphasised by Callon (1981) in the context of the sociology of science. Similarly the **PRODUCTION PROCESS LIFECYCLE**'s *WORKFLOWS* support the broad range of *KNOWLEDGE FLOWS*, either in terms of ***appropriation*** or ***transmission***.

These categories have impact not only on documentation, but also on archives as regards a digital archives model such as the OAIS (Open Archival Information System) (2002). This impact needs to be specified in order to provide relevant solutions.

7.1.3 Impact on models of digital archives

7.1.3.1 Models and lifecycles

In 2008, Higgins proposed a lifecycle in seven phases, namely the DCC curation lifecycle model, based on Pennock's (Pennock, 2007) lifecycle approach to digital curation. This lifecycle is composed of the following phases: create or receive; appraise and select; ingest; preservation action; store; access, use and re-use; and finally, transform, which links back to the first phase. According to Higgins, this "lifecycle approach ensures that all the required stages are identified and planned, and necessary actions implemented, in the correct sequence. This can ensure the maintenance of authenticity, reliability, integrity and usability of digital material" (2008, p. 135). Subsequently Constantopoulos et al. (2009) combined the DCC lifecycle with a second model influenced by semantic web technology in order to account for domain specific contextual information and user experience.

Higgins posits that the DCC model is a complement to the OAIS. Indeed, we may consider the lifecycle approach as an activity scheme on top of the OAIS logical model defined with component and class schemes. A notable difference, however, is the recognition of appraisal, a concept that does not appear much in the OAIS reference model. The DCC model may complement the OAIS, but we are still not provided with formal relationships, especially in terms of the SIP (Submission Information Package), AIP (Archival Information Package), RI (Representation Information), and PDI (Preservation Description Information).

In order to relate our categorisation (see chapter 6) to archival models and lifecycles, we will discuss three broad categories, namely, **ORGANOLOGICAL SPECIFICATIONS**, **KNOWLEDGE LIFECYCLE**, and **PRODUCTION PROCESS LIFE-**

CYCLE. The relevance of the most idiosyncratic category, **ELECTROACOUSTIC COMPOSITION**, is closely related to the other three categories (see section 6.3.4). Consequently, there is a general need to identify these three broad categories with digital archives concepts and to identify potential limitations.

7.1.3.2 Organological specifications

Organology, in our categorisation, refers to taxonomies of musical instruments as well as to systems that include computers, software, sensors, etc. (Stiegler, 2003). This category may be the most familiar to digital preservation systems since it deals with specifications. Therefore, as a premise, this category can be related to OAIS' *representation information*, namely "the information that maps a *data object* into more meaningful concepts" (2002, p. 1-13). *Representation information* still is a broad category that involves both *semantic representation information* and *structure representation information*.

The first subcategory of **ORGANOLOGICAL SPECIFICATIONS**, namely *LOGICAL FUNCTIONALITIES*, may relate to *semantic representation information*. Nevertheless, *structure information* refers to "common computer data types, aggregations of these data types, and mapping rules which map from the underlying data types to the higher level concepts" (2002, p. 4-21). As regards the last point, we might revise the categorisation of *LOGICAL FUNCTIONALITIES* into *structure information*. Interestingly, papers addressing *representation information* in terms of operationalisation (Matthews et al., 2010) or in terms of mappings to other conceptual frameworks (Sacchi, Wickett, Renear, & Dubin, 2011) do not refer to this distinction between *Semantic* and *structure representation information*. The OAIS (2002) acknowledges that: "*representation information* contains both *structure information* and *semantic information*, although in some implementations the distinction is subjective" (2002, p. 4-21). The semantic link between both types of *representation information* is specified in the OAIS logical model of the information object as "adds meaning to" (2002, p. 4-22), a very broad phrasing resulting in a description activity that may be difficult to manage. Furthermore, logical components and algorithms do not have to reflect physical components. This affects their relationship to potential *archival*

information collections (AICs) composed of various *archival information units* (AIUs). Indeed, they relate to a more abstract level of description.

The second subcategory, *SYSTEMIC DEPENDENCIES*, offers other challenges. The OAIS reference model defines two key concepts in its specification of *preservation description information* (PDI), namely provenance and context. Provenance and context relate to the basic archival principles, namely provenance and original order[4]. Nevertheless the OAIS (2002) *context information* may encompass a broader concept than original order, for it "documents the relationships of the *content information* to its environment. This includes why the *content information* was created and how it relates to other *content information* objects existing elsewhere" (p. 4-28). Accordingly, we may want to relate the part of *SYSTEMIC DEPENDENCIES* that refers to the network of contextual factors influencing ***reliability and adaptability***, such as inter/intra performer reliability issues (that is, *intra-/inter-individual characteristics and differences*) or organological adaptability (that is, *organological properties and variations*). These factors may still be difficult to formalise, which emphasises the need for a framework able to support such a network of contextual factors. Furthermore the OAIS *context information* is underspecified and may require a more extensive framework. Considering the InterPARES specification of the ambiguous relationship between the medium and the technological context (Duranti & Thibodeau, 2006) we may want to propose a framework which distinguishes technological context from other types of context.

Similarly *SYSTEMIC DEPENDENCIES* also involve ***engineering*** dependencies, i.e. the software architecture including external libraries and versioning information. The management of these dependencies, according to Matthews et al. (2010), fits *representation information* together with *preservation description information*. We argue that it relates rather to the formal link between different AIPs. This is critical in a process where different agents have different agendas, and where solutions discarded for a project may be useful for other projects, as observed in section 6.4.

[4]see Schellenberg (1965): "There are two basic principles of archival arrangement that have been developed through decades of experience. The first, which is known as the principle of provenance is that records should be kept according to their source. The second, which is known as the principle of original order, is that records should be kept in the order originally imposed on them" (p. 90).

The first point emerging from this analysis is the poor internal semantics of *representation information*, that is to say, the semantics of its various components. The second point to emerge is the need for further specification of the relations among AIPs and specifically between AICs and AIUs. The *context information*, according to its OAIS definition, may provide a better tool insofar as we provide the formalisation of these relations in the OAIS model.

7.1.3.3 The knowledge lifecycle

The second category, **KNOWLEDGE LIFECYCLE**, is critical since it accounts for relationships between multiple agents, human and non-human. It relates to the blackboxed instrument (Magnusson, 2009), since the category involves ***appropriation*** processes as well as ***transmission*** processes[5].

Appropriation procedures and *appropriation context* are especially relevant to musical works with technological components, since processes of embodiment are more complex with digital instruments than with acoustic instruments. With acoustic instruments, "the music is performed and perceived through gestures whose deployment can be directly felt and understood through the body, without the need for verbal descriptions" (Leman, 2010, p. 127). In the digital world however, mappings between gesture and electroacoustic outputs are arbitrary (Drummond, 2009), consequently, the transmission of interaction expertise with digital instruments is problematic. Matthews et al. (2010) conveniently specify that user interactions are outside of the scope of the OAIS. This point is crucial, since ***appropriation*** is not limited to performers' embodiment abilities. Indeed, we found that *appropriation procedures* applied to all human agents (including the composer, the computer music designer, and the scientific team), as well as to the technological environment, and took place throughout the entire creative process. *Appropriation procedures* are critical as they directly relate to the processes of blackboxing and delegation involved in technological mediation.

[5]Specifically, Magnusson (2009) states that "the blackboxed instrument contains the knowledge of its inventors" (p. 171) and questions the way the knowledge is written into artifacts and read from them.

Subsequently, Matthews et al. (2010) consider that user interaction "may be categorised as the *significant properties* of software" (p. 99). Indeed, there is a longstanding debate on the conceptual difference between *significant properties* and *representation information*. Adrian Brown, cited by Hockx-Yu and Knight (2008), summarised it this way: "while the former are about the intellectual intent and apply to the abstract information object and properties of the intellectual intent, the latter are specific technical manifestations of the information object and apply to the data object, e.g. format, encoding schemes, algorithms" (p. 148). Specifically, this concern regarding abstraction from the object is relevant to musical works with technological components, since digital sound processing artifacts "must be documented in an abstract form or, in other terms in an independent manner by the system used, since the machines have an extremely brief life" (Canazza & Vidolin, 2001, p. 290). Considering the definition of *significant properties*, that is to say, "the characteristics of an information object that must be maintained to ensure that object's continued access, use, and meaning over time as it is moved to new technologies" (Knight & Pennock, 2009, p. 160), Canazza and Vidolin's (2001) statement is in direct relationship with the issues addressed by the digital archives community. As regards the OAIS, Giaretta et al. (Giaretta et al., 2009) acknowledged the relevance of *significant properties* for migration purposes and proposed to integrate into the OAIS a similar concept, namely *transformational information properties*, "an *information property* whose preservation is regarded as being necessary but not sufficient to verify that the *non-reversible transformation* has adequately preserved information content" (p. 72). However, *transformational information properties* still do not account for the potential pertinence of abstraction levels, the fundamental concept of *significant properties*. Indeed, in 2002, Hedstrom and Lee advocated for the expression of *significant properties* at several levels of abstraction. Knight and Pennock (2009) implemented this proposal with the FRBR model (1998), "a framework that identifies and clearly defines the entities of interest to users of bibliographic records, the attributes of each entity, and the types of relationships that operate between entities" (p. 3). These entities describe four levels of abstraction for bibliographic records: the work, a distinct intellectual or artistic creation; the expression, a specific form for this intellectual or artistic creation; the manifestation, a physical embodiment of the expression; and finally, the item, a single exemplar of the manifestation.

In section 5.1, we introduced the concept of *significant knowledge*[6], an extension of *significant properties* that accounts for tacit knowledge. Indeed, this proposal converges with Knight and Pennock's (2009) implementation regarding the dimension of *abstraction*. Specifically, we operationalised a three-dimensional knowledge management model introduced by Boisot (1995) and tested and validated this operationalisation with composers using a survey on the use of sound spatialisation. This model, primarily concerned with tacit knowledge, provides a conceptual framework that describes knowledge. The three dimensions of the model are *abstraction*, *codification*, and *diffusion*. *Abstraction* represents the synthesis process, which reduces the quantity of categories needed to account for data, while *codification* "involves the assignment of data to categories, thus giving them form" (Boisot & Child, 1999, p. 237). Thus the more abstract and the less codified, the more tacit the knowledge. Furthermore, the dimension of *diffusion* measures the relevance to a given population (Boisot & Cox, 1999) and, according to Boisot and Child (1999), accounts for relational complexity. Our operationalisation of the model for musical works involving technological components relies on FRBR levels for the *abstraction* dimension. In this sense, the *abstraction* dimension of our proposal relates to the state of the art of *significant properties* research and therefore represents the potential link to digital archives models. Subsequently, we related *codification* to the potential level of formalisation of the knowledge described, on the basis of Boisot's specifications (1995, p. 169) and Zander and Kogut's (1995) operationalisation of codifiability[7]. The addition of *codification* to *abstraction* provides a fair rendition of the potential tacit dimension of the knowledge involved in the creative process, a dimension acknowledged by several authors in music research[8]. Finally, we related the *diffusion* dimension to the music research work of Donin and Theureau (2007) on the different cognitive time-scales of the creative process in music composition. This dimension is closely related to the subcategory *KNOWLEDGE RANGE* which emerged from our study. An example of a contextual knowledge categorisation, taken from our survey on the use of sound spatialisation, is provided in Figure 5.2.

[6] See also (Boutard & Guastavino, 2012a).

[7] Zander and Kogut (1995) state that "'Codifiability' captures the degree to which knowledge can be encoded, even if the individual operator does not have the facility to understand it ..." (p. 79), and operationalised it with a design meant to "to capture the extent to which the knowledge could be articulated in documents and software" (p. 81).

[8] See for example, Canazza and Vidolin (2001), as well as, Laura Zattra (2007).

This model addresses Lee's (2000) intelligibility, and therefore, Rothenberg's (2000) meaningful usability, in the sense that it allows to categorise various knowledge involved in the creative process and therefore provides a framework to capture it, in a way that reflects its potential tacit dimension, and to relate it to a digital archives model. In doing so, it may account for ***appropriations*** and ***transmissions*** that occur during the creative process. These are relevant in the context of digital records that have been described as performances (Cunningham, 2008), and especially in considering performance as a process that involves human and non-human agents. Indeed, the focus of InterPARES II on interaction converges on this question of performance. But the project's conclusion that a "work of digital music can only be reproduced if the author describes each digital, intellectual and performing component of it and the interactions among them, by producing a set of instructions for re-creating each part of the piece and the piece as a whole" (Duranti & Thibodeau, 2006, p. 36), accounts neither for *abstraction* nor *codification*, i.e. the tacit knowledge, nor for the multiple agents involved. Similarly, Matthews et al.'s (2010) framework for performance adequacy is built on a set of pre-defined *significant properties* evaluated on the basis of an input-output specification.

In 2011, Lee observed that "by directly attending to the creation, capture, management and sharing of contextual information, curators of digital collections can best ensure that the distributed network of digital collections will provide not only access to digital objects but also the means to make meaningful use and sense of the digital objects long into the future" (p. 120). The framework of our first study provides us with an opportunity to document not only contextual information but also, in a broader way, the knowledge involved in the creative process.

While the specification of *KNOWLEDGE FLOWS* and *KNOWLEDGE RANGE* fit adequately the three dimensions of the *significant knowledge* framework, the mapping of the *significant knowledge* framework to the OAIS still needs to be addressed. Matthews et al. (2010) consider that their narrowed notion of significant properties, as they put it, is outside of the scope of the OAIS. Consequently, our extended view of *significant properties* is a challenge to the model. *Significant knowledge* requires the inclusion of abstraction levels in the OAIS model as well as a mapping for both remaining dimensions, namely, *codification* and *diffusion*.

7.1.3.4 The production process lifecycle

We previously stated that the **PRODUCTION PROCESS LIFECYCLE** is the backbone of every other broad category. Thus it is the backbone of a potential ingestion framework. Together with the **KNOWLEDGE LIFECYCLE**, it accounts for *KNOWLEDGE FLOWS* during the creative process and therefore may be used to document blackboxing and delegation processes. Several authors in various domains, such as engineering knowledge preservation (Brunsmann & Wilkes, 2009) or video game preservation (Winget, 2011), acknowledged the production lifecycle's impact on sustainability. The **PRODUCTION PROCESS LIFECYCLE** category consists of *PRODUCTION STEPS* and *WORKFLOWS*. *PRODUCTION STEPS* especially account for the choices discussed previously that Williams and Edge (1996) refer to, in terms of evaluation procedures, and their counterparts: development and decision making processes. These *PRODUCTION STEPS* relate directly to **ORGANOLOGICAL SPECIFICATIONS**, since they track down the creative process on a longitudinal scale. They support modifications of *LOGICAL FUNCTIONALITIES* as well as the evolution of *SYSTEMIC DEPENDENCIES*. On the other hand, *WORKFLOWS*, either ***collaborative*** or ***independent***, account for the complex division of labor (Benghozi, 1995). *WORKFLOWS* are also critical, since they emphasise the stakeholders of the creative process. These stakeholders are essential because they mutually construct what is significant[9], either explicitly or tacitly, during the creative process in a way that can only be poorly acknowledged by the OAIS concept of *designated community*, which is oriented toward consumption rather than production. The combination of *PRODUCTION STEPS* and *WORKFLOWS* offers helpful grounding for an ingestion framework that accounts for the technology as a social product.

This ground for an ingestion framework in OAIS terms has to deal with the semantic relationships among *information packages*. The OAIS is not a software versioning system, but it may have to provide some of the features of such a system. Similarly to the management of the ***engineering*** sub-category, a potential solution lies in the semantic link

[9]See, for example, Angela Dappert and Adam Farquhar (2009): "In the digital preservation context, significance is determined by the stakeholders involved in the preservation process. These include the producer of the digital object, the custodian who holds it, and the consumer who will access it" (p. 302). The significance of stakeholders is also discussed in section 2.4.2.

between AIPs and the *context information*. However, the creative process does not end with the project. Works are migrated for re-performance purposes, providing new meaning to the work. As MacNeil and Mak (2007) put it, the authenticity is "also necessarily in a continuous state of becoming" (p. 33). In this context, FRBR may again provide a suitable conceptual framework for relating AIPs to AICs. Furthermore, FRBRoo (Aalberg et al., 2010) may be more relevant since it allows specifying transversal links between libraries, which are on the same abstraction level but are a semantically linked unit within the technological framework elaborated during the creative process.

On the other hand, *WORKFLOWS* also have to relate to *preservation description information*. This implies further specification on the *provenance information* side. Similarly to the ambiguity between *Semantic* and *structure representation information*, the distinction between OAIS *provenance* and *context information* may be challenging. The InterPARES specification for the necessary parts of the record[10] exemplifies this ambiguity. While features of the documentary form, such as the name of the creators of the record or the place of origin, typically relate to *provenance information*, features of context involve provenancial context. This ambiguity may lead to consider *provenance information* as a subset of *context information*. *WORKFLOWS* also have to be a fundamental part of the ingestion framework, since "to understand records as evidence of human activity it is necessary to understand how their systems of creation and use operated" (Cunningham, 2008, p. 532).

The implications of these various requirements on the modelling are numerous

7.1.4 Modelling

Representation information is only one part of the information required for meaningful use of the *data object*. In addition, according to the OAIS model (*Reference Model OAIS (Pink Book)*, 2009), the *transformational information property* is an *information property*, that is to say, "that part of the *content information* as described by the *information property description*. The detailed expression, or value, of that part of the information content is conveyed by the appropriate parts of the *content data object* and its *representation*

[10]For a thorough description, see, Duranti & Thibodeau, 2006, p. 17-18.

information" (p. 1-13). Thus these properties correspond to a pointer to a specific part of the *content information*. We argue that a different model is required: one that accounts for *significant knowledge* at different levels of *abstraction*, *codification*, and *diffusion*.

First, we posit that a data object is not (re)presented but is performed[11] to provide *content information*. This semantic shift emphasises the technological process involved in the use of digital records and offers further clarification on the difference from *preservation description information*. Therefore, we propose the term *performance information* rather than *representation information* for the sake of conceptual clarity. Consequently, the term *performance information* will be used in both Figures 3 and 4. The *performance information* can be used to (re)create the work.

The link between one *data object* and associated *performance information* is in fact multiple, whether this *performance information* relates to *significant knowledge*, *significant properties*, or the OAIS' combination of structure and semantics (see Figure 7.1). Typically, this last case requires the following information: *structure representation information* and *semantic representation information*. Whether this is a logical or a physical separation is a question of implementation. In the specific case of an implementation of *significant properties* on the basis of FRBR levels, using Knight and Pennock's (2009) proposal, the four levels of the FRBR model may require four different *performance information* submissions. Since the *performance information* is an *information object* (see Figure 7.2), its own *performance information* has to be provided according to the OAIS' recursive provision.

Each *performance information* instantiation of the *classification scheme* is independent of the data type. However, in the specific case of *significant knowledge* (the one for which we advocate), the focus on tacit knowledge is especially related to data collection methodologies. In this context, the relationship between *classification* and data types may be part of the appraisal process.

Like *preservation description information* and *performance information*, *classification* is an *information object* (see Figure 7.2). Consequently, it relates to its own specific *per-*

[11]The description of the digital record as a performance is discussed in, Helen Heslop, Simon Davis, and Andrew Wilson (2002).

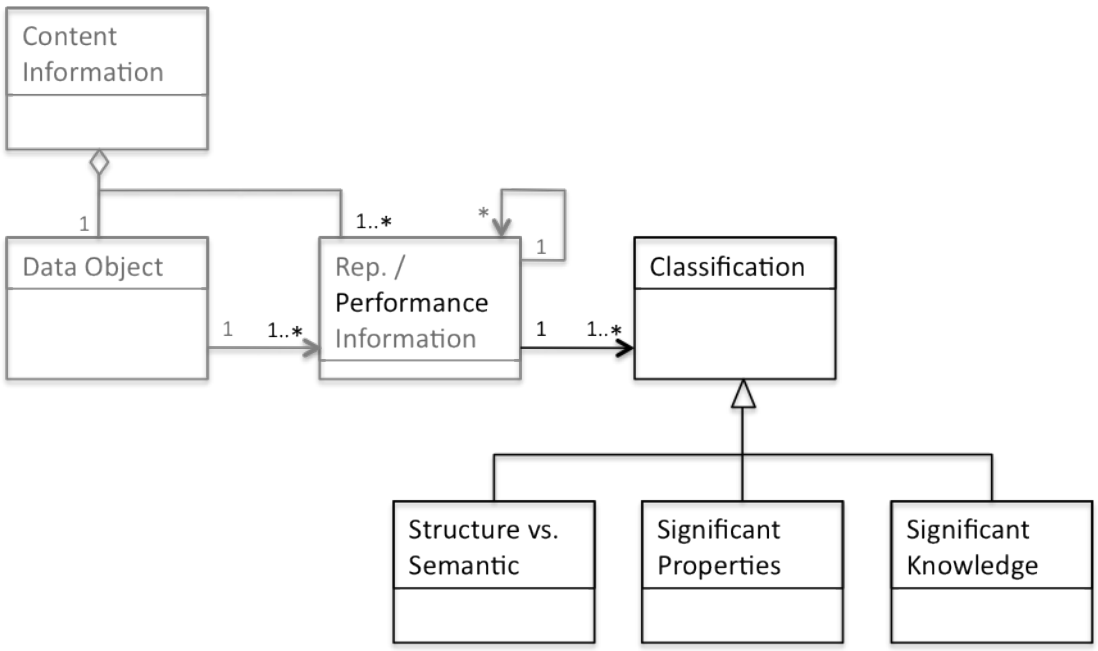

Figure 7.1 The relationship between the *performance information* and the *classification* (UML diagram – extensions and modifications to the OAIS model are displayed in black)

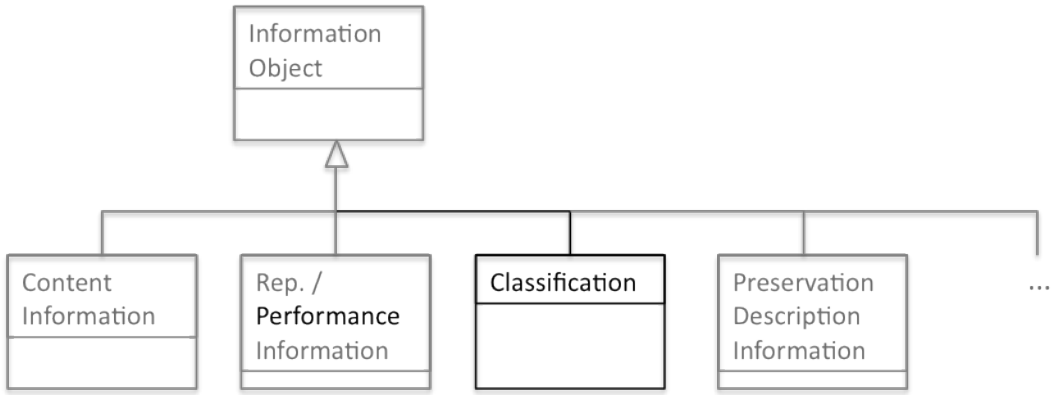

Figure 7.2 The list of *information objects*

formance information. Interestingly, if the *classification* relies on *structure* and *semantic information*, then the *performance information* of the *classification* may provide the specification of the difference between these two entities. Generally speaking, a fundamental part of this *performance information* is the *classification scheme*. Another part of this

performance information may be the categorisation of the creative process provided by our second study (in chapter 6)[12]. The *classification scheme* specifies the model proposed, for instance *significant knowledge*. In this sense the *classification* may be referred to as an instantiation of the *classification scheme* and the *classification scheme* as an implementation of the model. As an example of this, our survey (see chapter 5) offers an implementation of *significant knowledge*, that is to say a *classification scheme*, in the specific context of musical works with spatialisation technology (see Figure 5.2). In the specific case of *performance information* that addresses the most explicit part of the *significant knowledge*'s *classification scheme*, this *performance information* could adequately relate to Costantopoulos and Dallas' (2008) proposal of domain specific modelling[13]. The *performance information* of this *performance information* (since *performance information* is an *information object* and therefore is recursive) is, in this context, the domain specific model for which they advocate.

Institutions have different needs. TRAC (Trustworthy Repositories Audit & Certification) (2007) observes that "repositories are likely to differ the most in this area of ingest processes, depending on the type of material they collect and their relationships with its producers" (p. 21). The OAIS considers that standards for ingest methodology used by an archive and for submission of digital data sources to an archive are outside its scope, but still acknowledges that they are required. We posit that the *classification scheme* is the first essential part of a potential ingestion framework. Accordingly, it needs to be specified with the *submission agreement* (see Figure 7.3) which the OAIS model refers to but does not model. In any event, the OAIS needs to make explicit the relationship between the *submission agreement* and other entities. Furthermore, a *submission agreement* may relate to several *classification schemes*, for instance *significant knowledge* in addition to the OAIS' *Semantic* and *structure information*. Finally, a *preservation description information* instance has to be provided with the *submission agreement* (see Figure 7.3) to account for "professional assumptions, concepts, and processes–the profession's own metanarrative" (Cook, 2001, p. 35).

[12]In this sense, the *performance information* may account for various types of Information, such as reliability/adaptability or logical functionalitues specifications as well as ***appropriation*** and ***transmission*** procedures.

[13]Similarly, PREMIS' (2008) semantic unit *1.4 significantProperties* (p. 39) may offer a relevant *classification scheme* for *significant properties* (see also section 2.2.4.2).

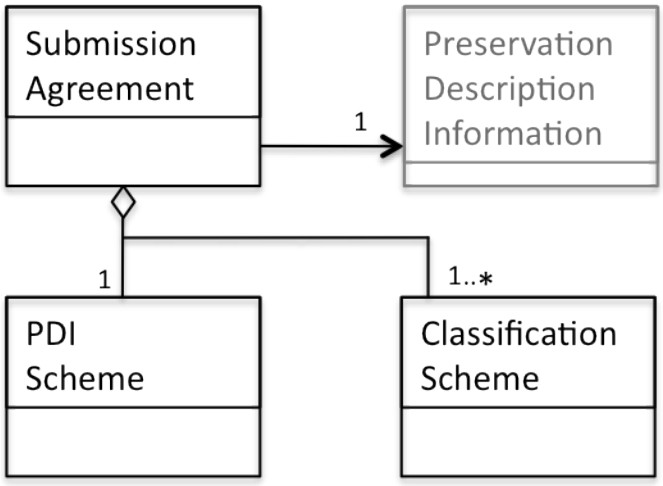

Figure 7.3 The *submission agreement*

The specification of a *submission agreement* thus implies the provision of the *performance information* for every *classification* that may be submitted in the context of this specific agreement, at least this fundamental part of the *submission agreement* that we call the *classification scheme*.

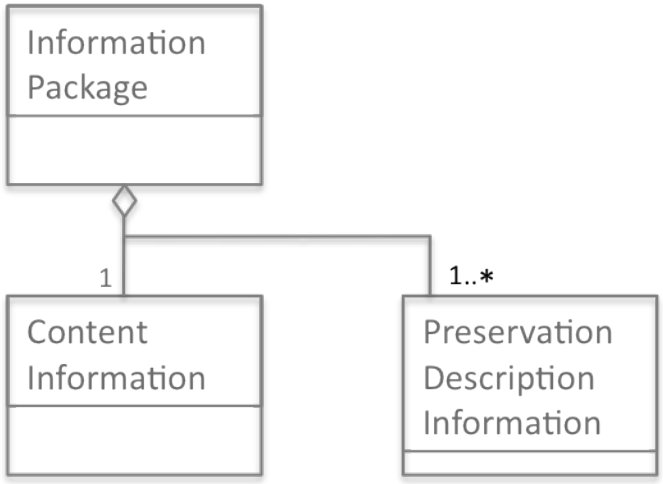

Figure 7.4 The *information package* content

Since *performance information* is potentially instantiated several times, each instance has to be provided with corresponding *preservation description information*. This implies a one-to-many aggregation relationship between the *information package* and the *preser-*

vation description information (see Figure 7.4). Thus each instance of *performance information*, which may be provided in various *submission information packages*, relates to the relevant *provenance*, *reference*, *fixity*, and *context information*.

A practical case that relates to our domain, the preservation of musical works with technological components, is the ingestion of the outcomes of a work session. The data is provided according to the *submission agreement*, which includes the classification scheme. It involves the current status of the sound processing software to be preserved as well as, potentially, video recordings of the performers during appropriation phases, technological setup specifications such as the one provided in Figure 5.2, and so on. Several *submission information packages* need to be provided, potentially, at different times. The *Administration* entity of the OAIS will confront each one of these *submission information packages* with the *submission agreement*, in conformity with the OAIS model (2002, p. 4-10). Finally, an *archival information package* will be constituted to reflect this work session. Each additional piece of information is a *performance information* instance, which relates to the *data object*, that is to say, the sound processing software created during the work session. Each *performance information* instance relates to a *classification* instance (see Figure 7.1) compliant with the *significant knowledge*'s *classification scheme*. This point is critical since all *performance information* instances require different data collection methodologies and therefore, need to be appraised accordingly. The consideration of this additional piece of information as *performance information* rather than another piece of *content information* fundamentally emphasises the semantic link between the *data object* and its *performance information*, this semantic link that we transformed with the term change from *representation information* to *performance information*.

This practical example reflects the lack of a longitudinal dimension of the model thus far. The model provides us with a relevant link between various submitted *information objects*, either *content information* or *significant knowledge* (i.e. a *performance information* instance together with the relevant *classification*), in order to account for a specific work session. As Thibodeau (2002) puts it: "domain knowledge is also needed to understand records. [...] This common knowledge includes both specific empirical information about prior steps in a multi-step process, generic knowledge about the process, and expectations about both subsequent steps and the norms for recording and communicating informa-

tion about the process" (p. 178). Consequently, we still need to address the longitudinal dimension of the creative process, which we have shown here to be highly relevant. We need a higher-level semantic relationship between *information packages* than the inclusion link that relates the *archival information collection*'s *content information* to other *archival information packages*.

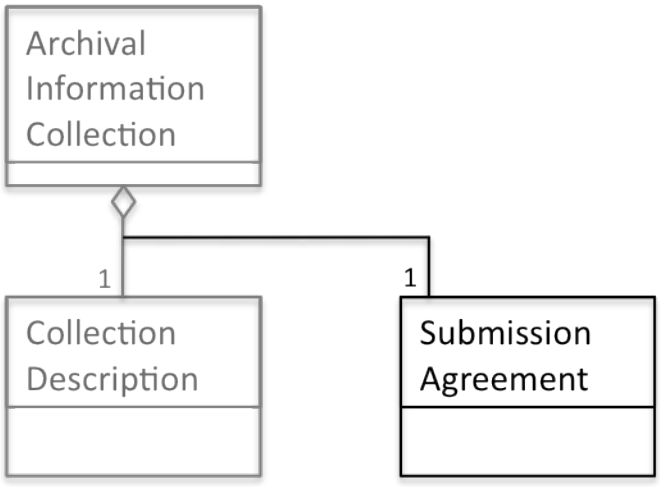

Figure 7.5 The *archival information collection*

In any event, the *archival information collection* is a meaningful concept. It provides us with a tool to define a project-scale collection of *archival information packages*. For consistency purposes, a *submission agreement* should be associated with this specific *archival information collection* (see Figure 7.5) as well as its *preservation description information* (see Figure 7.3), which especially documents its *provenance* and *context information*. In doing so, we provide *archival information collections* with semantic connotations that are not part of the OAIS model. This may be modeled in various ways, but it is still required in order to acknowledge the longitudinal dimension of the **PRODUCTION PROCESS LIFECYCLE**.

Creation of a work is a continuous process, and re-performances often imply technological migration. Each migration requires a new creative process, and thus a new **PRODUCTION PROCESS LIFECYCLE** and **KNOWLEDGE LIFECYCLE**. Consistently with our previous statements, this leads to the development of a new *archival information collection*. Therefore, the semantic link among collections has to be made explicit, which

means providing adequate *context information* for each *archival information package*. The *context information* needs to be specified according to a scheme; for example, the extensive framework provided by Lee (2011) or the InterPARES framework (Duranti & Thibodeau, 2006). Furthermore, the *context scheme* we advocate for should address stakeholders of the creative process in order to account for *WORKFLOWS*. This has to be specified in relation to the *provenance information* and thus to a potential *provenance scheme*. As a consequence, a *preservation description scheme* needs to be provided together with the *classification scheme* in the *submission agreement* (see Figure 7.3) which in turn relates to an *archival information collection* (see Figure 7.5). This *preservation description information scheme* is the second fundamental part of a potential ingestion framework. Similarly to the relationship between the *classification* and the *classification scheme*, the *preservation description information scheme* provides the fundamental part of the *performance information* of the *preservation description information*, since the *preservation description information* is an *information object* (see Figure 7.2).

Because of the potential ambiguity between *context information* and *provenance information*, we propose not to formalise in the model the occurrence of a separate *scheme* for each *preservation description information* constituent. In this sense, the InterPARES description of necessary constituent parts of every record, previously discussed, may be a relevant candidate for the *preservation description information scheme* insofar as the semantic of technological context is further specified. Indeed, this framework needs to emphasise the difference between *performance information* and both *provenance information* and *context information*. In order to do so the technological context needs to be circumscribed to the engineering part, that is to say, it needs to provide similar functionalities to software versioning tools (the extent of which needs to be specified). The relationship among AIPs, which reflects the longitudinal dimension of the creation process and its relevance to other creation processes may be adequately specified in the scope of the InterPARES documentary context, which is "manifested in, for example, classification schemes, records inventories, indexes, registers" (Duranti & Thibodeau, 2006, p. 18). As suggested above, a relevant candidate for the implementation of this part of the context is FRBRoo.

Another potentially interesting part of the InterPARES framework, which may relate to our categorisation of the creative process, is the procedural context, which is "manifested

in, for example, workflow rules, codes of administrative procedure" (Duranti & Thibodeau, 2006, p. 18). Indeed, in the context of the creative process, it may support both *PRODUCTION STEPS* and *WORKFLOWS*, which reflect the organisational management of institutions (whenever there is such a management). In this sense the **PRODUCTION PROCESS LIFECYCLE** and the archival lifecycle are integrated.

We provide a model that can be used in the context of various policies. Still, the more the semantics are specified, the more they correspond to the relevant policies. As Smith and Moore (2007) put it, "if a given preservation environment lacks a particular capability that a policy implies, the mapping from management policies to preservation capabilities will fail and the policy will devolve to an assertion that cannot be verified. This defines one essential component of a trustworthy preservation environment, that it support all capabilities required to implement assessment criteria" (p. 96). In this sense the use of the *classification scheme* for the *significant knowledge* in conjunction with a detailed *preservation description information scheme*, based on the InterPARES framework, within the *submission agreement*, will improve the ingestion policies of institutions and support meaningful use of digital records.

7.2 Conclusion

The preservation of cultural artifacts with technological components involves issues of readability, authenticity, and intelligibility. Several projects address readability and authenticity issues while ignoring or minimising the issue of intelligibility. Latour (Latour, 1999b, p. 304) states that more successful technologies become, accordingly, more obscure. As a consequence we argue that intelligibility and thus meaningful usability, is a critical concept for the preservation of digital technology. Indeed, intelligibility is especially relevant to records whose preservation relies on migration procedures and those that deal with performer-technology interactions, especially since issues of appropriation are more complex in the digital world. Thus a useful model needs to incorporate archival lifecycles, together with creative process lifecycles, within a digital archives framework. In doing so, such a model may account for a relevant part of the knowledge interactions among multi-

ple agents, both human and non-human, and provide the means to (re)perform the work. We argue that *performance information* adequately associated with its relevant *significant knowledge* classification provide a framework to capture these knowledge interactions and support the specification of data collection methodologies and ingestion policies.

In regard to the curation lifecycle, we emphasise the appraisal, ingest and transform phases and provide implementation of concepts we present as relevant to address these issues. The model we propose relies on the specification of the OAIS *submission agreement* thanks to a *classification scheme* and *preservation description information scheme*. We propose to further specify these schemes respectively with the *significant knowledge* framework and the outcomes of the InterPARES project in terms of the necessary constituent parts of the digital record. The specification of the *classification schemes* as well as the *preservation description information scheme* is a requirement for a policy-aware OAIS model, which supports ingest and appraisal thoughout the archival lifecycle.

Chapter 8

Conclusion

8.1 Introduction

The preservation of contemporary works with live electronics is at risk. In a context where the goal is to preserve the means to re-perform the work rather than a mere audio recording, contemporary works with live electronics epitomise issues that the digital archives research community is currently facing. The digital artefacts created for each work that compose the electronic part of this repertoire prevent the potential natural embodiment that performers may rely on in the context of instrumental music. This situation was aptly described by Magnusson:

> How do things 'contain' knowledge? How do we write our knowledge into artefacts, and how do we read that knowledge from them? By the same token, how does this relate to digital musical instruments. (Magnusson, 2009, p.171)

This lack of natural feedback between digital artefacts and performers epitomises this loss of semantics that the digital world implies. A project like InterPARES II, conscious of these

challenges, has used these artefacts as a paradigmatic example to theorise the authenticity of interactive digital records.

We have argued that, while CASPAR, a project grounded in the OAIS, addressed mainly readability issues, and InterPARES addressed mainly authenticity issues, there is room for investigation of the third notion proposed by Lee (2000), namely, intelligibility.

We have proposed that accounting for tacit knowledge within the framework for the specification of the significance of digital archives is a first step in the preservation of the intelligibility of digital artefacts. In this context, we designed a framework which builds on the state of the art of the research on the significance of digital archives, that is to say, the conceptual framework of *significant properties*. We have labelled this extension, *significant knowledge* and we have theorised it. Furthermore, we have proposed to complement this investigation in relation to the preservation of the intelligibility of digital artefacts with a social focus. This social focus was theorised in opposition to a purely technological approach to preservation, emphasising the role of multiple agents, both human and non-human, during the creative process of digital artefacts. We have argued that similarly, the social focus in the context of the creative process of contemporary works with live electronics echoes the need to extend the notion of performance in the context of digital archives research in order, as Cunningham (2008) puts it, to "deliver meaningful digital records as performances in context to our end users" (p. 540).

As a consequence, in order to investigate the preservation of the intelligibility of the archives of contemporary works with live electronics, we have designed three studies. Two of them are grounded in compositional paradigms (following Ungeheuer's (in press) conceptualisation), which level of complexity, in terms of human/machine relation, is ascending. Specifically, these three studies investigate:

- The integration of tacit knowledge documentation concerns within the scope of the specification of intelligibility preservation frameworks for digital archives: according to our criteria and in conjunction with the literature review in knowledge management, we identified a relevant model for our study. This model, Boisot's (1995) *information space*, is descriptive (as opposed to prescriptive), focusses on tacit/explicit knowl-

edge, and is composed of three dimensions with a high potential for operationalisation. We have designed an operationalisation of Boisot's model in the context of the first compositional paradigm (see section 2.4.1). This operationalisation is based on an interdisciplinary conceptual framework involving: information science, knowledge management, and music research. Specifically, we conducted an online survey in order to test and evaluate the operationalisation of the model in the context of spatialised works. We performed non-parametric measures of association to evaluate the dependence on intra and inter-dimensional measures. We further tested the dependence of the model on different orchestrations/styles acknowledged by the respondents, and on creative phases (derived from previous interviews). We presented the outcomes in chapter 5.

- The specification of creative processes involving multiple agents, both human and non human, in the context of contemporary works with live electronics: to address this, we proposed to broaden the scope of the specification of the stakeholders in the preservation of contemporary works with live electronics. We conducted a grounded theory analysis of a secondary data set, composed of two years of video recordings of work sessions, interviews, and written reports. Specifically this study was grounded in the creation of a work focussing on gesture-following. The extraordinary production setup, which involved the composer, the computer music designer, the performers (a string quartet), a research team, and an engineering team, provided us with a relevant context for the theorisation of the impact of the creative process on the preservation of the intelligibility of contemporary works with live electronics. The analysis generated a rich network of concepts on different levels of abstraction that account for different interdependant life-cycles. Each one of these life-cycles has an impact on documentation and, therefore, on the preservation of the intelligibility of contemporary works with live electronics. We presented the study of this creative process, which epitomises the second compositional paradigm (see section 2.4.1), and its outcomes in chapter 6.

- The analysis and modelling of the impact of the outcomes of both previous studies (that is to say, the *significant knowledge* conceptual framework and the characterisation of the creative processes life-cycles) within models for the management of digital archives, and specifically in the OAIS: we proposed a formalisation of the potential integration

of *significant knowledge* in the OAIS model according to its class models and in direct continuation of its software design practice. We proposed a general implementation, which allows for different frameworks to co-exist, namely, *representation information*, *significant properties*, and *significant knowledge*, as well as the potential inclusion of future frameworks. This modelling was designed to offer a basis for the accountability of policies (either in terms of ingestion or appraisal), keeping in mind that, "if a given preservation environment lacks a particular capability that a policy implies, the mapping from management policies to preservation capabilities will fail and the policy will devolve to an assertion that cannot be verified. This defines one essential component of a trustworthy preservation environment, that it support all capabilities required to implement assessment criteria" (Smith & Moore, 2007, p. 96). In response to this concern, we defined and proposed the addition of several classes to the model: the *submission agreement*; the *classification* (this class divides into *structure vs semantics*, which relates to the original OAIS model, *significant properties*, and *significant knowledge*); the *classification scheme*; and the *PDI scheme*. We further conceptualised the relationship between the creative process and the OAIS' *archival information collection* and proposed a comparison with several frameworks for the specification of context, and especially with the InterPARES outcomes. The details of the modelling have been discussed in chapter 7.

Together, the three studies define a theoretical and practical framework for the preservation of contemporary works with live electronics. they extend the notion of stakeholders in digital curation and the notion of performance for digital archives. These three studies were conducted in the same order as we presented them according to the literature review. In the following section, for the sake of clarity we present the main outcomes of our research in the same order.

8.2 Summary of the main findings

As a result of our literature review, we designed three studies. The music research literature provided us with a conceptual framework with different paradigms relevant to different

research questions. The knowledge management literature provided us with an epistemological context for the specification of our studies (see section 2.3 and section 4.4). The literature on digital archives research provided us with the theoretical background for the specification of the challenges at stake for the preservation of the intelligibiity of digital records; and the digital curation literature provided us with a basis to define future management policies.

Here we present our main findings in relation to our research questions, as reflected in our three studies:

Question 1 : Does Boisot's model adequately describe the knowledge involved during the creation of a spatialised work?

We presented our operationalisation of Boisot's model in chapter 5, using its three dimensions: abstraction; codification; and diffusion. We labelled this operationalisation, the *significant knowledge* in reference to the notion of *significant properties*. *Significant properties* provide grounds for the specification of a framework which intends to account for the preservation of the intelligibility of digital artefacts. The *significant knowledge* extend this framework with a focus on tacit knowledge. The operationalisation of the *significant knowledge* offers support for the specification of relevant data collection methodologies, that is, data collection methodologies which reflect the potential tacit dimension of the knowledge involved in the creation of a work which involves spatialisation techniques. Second, it offers support for the integration of tacit knowledge concerns within digital archives models.

Question 1 - Hypothesis 1 : Boisot's model is suitable for segregating knowledge descriptions.

The survey provided us with a wide range of knowledge descriptions that we categorised into technical skills, mapping strategies, dependence on performance venue, effects on perception, and dependence on compositional specifications (see the details in Table 5.1).

Each category provides us with a specific classification according to the implementation. We provided examples of the interpretation of these classes in table 5.3.

Our operationalisation of Boisot's model provides a significant discrimination of the knowledge within each dimension of the model, namely, abstraction, codification, and diffusion, and between dimensions (see the statistics in table 5.2 and the limitations in section 8.4).

Question 1 - Hypothesis 2 : The classification of the knowledge involved is independent from the orchestration/style of the composition.

The outcome of the Kruskal-Wallis test, a non-parametric equivalent to the ANOVA, shows no significant difference of classification among knowledge involved in contemporary works, whether the composers classify them as *fixed media*, *mixed works*, or *real time synthesis*. This outcome provides a basis for the potential expansion of this model to other artistic contexts. As we previously stated, the technologies involved in contemporary works with live electronics are relevant to a broad range of artistic productions (such as dance, theatre, and art installations). Thus we conclude that our research may have a broad impact.

We also performed a Kruskal-Wallis test to evaluate the effect of spatialisation experience over the model. We found no effect except for the diffusion dimension, which is consistent with the idea that more experienced composers have also more historical background to relate to, that is to say, they have the opportunity to diffuse and relate the knowledge involved in the creative process in different works. This suggests that further studies focussing on the dimension of diffusion would do well to target experienced composers.

Question 2 : How do multiple agents, both human and non-human, interact and produce knowledge during the creative process of contemporary work with live electronics?

Our literature review has shown that in order to account for all agents, both human and non-human of the creative process, it is necessary to extend the notion of stakeholders that can be found in the domain of digital curation as well as in the domain of art conservation. The extension of the scope of agents to non-human agents is critical in accounting for the technological mediations involved in contemporary works with live electronics. They are critical in a context of creation where different domains of research co-exist, that is, art, science, and engineering (see the list of agents provided in Figure 2.4). In this context, this research may have a broader impact, since, according to Hennion and Latour (1993), there is a need for a systematic comparison of the mediation involved in artistic and scientific objects.

During complex creative processes such as the one that was under investigation during this study, the knowledge flows are intricately related to production flows, and the global picture describes an environment that defies the text/interpreter paradigm that Gurevich and Treviño (2007) have criticised. This study presents a picture of a creative process with different agendas for different agents which may spread across several works by the composer as well as other composers through the mediated work of research and engineering teams.

The general framework which emerged out of the application of grounded theory is divided in four inter-related views on the creative process: **ORGANOLOGICAL SPECIFICATIONS**; **KNOWLEDGE LIFECYCLE**; **PRODUCTION PROCESS LIFECYCLE**; and **ELECTROACOUSTIC COMPOSITION**.

Question 2 - Hypothesis 1 : The knowledge production during creative processes impacts the documentation methodologies.

The outcomes of the second study (see chapter 6, together with our literature review (see section 2.4)) show a strong relation between the inclusion of creative processes within the documentation frameworks and the preservation of the intelligibility of contemporary works with live electronics. In particular, the category **PRODUCTION PROCESS LIFECYCLE** revealed a continuous process of construction of knowledge among multiple

agents, both human and non-human. As a consequence, the philological approach to the reconstruction of a work that Zattra (2007) advocates for can only be sustained by a relevant documentation framework which does not rely on *a posteriori* data collection. Indeed, we have argued that this collection must be integrated within the creative process, if possible in an unobtrusive way. In section 6.5, we proposed several directions for the management of this data collection.

Furthermore, the findings in terms of organological specifications show that a documentation framework based on non-grounded theory may disregard an issue that proves relevant during the creative process, that is, the question of the calibration of signals (in sub-category ***data pre-processing***).

Question 3 : Which implications to digital archives model come out of our previous studies?

Both previous studies, as we have argued in the course of the dissertation, propose a basis for the preservation of the intelligibility of the digital artefacts and as an extension for the preservation of digital archives. Nevertheless, the integration of their outcomes is complex. We proposed a minimal impact implementation of these outcomes, that is to say, we maintained the possibility of choosing at implementation time among the different paradigms for the preservation of digital records. Indeed, the implementation of the extended design we propose, may stick to readability issues in the context of the OAIS' *representation information*, it may consider the integration of authenticity related contextual information (such as that of the conceptual framework from InterPARES), or it may implement its entities according to the framework we propose as a ground for the preservation of the intelligibility of the digital records.

We have substantially modified the design of the OAIS to incorporate different classes which model the requirements that emerged from both previous studies. These classes (see section 8.1) attempt to account for the documentation of the knowledge involved in the creative process, either tacit or explicit, and the interactions among the agents, both human and non-human, during the creative process.

Question 3 - Hypothesis 1 : *significant knowledge* may be integrated with the OAIS' ingest entity.

We have proposed an integration of the conceptual framework of *significant knowledge* in the OAIS, which allows integrating different views on the *representation information* (subsequently we proposed to modify the label of this type of information as *performance information*). With the addition of a *classification* class, we proposed to offer the possibility to an OAIS implementation to choose among several paradigms of *performance information* or a combination of them. This choice can be made at the general implementation level or in conjunction with the definition of *submission agreements*. Nevertheless, the possibility is explicitly formalised in the model by the specification of the one-to-many relationship between the *performance information* class and the *classification* class (see Figure 7.1). Furthermore, we proposed to modify the relationship between the *content information* and the *performance information* from a one-to-one relationship to a one-to-many relationship (see Figure 7.1). In this way, we may associate different *performance information* as different points of view on the same *content information*. The advantage is that we can easily account for all levels of abstraction in the *significant properties* framework, and by extension for all levels of codification and diffusion in the *significant knowledge* framework.

The formalisation of the *submission agreement* class that is closely related to the ingest entity provides us with a specific means to define the relation between a potential ingest policy and the *significant knowledge* framework. Specifically, the relation between the *submission agreement* and the *classification scheme* provides a way to define *a priori* the nature of the data to be provided in the *submission information packages* and therefore grounds for their appraisal.

Question 3 - Hypothesis 2 : The grounds for the specification of ingestion policies may be integrated in the OAIS, with a focus on the production lifecycles of the creative processes.

We have specified the relationships between, on one hand, the outcomes of the second study in terms of categorisation of lifecycles, and, on the other hand, the *preservation*

description information and the literature on contextual frameworks. We further proposed to formally define the OAIS' *submission agreement* in the model and to relate it to the OAIS' *archival information collection*. In doing so, we provide a formalised way to define ingestion policies that are accountable within the OAIS model.

We have emphasised the appraisal, ingest and transform phases of the curation lifecycle (Higgins, 2008) and have provided an implementation of the relevant concepts in the OAIS with the following classes: the *submission agreement*; the *classification scheme*; and the *preservation description information scheme*. We have proposed to further specify these schemes respectively within the framework provided by the *significant knowledge* and the conceptualisation of the necessary constituent parts of the digital record by the InterPARES project (Duranti & Thibodeau, 2006).

8.3 Contributions

Interdisciplinary by nature, this research impacts all domains that formed the basis for our research, namely digital archives theory, knowledge management, and music research. The contribution of this research is both theoretical and practical. We will discuss each of them separately.

8.3.1 Theoretical contribution

In terms of theory the specific challenge of the preservation of the intelligibility of contemporary works with live electronices provided us with a ground for theorising the impact of digital technology on digital archives theory. In particular, we extended the notion of performance of digital records within a social theoretical framework, which accounts for technological agents as well as human agents, whereas digital curation tends to remove social theory from its conceptual framework.

We extended the notion of *significant properties* developed in the digital archives research community with a focus on tacit knowledge, which we labelled *significant knowledge*. We further conceptualised this notion with an interdisciplinary framework involving information studies, knowledge management, and music research.

Following Boisot, Canals, and MacMillan's (2004) request for more operationalisation and testing of models in knowledge management, we provided a first operationalisation of Boisot's model, in the context of artistic production, along its three dimensions: abstraction, codification, diffusion. As a consequence, we proposed potential grounds for the knowledge management community for further operationalisations in different domains.

We provided a grounded conceptualisation of the creative process of a contemporary work with live electronics on the basis of a large ethnographic data set, collected over a two-year creation and production process. This conceptual framework may help reformulate non-grounded theories on interactions in contemporary works with live electronics and provide a basis for the developement of formal theories (according to the grounded theory definition (Glaser & Strauss, 1967)) that build on different substantive theories in multiple domains, such as dance, theatre, and art installations.

We modelled the impact of our research within the framework of the OAIS, which we extended with several notions grounded in our first two studies. To our knowledge, this is the first formal proposal for a modification of the OAIS model that is grounded in scientific research.

8.3.2 Practical contribution

From a practical point of view, we proposed a framework to preserve contemporary works with live electronics. Specifically, we further specified, within the OAIS model, the link between data producers and digital archives in order to define accountable policies. As a consequence, the formalisation of the *submission agreement* and the specification of its relation to creative processes will benefit both data producers and digital archivists. Sub-

sequently, it provides grounds for the specification of best practices for the preservation of digital artifacts.

Because these live processing technologies are also applied in other artistic domains, such as dance, theatre, and art installations, we expect that the impact of our research will be broadened to include these domains.

8.4 Limitations

The limitations of each study have been discussed independantly in section 5.5 for the first study, and in section 6.6 for the second study. While the third study implied no further data collection, we discussed the limitation in ontological and epistemological terms in section 4.4. In this section, we will summarise the limitations.

First study: we identified several limitations at the intra-dimensional level. First in the *diffusion* dimension, respondents may have considered the dimension to be cumulative rather than truly exclusive, that is, a very diffusable asset is automatically less diffusable. A complementary study could focus on this dimension, which proved highly relevant during previous interviews. Second, a limitation of discrimination appeared significantly between two FRBR (Functional Requirements for Bibliographic Records) levels, namely *expression* and *manifestation*. This issue should be further investigated in order to specify the context where the distinction becomes meaningful.

Second study: while the large data set proved relevant for grounded theory research applied to secondary data, a potential lack of data directly related to the experience of performers was acknowledged. Further study should address the specific challenges of the appropriation of electronics by performers of contemporary works with live electronics. This research could adopt a similar methodology consistent with the theoretical underpinnings of grounded theory.

Third study: our research is interdisciplinary and involves mixed methods. We identified different ontological and epistemological assumptions according to the theories and models which form the grounds for each study. As a consequence these studies do not operate at the same level. The first study operates at a managerial level and relates to the specification of metadata superimposed on a theoretical framework implemented according to the outcomes of the second study. Thus the *significant knowledge* is integrated within our process of preservation of intelligibility, not as an epistemological validation of the data collection but for the regulation of the submission process of the data collected.

8.5 Future research

The contributions as well as the limitations (see section 8.4) suggest further scientific investigation on several axes related to data producers, data consumers, and digital archives.

The limitation in terms of performer knowledge and appropriation methods in our second study offers a strong basis for future investigations. To address this topic, we have already begun a research project with Dr. François-Xavier Féron (IRCAM), the theoretical and methodological basis of which is a direct continuation of our second study. Our goal is to document appropriation methods used by performers when learning the electronic part. We conducted semi-structured interviews with experienced performers and used the same methodology as that of our second study, that is, grounded theory. Preliminary outcomes have been disseminated (see Féron & Boutard, 2012) and a position paper was recently submitted (see Féron & Boutard, submitted). The main outcomes will be disseminated in a book chapter in early 2014.

The specification of relevant documentation policies that spring from our conceptual framework requires further investigation. Specifically, the implementation of the second study has to be further investigated in terms of data collection. We proposed several trails in section 6.5. Following these trails, we started a project with Prof. Fabrice Marandola (Schulich School of Music and CIRMMT - McGill University): Documentation, Dissemination and Preservation of Compositions with Real-time Electronics (DiP-CoRE). The

project was submitted to SSHRC in the context of the Connection Grants funding opportunity. The project will also benefit from our third study. The DiP-CoRE project aims at establishing and disseminating best practices for the preservation of contemporary works with live electronics.

On a smaller research scale, the relationship between data collection methods and the classification in Boisot's model should be investigated. This research could offer a basis for the automation of some parts of the appraisal process but also ease the work of data producers.

In addition to the research on the production side, our research suggest the specification and operationalisation of evaluation methods in terms of benefits for the intelligibility of digital artifacts. Such research could offer different levels of provision of metadata and *performance information* as a basis for quantitative and qualitative evaluations. Another area of interest would be the comparative evaluation of the three classifications defined in figure 7.1: the OAIS original *representation information*, the *significant properties* conceptual framework as implemented in the PREMIS data dictionnary[1], and our proposal for *significant knowledge*.

As we previously stated, we expect that the impact of our research could be broadened to include other artistic domains, such as dance, theatre, art installations, and net art. Thus we expect to start collaborative works with researchers in digital artefacts preservation. In this context I have started some editorial work specifically oriented to interdisciplinary research and multiple research areas dealing with preservation of digital artefacts. From this perspective, I am co-editoring a special issue of the journal *Les Cahiers du Numérique* on the preservation of digital artefacts. This journal issue is currently in press. I am also editing a special issue of the journal *Circuit — Musiques contemporaines* on the documentation and dissemination of cultural artefacts with technological components. Establishing research collaborations across domains could enrich the framework we proposed as well as benefit these domains with new operationalisations.

[1]It should be noted that the implementation of *significant properties* proposed in PREMIS is close, conceptually, to the OAIS' *transformational information property*. Thus another solution would be to rely on Knight and Pennock (2009) proposal.

From a digital archives point of view, the implication of the notion of performance of digital objects on the role of digital archivists suggests further research, both theoretical and empirical. This research could take place at several levels. The impact of the extension of the notion of stakeholders involved in the creation of digital records suggests an ethnographic-based investigation of record making-systems. The tendency to merge theoretical grounds as well as practical grounds on digital objects in the context of libraries, museums, and archives advocates for similar studies. These studies could happen at a lower level, for instance with a focus on a specific digital formats. From this perspective, we could extend the research of InterPARES II with an investigation of the multiple delegation processes involved in specific interactive documents in these three different contexts.

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Appendices

Appendix A

Study 1: survey questionnaire structure

Introduction

In this questionnaire i'd like you to remember the creative process of your latest work with spatialisation, from the very first ideas to the concert hall.

I am going you to ask you to list the items of knowledge required during the creative process specifically related to spatialisation.

These items of knowledge, related to spatialisation, may have been acquired during the creative process as well as previously, either in an empirical manner, or through documentation, a knowledgeable third party, etc. These items of knowledge may be theoretical as well as technical.

Profile

Questions — [Instrument]

- Q1: *How many years have you been composing?* — [Integer]

- Q2: *How many years have you been using spatialisation in your composition?* — [Integer]
- Q3: *How many years have you studied music?* — [Integer]
- Q4: *In what orchestration/style would you say you composed this work?* — [Single choice: 1) *mixed works (acoustic instruments and electronics)* ; 2) *fixed media* ; 3) *real time synthesis (e.g. laptop, digital musical instrument)* ; 4) *Other*]

Description

Questions — [Instrument]

- Q5: *Briefly describe this item of knowledge required during the creative process of your work specifically related to spatialisation* — [Free text]

Abstraction

Questions — [Instrument]

- Q6: *In your opinion, to what extent is this item of knowledge relevant to* :
  - Q6.1: *the work as an abstract entity at a conceptual level* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]
  - Q6.2: *the work as expressed with a specific spatialisation method (e.g.: Ambisonics, WFS, 5.1, stereo, etc)* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]
  - Q6.3: *the work as realized in software and hardware (e.g. loudspeaker system, max/msp patch, etc.)* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]

Codification

Questions — [Instrument]

- Q7: *In your opinion to what extent is this item of knowledge likely to be formalized?* — [5 points Likert scale: 1) *not formalizable* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *completely formalizable*]
- Q8: *In which formal system? Choose from this list or add your own* — [Single choice (randomized): 1) *schema* ; 2) *documentation text* ; *mathematics* ; 3) *score* ; 4) *max/msp, pure data, or reaktor patch (etc.)* ; 5) *other*]

Diffusion

Questions — [Instrument]

- Q9: *Please rate this item of knowledge according to its relevance to* :
  - Q9.1: *a specific part of the work* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]
  - Q9.2: *the whole work* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]
  - Q9.3: *several works of yours* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]
  - Q9.4: *other composers' works (in your opinion)* — [5 points Likert scale: 1) *not relevant* ; 2) *slightly* ; 3) *fairly* ; 4) *very* ; 5) *extremely relevant*]

Lifecycle phase

Questions — [Instrument]

- Q10: *During which creative phase is this item of knowledge most relevant? Choose from this list or add your own* — [Single choice (randomized): 1) *sound recording* ; 2) *post-production* ; 3) *studio mixing* ; 4) *spatialisation system implementation* ; 5) *tests in studio* ; 6) *test in a studio with performers* ; 7) *test in performance space* ; 8) *rehearsal* ; 9) *conception* ; 10) *other*]

Appendix B

Study 2: original quotations

id	date	session	agent	translated quote
1	2/6/07	Project's Presentation Meeting	COM	"[...] ce quatuor est un vrai challenge, je voudrais qu'il soit vraiment augmenté. Quand j'ai commencé à participer au groupe geste [à l'IRCAM], quand j'ai écrit Bogenlied, j'avais déjà en tête l'idée du quatuor mais c'était impossible de s'y attaquer tant qu'on n'avait pas validé la possibilité de travailler avec le geste comme un paramètre compositionnel à part entière"
2	5/22/07	Debriefing Session	STL	"la partie électronique va devenir comme le cinquième instrumentiste"
3	2/6/07	Project's Presentation Meeting	STL	"le capteur, qui est un accéléromètre trois axes et un gyroscope deux axes. Donc l'accéléromètre mesure les accélérations selon trois axes possibles et le gyroscope mesure les vitesses angulaires et les vitesses de rotation suivant deux axes"

Continued...

id	date	session	agent	translated quote
4	2/6/07	Project's Presentation Meeting	STL	"et dans une certaine mesure en fait ça veut dire que la pièce pourrait être refaite avec même autre chose en fait. Ca pourrait être refait avec peut-être pas des accéléromètres mais autre chose si on arrive après à déduire les mêmes types d'information"
5	9/19/07	Interview COM+CMD	COM	"y'a une petite bague qui rentre sur la [...] qui est adaptée à chaque archet parce qu'il y a pas deux archets pareils"
6	3/6/07	Interview COM	COM	"le capteur 2 est mal étalonné, et pourra donner des infos plus significatives à l'avenir"
7	2/6/08	Work Session (afternoon)	STL	"faudrait remettre un gate sur le son [...]"
8	9/19/07	Interview COM+CMD	COM	"[...] le suivi de geste, parce que c'est quand même... une des grandes finalités au niveau électroacoustique, enfin informatique de cette pièce"
9	2/6/07	Project's Presentation Meeting	STL	"c'est en comparant ces différentes unités [de signal] entre elles... qu'on cherche à extraire des paramètres"
10	5/22/07	Interview STL	STL	"En fait ce qu'on fait, c'est qu'on écoute toute la pièce et on donne juste des indications 'là on peut passer à la détection suivante'. Par exemple y'a un exemple ou c'est les écrasés qui s'enchainent très très rapidement avec les martelés; à la limite on peut tout ça les prendre comme une section en entière"
11	2/6/07	Project's Presentation Meeting	COM	"et il y a la 3ème chose qui est intéressante, c'est non seulement de le reconnaître, en contexte, hors contexte, joué par une interprétation, joué par le même avec une autre interprétation, mais aussi de pouvoir en apprécier, justement, les différences, entre la façon dont il a été élaboré et la façon dont il est interprété. Qui est plus intéressant que le simple fait de dire 'j'ai reconnu', j'ai gagné quoi, qui va rester pauvre"

Continued...

id	date	session	agent	translated quote
12	5/22/07	Interview STL	STL	"si ça c'est la référence ce qui est joué, et si ça c'est ce qui est réaligné avec erreur d'alignement, on met ça en fonction de ça et on obtient ça, puis on calcul la pente, et ça me donne la moyenne de cette différence [...]"
13	11/19/08	Project's Debriefing Meeting	CMD	"[...] et à quel moment il y en à trop et c'est plus la peine parce qu'on perçoit plus? Et en fait que chaque instrumentiste contrôle un paramètre de la synthèse simultanément, [...] ça fonctionne [...]"
14	4/2/07	Work Session	COM	"je voudrais régler son geste sur l'électroacoustique, je reçois très peu de gestes et je voudrais l'affecter à la densité des graves"
15	3/6/07	Interview COM	COM	"la reconnaissance de geste n'a pas de problème si on transpose jusqu'à la sixte"
16	1/15/08	Work Session	CMD	"on réajuste juste un petit peu les pressions, tu sais on a changé les potentiomètres, maintenant on arrive mieux à les calibrer"
17	5/22/07	Interview STL	STL	"Ça va de mieux en mieux marcher parce que leur jeu va moins varier"
18	11/19/08	Project's Debriefing Meeting	CMD	"quand tu joues [...] dans des salles différentes [...], il faut un système pour s'adapter vite, tu ne peux pas tout refaire à chaque fois. Là, tu avais un système où tu pouvais t'adapter vite"
19	9/19/07	Interview COM+CMD	CMD	"tu sais bien que c'est instable, même entre une générale et un concert. Il faut au suiveur le plus de variété possible, entre le truc presque bien, et le truc pas bien du tout"
20	9/26/07	Interview STL	STL	"y'a une machine qui fera tout ce qui est processus sonore et une machine qui fera tout ce qui est analyse"
21	10/30/07	Work Session	COM	"B : et c'est lib et... ? A : lib, snd et FTM [...] B : ok, et ton patch c'est ? A : 30 octobre 001"

Continued...

id	date	session	agent	translated quote
22	2/6/07	Project's Presentation Meeting	COM	"ça passe par la culture instrumentale parce qu'elle a bossé pendant huit heures par jour au conservatoire pour faire son geste, le répertoire, ça passe par l'habitude de la musique contemporaine [...] et puis ça passe par la précision de la note dans telle situation liée à l'instrument... et puis ça passe par la tradition orale [...]"
23	10/30/07	Work Session	COM	"[Instrumentiste] et nous on le sait ou... c'est pas important ? [Compositrice] si, vous le savez, [...]. Donc celui qui a la ligne a le capteur de pression en temps réel sur le frequency shifter. Donc en fait vous verrez que les événements fonctionnent, [...]"
24	2/6/07	Project's Presentation Meeting	CMD	"[...] on a abandonné [la position du capteur] en cours de route, parce que c'était assez contraignant"
25	4/2/07	Work Session	COM	"d'adapter son jeu à ça, on avait vu qu'il fallait qu'il tienne plus longtemps les flautendo pour que ça fonctionne"
26	2/6/07	Project's Presentation Meeting	STL	"si quelque chose ne marche pas mais qu'on voit très bien pourquoi, [...] et que le système réagit exactement comme attendu parce que y'a cette erreur et tout ca, ca nous permet quand même d'avancer parce qu'on se familiarise avec le système [...]"
27	1/15/08	Debriefing Session	COM	"je leur ai expliqué l'électroacoustique, ce que je voulais faire ici, ce que je voulais faire là"
28	2/12/07	E-mail	COM	"1 j'ai besoin de précisions sur la captation du flautendo. 2 L'accéléromètre est-il en 3D ? [...]"
29	10/30/07	Work Session	COM	"par exemple là c'est le violon 1 qui... attends je le [transformation du son] mets au violon 2, va y joue ce que tu veux, joue une ligne et tu vas entendre le frequency shifter qui..."

Continued...

id	date	session	agent	translated quote
30	9/19/07	Interview COM+CMD	CMD	“dans la première section, c’est vraiment des comparaisons entre des modèles individuels ou interindividuels, mais ça c’est pas quelque chose qui est forcément contrôlé de façon consciente par le geste”
31	11/19/08	Project’s Debriefing Meeting	STL	“en gros, si on reprenait la pièce dans un mois, je crois qu’il y a un marqueur que j’avancerais au début d’une section et refaire éventuellement l’apprentissage d’une section, ou rien. . . ”
32	2/21/08	Interview COM+CMD	CMD	“elle a réutilisé les résultats de cette expérience là et c’est vrai, parce que c’est pas la peine de refaire, et maintenant tu sais les choses qui marchent, les choses qui marchent pas”
33	2/21/08	Interview COM+CMD	CMD	“[...] synthèse granulaire qui est la même que Bogenlied”
34	11/19/08	Project’s Debriefing Meeting	CMD	“on a fait des tests là-dessus, on s’est rendu compte, du coup, le paramètre de vitesse faisait rien quoi”
35	9/26/07	Interview STL	STL	“Florence commençait plutôt par Plot [. . .] on peut visualiser donc on voit déjà a peu près les différences [. . .] et on regarde comment la machine analyse. . . et on peut retourner vers plot quand y avait des choses qui nous étonnait , là il arrive vraiment pas à reconnaître ou suivre , on retourne dans Plot et on regarde vraiment en détail les données [...]”
36	4/12/08	Interview COM	COM	“j’ai éliminé des modules et je me restreint à harmonizer, granulaire, flute euh frequency shifter, la disto, reverb [...]”
37	9/26/07	Interview STL	STL	“C’est à dire qu’il y a des choses qui vont changer ici. Ici on sélectionnait un instrument à la fois et ça, c’est en train de disparaître. . . on va plutôt choisir un groupe de capteurs mais qui peut provenir de chaque instrument”

Continued. . .

id	date	session	agent	translated quote
38	11/19/08	Project's Debriefing Meeting	COM	"après, il y a eu une négociation terrible avec [le réalisateur en informatique musicale], [il] m'a dit si tu fais ça on ne revient pas au mode réel, on reste au mode fictif. Je lui ai dit 'pas question, je reste en mode fictif le temps de la panne et je repasse en mode réel ensuite'"
39	11/19/08	Project's Debriefing Meeting	COM	"Mais on a fait un très beau travail avec [l'ingénieur du son], on a fait tourner toute la pièce, il l'a entendue, il a très bien compris, il prenait des notes, etc."
40	2/21/08	Interview COM+CMD	CMD	"je pense qu'il faut que Florence avance sur ses évènements [Florence Baschet acquiesce] que moi j'avance bien aussi , qu'on arrive à converger avant... dans quinze jours quoi. [...]"
41	2/6/07	Project's Presentation Meeting	STL	"il y a eu beaucoup d'allers-retours, toi [Florence Baschet] tu venais avec des bouts de partitions, et nous, on te disait si on pensait que ça allait marcher ou pas"
42	2/6/07	Project's Presentation Meeting	STL	"pour l'instant, on fait les choses en série. [...] On va enregistrer toutes ces phrases, après on va regarder comment le système se comporte."
43	2/21/08	Interview COM+CMD	CMD	"ce qu'on a pas vu c'est la façon de stoquer les évènements. Donc on utilise Patter, et tout est là [montre tableau de données] donc la partition de ? C'est ca"
44	10/30/07	Interview COM+STL	COM	"le gyro 1 est assez intéressant, moi je regarde beaucoup le gyro 1"
45	9/26/07	Interview STL	STL	"[le logiciel Plot] a servi énormément à Florence, [...] elle s'est construit une représentation, enfin une intuition par rapport à ce que donnent les capteurs par rapport à la musique"
46	2/6/07	Project's Presentation Meeting	COM	"j'ai pensé, [...] en dessous de la partition, d'avoir un autre pentagramme et écrire exactement... Je ne l'ai pas fait [...] car je voulais associer l'instrumentiste dans le geste [...]"

Continued...

id	date	session	agent	translated quote
47	7/9/07	Debriefing Session	COM	"[montre le créneau] ca c'est des trajectoires ca passe du violon au violoncelle. [...] [montre le losange] c'est vraiment des complexes de gestes cumulés"
48	4/12/08	Interview COM	COM	"Et au niveau de l'espace , j'ai fait 5 espaces différents"
49	7/11/08	Interview COM	COM	"J'avais essayé cette écriture 2 à 2, avec ces triples croches, en pensant vraiment à une transformation électro [...]"
50	5/22/07	Debriefing Session	STL	"c'est bien qu'ils aient joué de façon excessive avec le dispositif [...] ils se familiarisent avec les bornes de ce qui est possible, en attendant de travailler plus dans la nuance [...]"
51	2/6/07	Project's Presentation Meeting	STL	"[les choses] qu'on abandonne c'est pas définitif [...], ca peut revenir après dans d'autres projets... suivant les compositeurs on est dans des cas différents"
52	2/6/07	Project's Presentation Meeting	COM	"je préfère le decider [le type de transformation], ca c'est compositionnel"