A Nursing Workload Manager for a Patient Data Management System

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Abstract

This thesis presents the design and implementation of a Nursing Workload Manager module for a Patient Data Management System in an intensive care unit. The Nursing Workload Manager aids in the planning and documentation of the nurse's workload. It automates the generation of the nursing care plan and automatically assigns a score to the care plan based on a nursing workload measurement system. In the thesis a literature survey of patient data management systems, nursing workload measurement systems and system evaluation methods is presented. This is followed by an overview of the work environment of an intensive care unit. The functionality of the Nursing Workload Manager is described and details of the software environment and application implementation are discussed. Finally, the results of a user evaluation of the module are presented, and future work on the module is discussed.

Sommaire

Cette dissertation présente la conception et la mise en application d'un module servant à administrer le travail du personnel infirmier. Ce module fait partie d'un système de gestion de données des malades dans une unité de soins intensifs, et aide à planifier et documenter les activités du personnel infirmier Il automatise la création du plan des soins et évalue la charge de travail. Dans cette dissertation, les systèmes informatiques médicaux, les systèmes de mesure de charge de travail, et les méthodes utilisées pour évaluer ceux-ci sont passés en revue L'environnement de travail d'une unité de soins intensifs est décrit. Les fonctions du module et les particularités de sa mise en application sont détaillees Les résultats de l'évaluation du module par le personnel infirmier sont présentés, et les lignes directrices d'une évolution future du module sont discutées.

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Chapter 1 Introduction

The intensive care unit has seen a rapid increase in the amount of information and equipment available and necessary for its day to day functioning. The resulting large amounts of data must be documented and interpreted. With existing manual methods this is not always possible and much data is neither collected nor analyzed. Patient data management systems or computer-based clinical information systems attempt to redress this shortfall In its simplest definition, a patient data management system is a computerized method of recording patient information. It can interface with monitoring equipment and acquire and store data on a continual basis. In recent years this definition has been expanded to include diagnostics, care planning and clinical administration.

There are many factors that contribute to the success of a patient data management system. The system must satisfy the functional requirements identified at its inception. It must be able to integrate new functions or interact with external computing facilities, and its user interface must be perceived as responsive, unobtrusive and "normal" User attitudes to computerization and to the patient data management system must also be considered.

One of the activities of a nurse in the intensive care unit is to create a nursing care plan. This identifies the tasks required to care for the patient Tasks such as initial assessment of the patient and reassessments, meeting patient care needs and planning and carrying out of interventions to meet those needs. The care plan may also be used by the hospital administration to measure the nursing workload Many workload measurements systems exist. The tasks on the care plan are then scheduled for the coming shift. The generation and scheduling of care plans and the measurement of nursing workload are well suited to computerization. Computer-assisted care plans have the potential to decrease the time spent creating care plans and measuring workload, improve the quality of the care plan, institutionalize standards of care and behave as a reminding mechanism for critical tasks [Roger *et al.*, 1990, Roger *et al.*, 1991].

In this thesis a Nursing Workload Manager module for a patient data management system in a pediatric intensive care unit will be presented. In Chapter 1, patient data management systems will be discussed in general with existing systems being presented. User interaction styles and devices will also be discussed. A description of nursing care plans and nursing workload measurements systems will follow. Chapter 1 will finish with a presentation of issues and considerations in system evaluation, user acceptance and nursing attitudes to computers

Chapter 2 presents an overview of an ICU and describes the procedures used in the Pediatric Intensive Care Unit (PICU) of the Montreal Children's Hospital. The hardware and software configuration of the Patient Data Management System installed in the PICU will be outlined

Chapter 3 describes the functionality and user interface of the Nursing Workload Manager module, and chapter 4 discusses the implementation and evaluation of the module. Future work is also presented.

1.1 Patient Data Management Systems

1.1.1 Definition

Over the past fifteen years, a large number of Patient Data Management Systems (PDMS) have been developed and installed in hospitals. Many of these installations have been in the Intensive Care Unit (ICU). Gardner [Gardner *et al.*, 1989] identifies four functions of computers in an ICU setting:

1. Physiologic monitoring
2. Computers that facilitate the timely and accurate communication of data among multiple hospital locations and departments.
3. Management of medical records.
4. Expert computer systems to aid in patient care decision making.

Andreoli and Musser [Andreoli and Musser, 1985] identify three types of computer applications for patient care: patient monitoring computer systems, medical information systems, and computer-assisted diagnosis systems. Kriewall and Long [Kriewall and Long, 1991] characterize computer-based medical systems as controllers, information managers or diagnostic tools.

These three definitions overlap to comprehensively describe the realm of computer-based medical systems or PDMSs. Physiologic or patient monitoring was the earliest function implemented in a PDMS [Milholland, 1988]. Physiologic monitoring systems can monitor ECG, arterial blood pressure, atrial blood pressures, temperature, chest drainage, urine, cardiac output and respiratory parameters [Andreoli and Musser, 1985]. A wide variety of computer applications in nursing have been identified [Carnevale, 1986, Nolan-Avila and Shabot, 1987]

1.1.2 Physiologic Monitoring Systems

In many cases the parameters monitored by the physiological monitoring equipment are not automatically recorded in the patient's chart. Even though the monitoring is continuous, the nurse takes a reading at half-hour or hour intervals and enters this reading into the paper chart [Collet *et al.*, 1989]. Transcription errors occur or scraps of paper, used to temporarily hold information, are misplaced or forgotten [Hendrickson *et al.*, 1991, Nolan-Avila and Shabot, 1987, Soontit, 1987, Staggers, 1988]. Hammond et al. [Hammond *et al.*, 1991a] report that nearly one third of all errors in an ICU involved mistakes in charting or relaying information between shifts. The automatic acquisition of physiological data is seen as a primary goal. When McDonald et al. [McDonald *et al.*, 1988] developed their Regenstreif Medical Records Systems they started with laboratory results and vital signs - in their opinion, the easiest to capture. Milholland [Milholland, 1988] references many of these computer-based monitoring systems.

Physiologic monitoring can be extended to not only measure and record vital signs, but also to control medical conditions. Systems have been developed for pharmacological drug administration and diabetes management [Kriewall and Long, 1991]. The monitoring must be done in real-time.

Collet et al. [Collet *et al.*, 1990] describes a Trend Analysis module in a PDMS which analyzes cardio-vascular data from physiological monitors to generate an early warning alarm. Trend patterns are recognized and analyzed. Relationships between different parameters are considered. Andreoli and Musser [Andreoli and Musser, 1985] criticize many monitoring systems for their inability to comprehend such relationships.

Subramanian [Subramanian, 1989] describes a microcomputer based obstetrics information management system that monitors an eight bed unit continuously Analog information from a fetal monitor is digitized and stored in an IBM personal computer. Waveform information can be displayed on a central monitor for all eight beds simultaneously. The University of Louisville Medical School [Strickland Jr., 1991] have developed an information management system to assist in the monitoring of patients with severe head injuries. It supplements the monitoring done by the ICU nurses and concentrates on the recording of brain function.

Since their early beginnings of patient monitoring, PDMSs are now responsible for the collection, organization, retrieval, manipulation and interpretation of patient data [Bradshaw *et al.*, 1989, Hammond *et al.*, 1991b, Milholland, 1988]. Improved quality, both content and legibility, of the patient record has been cited most frequently as the reason and benefit of installing a PDMS [Bradshaw *et al.*, 1989, Hammond *et al.*, 1991a, McDonald *et al.*, 1988, Milholland, 1988, Nolan-Avila and Shabot, 1987, Soontit, 1987, Staggers, 1988]. Efficiency and productivity gains have also been reported [Bradshaw *et al.*, 1989, Hammond *et al.*, 1991a, McDonald *et al.*, 1988, Soontit, 1987], allowing the nurse more time in direct patient care [Hammond *et al.*, 1991a, Milholland, 1988, Nolan-Avila and Shabot, 1987, Soontit, 1987]. Improved morale and job satisfaction have been the by-product of these results. The patient chart produced by a PDMS is more complete, more accessible and more suitable for research analysis than a manually produced one [Hammond *et al.*, 1991a, Soontit, 1987, Staggers, 1988]. The incidence of duplicated or unnecessary tests decreased with the use of a PDMS [Nolan-Avila and Shabot, 1987].

1.1.3 Commercial versus In-House Hospital-Developed Systems

Both commercial and in-house hospital-developed PDMSs have been successfully implemented [Bradshaw *et al.*, 1989, Brennan, 1991, Hasman *et al.*, 1988] [Kuhn *et al.*, 1990, McDonald *et al.*, 1988, Nolan-Avila and Shabot, 1987] [Soontit, 1987]. Some commercial vendors and products are: Hewlett-Packard [Hammond *et al.*, 1991a, Nolan-Avila and Shabot, 1987], Marquette, EMTEK [EMTEK, 1988], MedTake [Pesce, 1988] and CliniCare [Hughes, 1988]. Factors influencing choice of commercial versus hospital-developed include: ability to customize, functionality, cost, user interface, modularity and multi-vendor equipment support [Paganelli, 1989].

Some commercial vendors and products are: The commercial systems offer the advantage of being ready to install in their entirety with little involvement from the medical staff, which contrasts to the sometimes long development cycle of an in-house system with its many staff consultations and try-outs. They are usually large and comprehensive, but may offer more than is needed or desired [Brennan, 1991, Hasman *et al.*, 1988] and customization may be difficult and costly [Paganelli, 1989]. Excess functionality increases the cost and can complicate the user interface. Logistic and regulatory constraints can necessitate the development of customized systems for many government and academic institutions [Essin, 1988]. Another factor to consider is the difference in environments between an adult institute and a pediatric one. Most commercial PDMSs are geared to the adult market. Certain functions may be inappropriate or incorrect for a pediatric situation.

1.1.4 User Interaction

There are three areas of interest in user interaction: user access, interaction styles, and interaction devices. In a PDMS, user access can be confined to a discussion of bedside access versus centralized access. There are five main interaction styles: menu selection systems, form fill-in, command languages, natural language and direct manipulation. Among the many interaction devices exist today, the primary mode of data entry is the keyboard. In recent years the mouse has gained popularity, and automatic speech recognition is beginning to be used.

Bedside terminals are becoming increasingly popular because of: reduced duplication of data, reduced time spent waiting for central terminals, more sophisticated displays, improved retrieval capabilities and timely documentation [St. Andre and Eckerty, 1990, Hammond *et al.*, 1991a, Hendrickson *et al.*, 1991] Halford et al. [Halford *et al.*, 1989] found that with centralized terminals, 82% of nurses first wrote down data, then later entered it into the computer. There are some concerns though: additional cost, effect on patient (noise and light may be distracting or annoying), patient confidentiality and data security, lack of space and infection control [Hendrickson *et al.*, 1991, McNeal, 1990].

Menu selection systems offer a structured decision-making by presenting only a few choices at a time. It shortens learning time and reduces the number of keystrokes required by the user. It is popular in teaching systems and is appropriate for novice and intermittent users. Frequent users may find it slow [Shneiderman, 1987].

Form fill-in systems simplify data entry for knowledgeable intermittent users. It requires some training as users must understand field labels and which values are permissible [Shneiderman, 1987].

Command language systems are popular with frequent users. They are flexible and users can often express complex possibilities rapidly. It requires much training however, and memory retention may be poor [Shneiderman, 1987].

Natural language systems allow the user to interact with the application without learning its syntax. They have been successfully used in interfaces for database querying. Their scope is limited though, as they tend to be slow and cumbersome [Shneiderman, 1987].

Direct manipulation systems create a visual representation of task concepts and allow a user to directly manipulate objects on the screen. They are easy to learn and memory retention is high. Direct manipulation is appealing as users do not have to learn commands, there are fewer errors than on a keyboard and the user's attention is kept on the display. Disadvantages are that they may be hard to program, and they require graphics display and pointing devices [Shneiderman, 1987].

User interaction with the PDMS can range from keyboard entry to automatic speech recognition. The most common data entry device is the standard typewriter-like "QWERTY" keyboard. Keyboard entry offers a wide range of data entry capabilities, but as de Dombal [de Dombal, 1989] states, "It is really something of an irony that we appear to be in many instances striding toward the twentieth century with devices which employ nineteenth century technology (typing)". Keyboards may be off-putting for users without typing skills

[McNeal, 1990, Murchie and Kenny, 1988]. For non-typists, questioning modes or menu-driven modes may be more "friendly" by reducing the amount of typing required of the users [Hudson and Cohen, 1985]. Some systems use a simplified keyboard with special function keys [Pesce, 1988]. Portable hand-held terminals are also available. They are composed of a small display screen and custom function keys. The CliniCare system by CliniCom [Hughes, 1988] uses hand-held terminals and bar-code labels to input data.

Direct manipulation is another means to input data. A pointing devices such as a mouse, trackball, light pen or a finger on a touchscreen are used [Shneiderman, 1987]. There are drawbacks to the use of these input means to medical applications. Light pens or touchscreens are fast, but are inaccurate The screen is obscured by the hand, arm fatigue may result and, in the case of touchscreens, the screen becomes smudged. A mouse requires a neighbouring flat surface on which to move which may be difficult to accommodate in the crowded space of an ICU. A light pen or mouse has the additional disadvantages of being easily misplaced or stolen, and having cords which may become entangled [McNeal, 1990]

Automatic speech recognition has been successfully used as an input means to medical applications [Kuhn *et al.*, 1990, Petroni *et al.*, 1991, Shiffman *et al.*, 1991] A Patient Data Mangement System where the user's hands and eyes are occupied, mobility is required and cramped conditions may preclude the use of the keyboard [Shneiderman, 1987] is an obvious application for speech recognition. Automatic speech recognition systems are becoming affordable, but their current error rates, speaker dependence requirements and controlled vocabulary limit their application [McDonald *et al.*, 1988]. As Landau [Landau *et al.*, 1989] states, "the necessity of training the vocabulary to a particular voice and of using feedback to verify the input would prove frustrating to the busy physician".

Murchie and Kenny [Murchie and Kenny, 1988] conducted a study to compare three different input devices: standard keyboard, light pen and voice recognition. Intensive Care Unit staff found keyboard input to be the quickest, most accurate, easiest and most preferred method of data entry. A group at MIT [Schmandt *et al.*, 1990] have augmented the X Window system with speech input. It is used in conjunction with the keyboard. There was no difference in speed of access between using the speech input or using the mouse. The choice of medium was related to convenience. The most likely solution of which input means to use is to allow the user to operate an application with many different input means: automatic speech recognition, direct manipulation device or keyboard.

Deciding on a user interface for an application can be difficult. The community of users must be known to determine if training will be possible, how often the user will use the system, what equipment can they use, etc. Often there is a broad range of user's needs, capabilities and environments. Two methods to address this range is to build more than one interface for an application, or to build a user-supportive interface.

Hudson and Cohen [Hudson and Cohen, 1985] found it necessary to provide three user interfaces for their medical expert system in order to satisfy their community of users over time. The user interface may be used in a questioning mode, a data-driven mode and a menu-driven mode.

A user-supportive interface provides a custom interface to an application based on the user's application domain, experience level and preferences [D'Atri and Felice, 1989]. User profiles are maintained in a knowledgebase. An individual user model is built from this information.

1.1.5 Data Validation

Once data has been entered into the system it is desirable to have background procedures to check the quality of the data. Procedures can validate ranges for physiologic possibility and probability, assess variables for anatomic and physiological compatibility and do delta checking for repeated variables [St. Andre and Eckerty, 1990, McDonald *et al.*, 1988, Milholland, 1988]. Range validation procedures check numeric observation against normal, critical or absolute ranges. Data outside of the absolute range is rejected and confirmation is required for data in the critical range or the range of possibility, but not probability Anatomic and physiological compatibility procedures check the appropriateness of sequential data. Delta checking for repeat variables compares sequential data for the same variable. Confirmation is required if an unusually large change occurs in a short period of time.

Another means of controlling the validity of data inputs is to encode the data. In DIOGENE, a Hospital Information System in Geneva, [Scherrer *et al.*, 1990] physicians enter coded diagnosis. Statistical analysis can then be done on the data McDonald et al. [McDonald *et al.*, 1988] also encode data in their Regenstreif Medical Records System.

1.2 Nursing Care Plans

A nursing care plan is a plan of the care required for a patient based on the patient's age, diagnosis, operation performed, allergies and possibly other individual circumstances. In many hospitals the nursing care plan is formally structured into etiologies, expected outcomes or goals, and nursing interventions [Bailey, 1988, Edmunds, 1982, Hendrickson *et al.*, 1991, Probst and Rush, 1990]. The nursing care plan may also more simply list the diagnosis and operation information, and nursing actions or tasks.

Albrecht and Lieske [Albrecht and Lieske, 1985] describe an automated care planning system installed at the Milwaukee County Medical Complex. The care planning system was developed under the premise that nurses should not only directly care for patients, but should also manage the organization of the patient's hospital care. It was one of the first patient care planning systems.

In most computerized care plan systems, the nurse can preload a standard care plan from a library of care plans [Allen, 1991, Bailey, 1988, Brider, 1991, Buck, 1991, Edmunds, 1982, Hinson and Bush, 1988, Keenan, 1991]. The library is usually indexed by diagnosis. Standards of care are automatically loaded in some systems. The nurse customizes the "standard" care plan to meet with the particular requirements of each patient.

In other cases, expert systems are used to assist the nurse in creating the care plan [Probst and Rush, 1990, Hendrickson *et al.*, 1991, Sinclair, 1990]. In Probst's and Rush's system [Probst and Rush, 1990], novice nurses are assisted in the assessment process by answering questions about key parameters. From the assessment parameters, the expert system generates an analysis of the situation. This includes the patient risks and a plan of care. "Fuzzy" logic is used to take into account the degree or extent to which a concept applies.

Computerization of nursing care plans offers substantial benefits. Many of these benefits are the same as those resulting from computerization of the nursing activities in general: less time is spent developing and updating a care plan [Allen, 1991, Bailey, 1988, Edmunds, 1982], the content and legibility improve [Allen, 1991, Hendrickson *et al.*, 1991], productivity increases [Bailey, 1988, Brider, 1991], and morale and job satisfaction improve [Bailey, 1988]. Additionally, computerization of nursing care plans produces a consistency of care in a hospital or association of hospitals, and institutionalizes corporate standards of care [Allen, 1991, Edmunds, 1982, Hinson and Bush, 1988, Iyer, 1991, Keenan, 1991].

Allen [Allen, 1991] mentions two obstacles to automated nursing care plans: computer anxiety and lack of computer knowledge by nurses, and the sometimes non-critical acceptance by a nurse of a pre-loaded care plan.

1.3 Nursing Workload Measurement Systems

Nursing workload measurement systems aim to measure the patients needs for nursing attention and determine how many nursing staff are required to provide that care [O'Brien-Pallas, 1988]. The output of nursing workload measurement systems provides data to the administration of the unit or hospital to be used in determining staffing allocations, monitoring productivity, and costing and billing of nursing services [Bradshaw *et al.*, 1989, Cockerill and O'Brien-Pallas, 1990, Karshmer, 1991, Keenan, 1991, van Slyck, 1991]. In a study by O'Brien-Pallas and Cockerill [O'Brien-Pallas and Cockerill, 1990], senior nursing administrators ranked the most important use of workload measurement systems was to predict and justify staffing requirements. The second and third ranked uses were budget preparation and productivity analysis.

Thibault [Thibault, 1990] believes that workload measurement systems have two main functions: data collection over a long period of time to establish trends and to adjust teams on a daily basis according to variations in patient's needs

A nursing workload measurement system is in use in the majority of hospitals in North America and in Great Britain [Cockerill and O'Brien-Pallas, 1990]. Many accreditation bodies mandate its use. Some of the systems in use in Canada are GRASP, HSSG, MEDICUS, NHPIP, NISS and PRN.

O'Brien-Pallas [O'Brien-Pallas, 1988] describes a history of workload measurement systems. The first attempts to predict nursing workload used data averaged from a survey of hospitals. Characteristics and care requirements of individual patients were not considered. The industrial and management engineering model was applied in the 1950's to measure workload. Systems using this model are often termed Patient Classification Systems (PCS). The tasks required to care for the patient and the average time required for each task were used to determine how much nursing time was required by the patient. Most current measurement systems used today are based on this model. Operations research methodologies have also been applied to measure workload. The approach is based on the assumption that the nursing attention required by patients is greater that the sum of the times associated with tasks that nurses complete on behalf of those patients

Patient Classification Systems, patient dependency levels, acuity scores and medical Diagnostic Related Groups (DRGs) are all methods used to measure the severity of the patient's illness and level of care required. DRGs reflect a medical model and as such are unsuitable for measuring the nursing component of patient needs [O'Brien-Pallas, 1988, van Slyck, 1991]. A study by Halloran [O'Brien-Pallas, 1988] found that there was no strong association of DRGs with variations in nursing workload.

One criticism of nursing workload measuring systems is that many of the systems do not accurately measure workload [Cockerill and O'Brien-Pallas, 1990, Thibault, 1990]. The risk, complexity or skill of a task is not considered, only the time to complete it [van Slyck, 1991]. Also physiological and social care tasks are often not scored [O'Brien-Pallas, 1988, Stelling, 1991, van Slyck, 1991], along with organizational and background work [Stelling, 1991]. "Invisible" work is described as that work which is difficult to quantify or less easily measurable [Thibault, 1990]. It consists of physical, cognitive, emotional and intangible coordination components. The invisible work is not documented, scheduled or scored by the system and is thus ignored The lack of recognition for this work is frustrating to nurses and leads to professional dissatisfaction [Stelling, 1991, Thibault, 1990].

A second criticism is that it encourages a perception of nursing as a series of timed, well-defined tasks [O'Brien-Pallas, 1988, Stelling, 1991, van Slyck, 1991]. A third criticism is that the systems are too bureaucratic and time consuming [Cockerill and O'Brien-Pallas, 1990, Karshmer, 1991].

Also there are inconsistencies in measurement scores between different systems. O'Brien-Pallas [O'Brien-Pallas, 1988, O'Brien-Pallas *et al.*, 1989] found differences in care estimates between GRASP, PRN and MEDICUS for generic case groups and sorted case mix groups .

Resolving these critical issues will contribute to positive nursing and administration attitudes to nursing workload measurement systems [Cockerill and O'Brien-Pallas, 1990, O'Brien-Pallas, 1988, van Slyck, 1991] , and as Thibault [Thibault, 1990] states, "even if the instruments do not measure "all" the workload, as long as they are correlated to the load, they will permit trends to be established over time and allow valid administrative decisions to be made".

Computerization of the measurement process would solve some of the criticisms. Thibault [Thibault, 1990] feels the lack of computer support creates work for managers and nurses and greatly reduces interest in workload measuring systems. Bradshaw (U.S) [Bradshaw *et al.*, 1989] and Keenan (Great Britain) [Keenan, 1991] have both observed positive results of computerizing measurement methods. In both cases the care planning and measurement process were automated. Karshmer [Karshmer, 1991] and Bailey [Bailey, 1988] advocate an integration of the two activities in order to streamline nursing care management.

In the study by O'Brien-Pallas and Cockerill, the second highest rated research priority of senior nursing administrators was to develop a system that would generate a care plan with workload assignment. Many respondents of the study believed future tools must be computerized [O'Brien-Pallas and Cockerill, 1990].

Three of the most commonly used workload measurement systems in Canada are PRN, GRASP and MEDICUS. Each system attempts to calculate the total number of hours required to care for a patient. The methods and information they use differs, as do their results. PRN, GRASP and MEDICUS are described on the following pages.

1.3.1 PRN

The Progressive Research in Nursing (PRN) system measures direct and indirect clinical activities. It can measure non-nursing activities like clerical tasks, tasks of other clinical professionals and hotel type tasks. It supports the measurement of administrative non-clinical activities such as management of human, material and financial resources. It is not able to measure invisible work. [O'Brien-Pallas *et al.*, 1989] [Thibault, 1990]

The total number of hours of care required is calculated as [O'Brien-Pallas *et al.*, 1989],

THC = TDCH + (TDCH x %IC/%DC)

where

THC = total hours of care per patient per day

TDCH = total direct care hours per patient per day

%IC = percent indirect care

%DC = percent direct care

The most recent version of the PRN system scoring form (1987) is a list of 260 items. Segments of the PRN system scoring form are shown in figures 2.4 and 2.5 [Tilquin, 1978, Tilquin, 1987]. Each item describes one or several nursing actions and may be qualified by certain attributes: type of patient concerned, modes of patient managements, range, intensity, frequency, etc. There are eight categories: respiration, nutrition and hydration, elimination, personal care, ambulation, communication, treatments and diagnostic procedures. Each item has a score associated with it. One point is equivalent to 5 minutes. The score signifies the amount of time deemed to be required to carry out the activity over a 24 hour period [Thibault, 1990].

Two main strengths of the PRN system are that it is developed from a rigorous scientific basis and testing, and that by measuring the required care rather than realized care, it facilitates external validation. Others are that it can take into consideration the psycho-social needs of the patient, and that it is specific and easy to use [Thibault, 1990].

Two main limitations of PRN are that it does not take into account the degree of effort required to perform the task and that it cannot take into account unpredicted care in the estimate of required care. Also the number of indicators can be overwhelming for beginners [Thibault, 1990]. Thibault recommends that the PRN system be computerized.

1.3.2 GRASP

The GRASP system follows standard engineering practices to measuring workload. It is primarily an instrument of efficient management of personnel rather than an objective measurement of workload. GRASP measures direct and indirect clinical activities. Indirect clinical activities include nursing process, clinical meetings and charting. It does not measure non-clinical activities such as administration. The measurement of the invisible work is limited [O'Brien-Pallas *et al.*, 1989] [Thibault, 1990]

The chart value is determined as [Thibault, 1990],

Normal Time Value
+ Fatigue and Delay Factor
= Standard Time Value
x Frequency of Activity in 24 hours
= Total Time in 24 hours
Adjustment Factor
= Adjusted Time
6 (One-tenth of an hour)
= Chart value

A patient is assessed by selecting appropriate nursing care interventions required in ten major care elements: diet, elimination, hygiene, vital signs, turning and ambulation, medications, respiratory aids, teaching, emotional support, and indirect care. The GRASP values are presented in tenths of an hour. The score for a patient is the total number of points generated across the ten major care elements [Thibault, 1990].

1.3.3 MEDICUS

The MEDICUS system measures direct and indirect clinical activities. It also measures some non-nursing activities such as clerical tasks, tasks of other clinical professionals and hotel type tasks. It is able to measure non-clinical activities such as administration and to a limited extent teaching. It purports to measure invisible work considering physical, cognitive, emotional and intangible coordination aspects [O'Brien-Pallas *et al.*, 1989] [Thibault, 1990].

The total number of hours of care required is calculated as [O'Brien-Pallas *et al.*, 1989],

THC = RV x TH

where

THC = total hours of care per patient per day

RV = relative value per level of care (pre-set)

TH = target hours per unit of workload

and DCT = TCH x %DC

where

DCT = direct care per patient per day

TCH = total care hours

%DC = percent direct care

There are two major strengths of the system. Firstly, MEDICUS was developed from the start with an objective of administration support. Its approach is practical. Secondly, its focus on patient needs and the nursing process considers the complexity of a patient situation. Its limitation is its lack of documentation concerning its original protocol [Thibault, 1990].

1.4 User Evaluation

As Tombaugh [Tombaugh *et al.*, 1989] states, "A usable system is one which is easy to learn to use, provides a powerful tool for the expert and produces user satisfaction within the system". To properly evaluate a system, goals must be set and measured. System evaluation applies the designer's original goals against the product, and tests the reliability and validity of the system [Peterson, 1988]. Goal setting should involve budget, deadlines, machine performance and user performance [Tombaugh *et al.*, 1989].

Essin [Essin, 1988] describes the components of general success of a clinical computer system as,

- Completion on time.
- Completion within budget.
- The system actually performs the desired functions.
- The system interacts cooperatively with other systems at the institution
- Users find the system normal to use (The system is logical, predictable, and comfortable to use, and does not conflict with the way the users normally work. It does not create an escalating level of frustration as time passes).

- The system meets future 'unanticipated' demands without substantial modification of work completed.

This criteria could equally apply to any computer system.

In recent years, much attention has been paid to the user interface. Many systems have floundered due to ignoring or misunderstanding users' subjective preferences and biases. [Peterson, 1988, Tombaugh *et al.*, 1989]

There are several techniques available to evaluate the user interface. One method is to apply a set of guidelines derived from generic requirements of human-computer interfaces to a design [Edmonds, 1990]. Unfortunately producing such a set of guidelines is difficult.

Both Edmonds and Tombaugh feel the best approach in evaluating the user interface is to evaluate the interface alongside its design and development. It should be an iterative participative activity. The later a problem is recognized, the more difficult and costly it is to address. On-going user testing ensures that feedback from the users aids in forming design decisions.

Jeffries et al. [Jeffries *et al.*, 1991] describe four techniques for evaluating user interfaces: heuristic evaluation, usability testing, guidelines and cognitive walk-through. Heuristic evaluation consists of user interface specialists using their experience to study an interface in depth and search for factors that will lead to usability problems. Usability testing is also carried out by user interface specialists. The specialists gather data on problems that occur during the use of the interface under real-world or controlled conditions. The application of published guidelines is the third technique. The guidelines make specific recommendations to interface developers. Cognitive walthrough attempts to mimic a typical user's tasks by combining software walkthroughs with a cognitive model of learning by exploration. Table 1.1 [Jeffries *et al.*, 1991] lists advantages and disadvantages of the four techniques.

Technique	Advantages	Disadvantages
Heuristic Evaluation	Identifies many more problems Identifies more serious problems Low cost	Requires UI expertise Requires several evaluators
Usability Testing	Identifies serious and recurring problems Avoids low-priority problems	Requires UI expertise High cost Misses consistency problems
Guidelines	Identifies recurring and general problems Can be used by software developers	Misses some severe problems
Cognitive Walkthrough	Helps define users' goals and assumptions Can be used by software developers	Needs task definition methodology Tedious Misses general and recurring problems

Table 1.1: Comparison of Evaluation Techniques

Eaves [Eaves, 1991] recommends forming a checklist of items evaluating system functionality, performance, reporting and support. Items on the checklist should be scored and discussed by members of an evaluation team.

de Dombal [de Dombal, 1989] asks three questions when evaluating an innovation: "Is the innovation necessary?", "Can the innovation improve performance?", and "Can this be done without problem?".

Milholland [Milholland, 1988], in evaluating a PDMS believes the primary question is to determine the effect the system has on the institution. She poses the following questions:

> Have working conditions been improved or have nurses, the primary users of such systems, had additional work imposed on them? Is information more accessible? Are more data recording and retrieval activities expected of the nurse? Is the information provided by the PDMS appropriate for the needs of the clinicians in providing patient

> care? For which clinicians? Does the increased availability of computed physiologic indices improve the quality of patient care? Has the installation of the computer system led to increased or decreased costs to patients, staff, and the intensive care unit? [Milholland,1988,page 204]

Many authors in the health field warn against the danger of not assessing computer literacy and attitudes to computerization prior to installation of a medical system [Bongartz, 1988, Brodt and Strong, 1986, Bryson, 1991, Burkes, 1991, Strong and Brodt, 1985]. Resistance and fear of computers by medical staff and particularly nurses, the principle user of a PDMS, have been widely documented [Allen, 1991, Hammond *et al.*, 1991a, Bongartz, 1988, Brennan, 1991, St. Andre and Eckerty, 1990, Stonham, 1991, Strong and Brodt, 1985]. Computer illiteracy impacts training times and costs, and , if not considered, can lead to a quick rejection of a system by users.

Chapter 2 Overview of an Intensive Care Unit

This chapter describes the functions of a Pediatric Intensive Care Unit (PICU) from a nursing perspective. There are eight general categories of functions carried out in a PICU: patient admission, cardiovascular monitoring, fluid balance monitoring, the preparation of nursing care plans, the measurement of nursing workload, the request of laboratory tests and [illegible]y of laboratory results, the request of pharmaceuticals and the tracking of medications. Each general functional category will be described along with the existing procedures used in the PICU of the Montreal Children's Hospital. The research described in this thesis has been done in conjunction with the development of a Patient Data Management System (PDMS) in the PICU of the Montreal Children's Hospital. The existing implementation of the PDMS will be outlined.

In the PICU is a Hewlett Packard (HP) CareNet System. The CareNet System is made up of a number of components. One set of components is fourteen HP 78534A physiological bedside monitors. The monitors are capable of smoothing measured parameters, real-time display of measured data and alarm generations These monitors are linked in a star configuration local area network to a HP78581A Network System Communications Controller

The PDMS software operates on an IBM PS/2 Model 50 personal computer running OS/2 1.0 with a 40MByte hard disk. The personal computer has a high resolution display and an EPSON LQ-2550 letter quality colour printer attached to it.

A HP78588A Careport network interface is used to communicate the monitored data to the PS/2 personal computer. The Careport translates the data from the Hewlett Packard proprietary format into RS-232C messages. Figure 2.1 shows this

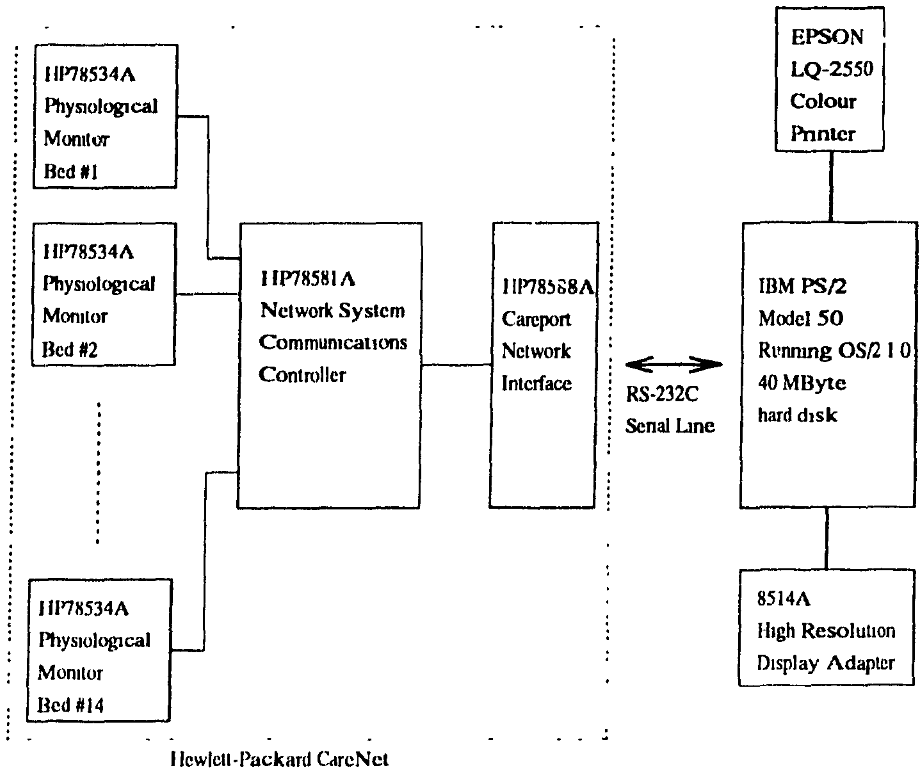

Figure 2.1: PDMS hardware configuration

hardware configuration.

The PDMS software modules which are installed in the PICU are the System Manager modules, the Data Link Controller module, the Patient Registration Module, the Trend Display module, and the Fluid Balance module. Figure 2.2 shows this software configuration.

System Manager - this module starts up the other modules and acts as a main menu to access the other modules.

Data Link Controller - this module fetches, through the RS-232C link, the data acquired at the bedside monitor and stores it. It also acts as an intermediary by transmitting commands between modules.

Patient Registration - this module manages the administrative patient information and initializes the on-line data collection from the network.

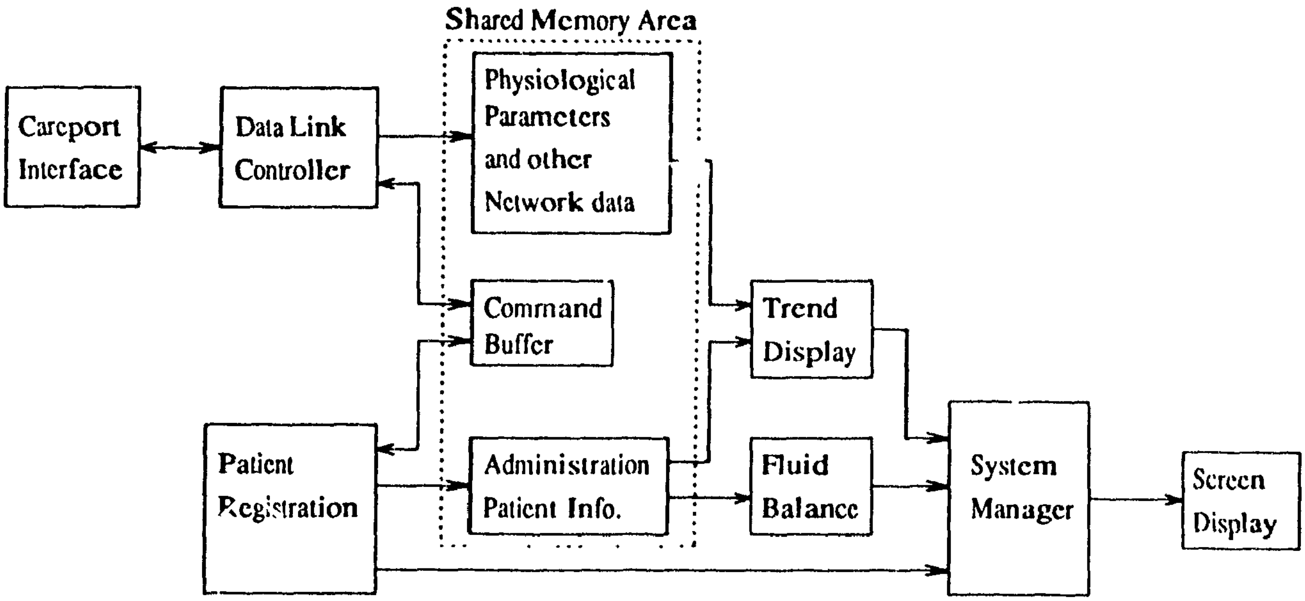

Figure 2.2: PDMS software configuration

Trend Display - this module graphically displays the physiological measurements acquired by the Data Link Controller.

Fluid Balance - this module displays the measurement of substances taken in by the patient (ingesta) and put out by the patient (excreta).

2.1 Patient Admission

The Hospital Information System (HIS) handles the patient admissions, discharge and billing procedures. The PDMS is not linked to the HIS. Without a link between the systems, some administrative patient information is duplicated. In the future it would be desirable to automatically load the necessary information directly into the PDMS. The PDMS patient header file contains static information such as name, date of birth, sex, address, admission date and time, and dynamic information such as diagnostic codes and boolean treatment indicators. The treatment indicators list monitoring and respiratory parameters.

2.2 Cardiovascular Monitoring

The vital signs of the patient are monitored in the PICU both through the Hewlett Packard CareNet System (for example, blood pressure) and by nursing observation (for example, pupil size). In the current PDMS the Trend Display module displays the vital signs monitored by the CareNet System on the 8514/A colour monitor of the personal computer. Measurements are acquired by the Data Link Controller every two seconds. The 'seconds' data is averaged every minute. The 'minute' data is averaged every half-hour. The data is placed in shared memory where it can be accessed by the Trend Display module.

A multi-level expert system is being developed for the Trend Display module. The expert system will aid in the detection and diagnosis of critical patient conditions. Automatic real-time analysis of the trends provides a warning about slowly varying trends or short interval disturbances. The new Trend Analysis module will involve recognition of trends, followed by analysis to determine the patient's state.

2.3 Fluid Balance Monitoring

Patients must be monitored on their fluid balance. Fluid balance accounts for the patient's fluid intake (ingesta) and fluid output (excreta). The nurse takes periodic measurements from infusion pumps or urine bags, and enters these numbers into the fluid balance chart. Medications are also entered here. Running totals must be calculated and abnormalities noted. The current PDMS has duplicated the paper fluid balance chart. The computerized chart is set up as a spreadsheet and key combinations are used to navigate through the chart. It is cumbersome and slow, and provides no advantages to the nurse over the manual method. For these reasons a new fluid balance module is being developed that uses keyboard, mouse or automatic speech recognition to enter values. The new module uses the graphical user interface of OS/2. Validation procedures are used on the data to warn the user on data entry of an abnormal value.

2.4 Nursing Care Plans

Currently the nurse prepares a nursing care plan for a patient on admission to the PICU, and updates it as the patient's state requires. Figure 2.3 shows the Nursing Care Plan Worksheet used by the Montreal Children's Hospital. The care required is determined by the patient's age, diagnosis, operation performed, allergies and possible other individual circumstances. Nurses use their training and previous experience with other patients to know which tasks to perform There are reference books on the floor. The tasks are listed on the Nursing Care Plan Worksheet The Nursing Care Plan Worksheet is divided into nine sections The first section lists general patient information and the remaining eight sections list the tasks. The tasks are categorized into Respiration, Nutrition and Hydration, Elimination, Personal Care, Ambulation, Communication, Treatments and Diagnostic Procedures.

Once the care plan has been filled out the nurse must assign a score to the plan The score is derived from the Progressive Research in Nursing (PRN) workload measurement system. Segments of the PRN system scoring form are shown in Figures 2.4 and 2.5.

The task description in the care plan may differ from those in the PRN scoring form, so some translation may have to be done by the nurse. Also, translation of the frequency measurement must often be made. Most orders are described as "every x hours", while the PRN scoring form describes frequency as "x times [per 24 hours]". Scoring medications and intravenous solutions is more complicated. The nurse scores the medication by calculating how many times the medication is to be given based on its "every x hours" order and by which route. Intravenous

NURSING CARE PLAN WORKSHEET

Name		Age:	**TREATMENTS**	
Diagnosis.			MEDICATIONS	Self administered
			PO/PR/PV/UNG/DROPS	IV.
Operation			IM/SC/ID	IV Pre-mixed
			MEDICATIONS	Start IV
Allergies			IV Therapy	
RESPIRATION				
Humidification				
Respiratory exercises			Blood and Derivatives	
Chest physio			TPN	
Aerosol				
Suctioning				
Trach./Intubated				
Oxygen				
NUTRITION AND HYDRATION				
Feeding S/P/C/I/Hydration P O				
Diet				
Gavage				
ELIMATION				
Urinal	Bedpan.	Assist to B R .		
Diapers/Incontinence.				
PERSONAL CARE				
Hygiene S/P/C			Precautionary Techniques	
Preventive Skin Care			**DIAGNOSTIC PROCEDURES**	
Mouth Care			Observation	V S
Hair Care			Vascular	N S
Street Clothing				
AMBULATION			Intake and Output	
Up with help			Weigh/Measure	
Turn and Position			Speciment Procurement	
Muscular Exercises				
Restraints			Blood	
COMMUNICATION				
Supportive			Analysis on Unit	
Data Collection				
Teaching			Assist Exam or X-Ray.	Assist M D ·
Preventive			Points	

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Figure 2.3: Nursing Care Plan Worksheet

RESPIRATION		
Humidification		1
Respiratory Exercises	Guidance	2
Respiratory Exercises	1 6 times	4
Respiratory Exercises	7 times or more	12
Chest physiotherapy (c p)	1 2 times	4
Chest physiotherapy (c p)	3 6 times	12
Chest physiotherapy (c p)	7 times or more	21
Aerosol Treatment	Guidance	3
Aerosol Treatment	Complete Assistance	14
Suctioning	1 6 times	3
Suctioning	7 19 times	6
Suctioning	20-47 times	13
Suctioning	48 times or more	24
Tracheostomy care	Guidance	1
Tracheostomy care	Partial or complete Assistance	4
Intubation care	1 2 times	2
Intubation care	3 times or more	7
Manual ventilation	1 11 times	3
Manual ventilation	12 times or more	7
Oxygen therapy (catheter, mask etc)		3
Oxygen therapy (croupette covered tent, T tube, etc)		6
Assisted ventilation		15

Figure 2.4: PRN System Scoring Form - Respiration segment [Tilquin,1987]

TREATMENTS		
Medication self administered		2
Medication PO/PR/PV/Ung/Drops	1 4 times	1
Medication PO/PR/PV/Ung/Drops	5 14 times	3
Medication PO/PR/PV/Ung/Drops	15 24 times	4
Medication PO/PR/PV/Ung/Drops	25 times or more	5
Medication IM/SC/ID	1 3 times	1
Medication IM/SC/ID	4 7 times	3
Medication IM/SC/ID	8 times or more	6
Medication IV	1-3 times	2
Medication IV	4 10 times	5
Medication IV	11-15 times	9
Medication IV	16-30 times	15
Medication IV	31 times or more	24
Medication IV pre mixed	1 5 times	2
Medication IV pre-mixed	6 9 times	4
Medication IV pre-mixed	10 times or more	7
IV or SC infusion start	1 puncture	4
IV or SC infusion start	2 punctures or more	7
Intravenous therapy (continuous)	1 solution	4
Intravenous therapy (continuous)	2 solutions	8
Intravenous therapy (continuous)	3 6 solutions	14
Intravenous therapy (continuous)	7 or more solutions	19
Intravenous blood and derivatives	1 2 transfusions	6
Intravenous blood and derivatives	3 or more transfusions	15
Intravenous TPN (continuous)		8

Figure 2.5: PRN System Scoring Form - partial Treatments segment [Tilquin,1987]

RESPIRATION	
	Humidification:
	Respiratory Exercises:
12	Chest physio: *every 4 hours*
	Aerosol:
6	Suctioning: *every 2-3 hours*
	Trach./Intubated:
	Oxygen:

Figure 2.6: Nursing Care Plan Worksheet - Respiration segment

solutions must be counted and separated by type. Two examples are shown below.

EXAMPLE 1

Figure 2.6 shows the Respiration segment of a Nursing Care Plan Worksheet. Two tasks are entered.

To score "Chest Physiotherapy every 4 hours':

Step 1 Refer to the Respiration section of the PRN form shown in Figure 2.4. Note that the PRN form describes "Chest physiotherapy" as "x times [per 24 hours]"

Step 2 Convert "Chest Physiotherapy every 4 hours" to "Chest Physiotherapy x times [per 24 hours]".
Result: 6 times [per 24 hours].

Step 3 Find "Chest physiotherapy 6 times" on the PRN system form.
Result: "Chest Physiotherapy 3-6 times".
Score: 12

EXAMPLE 2

Figure 2.7 shows the Treatments segment of a Nursing Care Plan Worksheet. Four medications, three intravenous (IV) solutions and one blood product are entered in the Treatments section.

To score the medications:

Step 1 Refer to the Treatments section of the PRN form shown in Figure 2.5. Note that the medications are divided into groups by the route of entry and that the frequency measurement is described as "x times [per 24 hours].

Step 2 Convert the frequency measurement of each medication to "x times [per 24 hours]".

Result:

"Medication1 PO every 4 hours" becomes "6 times"

"Medication2 PO every 12 hours" becomes "2 times"

"Medication3 PO every 6 hours" becomes "4 times"

"Medication4 IV every hour" becomes "24 times"

Step 3 Find the matching line on the PRN form.

Find "Medication1 PO 6 times"

Result: "Medication PO 5-14 times"

Score: 3

Find "Medication2 PO 2 times"

Result: "Medication PO 1-4 times"

Score: 1

Find "Medication3 PO 4 times"

Result: "Medication PO 1-4 times"

Score: 1

Find "Medication4 IV 24 times"

TREATMENTS			
MEDICATIONS.			Self administered
5	PO/PR/PV/UNG/DROPS	15	IV
	IM/SC/ID		IV. Pre-mixed
MEDICATIONS:			Start IV
14	IV. Therapy: *IV soln continuous xx ml/hr R foot*		
	IV solution continuous xx ml/hr L jugular		
	IV solution continuous xx ml/hr L foot		
15	Blood and Derivatives. *whole blood as required*		
	TPN.		
	Medication1 PO every 4 hours xx mg/hr		
	Medication2 PO every 12 hours xx mcg/hr		
	Medication3 PO every 6 hours xx units/hr		
	Medication4 IV every hour xx mg/hr		

Figure 2.7: Nursing Care Plan Worksheet - Treatments segment

Result: "Medication IV 16-30 times"

Score: 15

Step 4 Note scores are entered onto the nursing care plan worksheet under PO or IV.

Total PO score is 5.

Total IV score is 15.

To score the intravenous solutions:

Step 1 Refer to the Treatments section of the PRN form shown in Figure 2.5. Note that the intravenous solutions are divided into groups by type (standard continuous, blood and products, and TPN) and scored by total number of solutions.

Step 2 Count the total number of solutions of each type

Result: 3 standard continuous intravenous solutions.

Result: 1 blood product "as required" is translated by the nurse to mean "approximately 4 transfusions" for a patient in this condition.

Step 3 Find the matching line on the PRN form.
Find "3 standard continuous intravenous solutions"
Result: "3-6 solutions"
Score: 14

Find "4 blood transfusion"
Result: "3 or more blood product transfusions"
Score: 15

Step 4 Note scores are entered onto the nursing care plan worksheet according to type.
Total standard IV therapy score is 14.
Total blood and derivatives score is 15.

In addition to creating the nursing care plan, the nurse must schedule the tasks listed on it. A timetable is manually created assigning times for the various tasks in the care plan. Some tasks must follow a strict timetable, others a specific order. Some are high priority, others are routine low priority. The nurse must mentally juggle the alternatives and recognize the benefits and dangers of the different possibilities. Schedule conflicts do occur, as do mid-shift schedule changes [Stelling, 1991].

The Nursing Workload Manager module described in chapter 3 focuses on improving the process of nursing care plan generation, workload measurement and workload scheduling.

2.5 Laboratory Tests and Pharmacy Orders

Laboratory test requests and results are handled through the Hospital Information System (HIS). At this time there is no link between the HIS and the PDMS. Building a link between the two systems would allow for an integration of the laboratory results with the PDMS data. The new Trend Analysis module could use laboratory test results to aid in its diagnostic decision making.

Pharmacy orders are filled through the drugs on hand in the PICU, or are filled by the hospital pharmacy. The hospital pharmacy is notified of the order and it is then delivered to the unit. There is no link between the PDMS and the Pharmacy computer system. The hospital is examining ways to streamline the process of placing a pharmaceutical order.

2.6 Medications

For each patient a Medication Record is made up which lists scheduled medications. The chart is divided into the following columns: prescription date, medication, dosage, route, frequency, hour and several blank columns. In the hour column are written the scheduled times for administering the drug. The blank columns are dated sequentially from the prescription date and hold the initials of the nurse who administered the medication.

An additional sheet is used to calculate drug doses. For example, an order of 0.6 mg of Valium intravenous must be converted to a volume in cc. The drug dose calculation must be signed by two nurses. The charting of medications and drug dose calculations is done manually. In chapter 3, a scheme for automating the medication charting process, and linking it to the modules of the PDMS is discussed.

Chapter 3 Nursing Workload Manager

In this chapter the Nursing Workload Manager module is presented. The first section describes its purpose and functionality. It is followed by an outline of OS/2 and the Presentation Manager environment. This is the development platform used in the Nursing Workload Manager module. Finally, the user interface is described in detail.

3.1 Overview of Nursing Workload Manager

The Nursing Workload Manager is envisioned to run at the bedside. It will provide those nursing services performed there, and will be used primarily by the nurses. The Nursing Workload Manager will generate nursing care plans, automate PRN workload measurement scoring, schedule nursing activities and set up fluid balance charts by integrating with the Fluid Balance module described in section 2.3.

3.1.1 Nursing Care Plans

The Nursing Workload Manager module can be used to generate nursing care plans. The nurse can create the whole plan manually, or call up a standard care plan from a library of plans and customize it for the patient. The library holds a standard care plan that lists the general tasks required to care for most patients in the PICU and many diagnosis-specific standard care plans. Care plans for the most common diagnoses have been prepared.

An on-line help facility is available during the generation of the plan to guide the user in producing the plan. A printing facility is provided to produce a print-out of the nursing care plan. Filing procedures enable the nurse to save a care plan to file, or load one from file. The nurse is able to edit existing care plans.

There will be a utility within the nursing care plan portion of the module to perform drug conversions, and verify drug dosages. The nurses are routinely required to perform minor arithmetic to convert a medication dosage, from a mass to a volume for instance. This is part of the medication charting described in section 2.6. Though minor, with the stress and noise of the PICU, calculation errors are not uncommon. For this reason, all dosage conversion calculations must be countersigned for verification. A mathematical error could result in a fatal drug administration.

3.1.2 PRN Workload Measurement Scoring

The Nursing Workload Manager module scores the nursing care plan according to the PRN workload measurement scoring system. This scoring occurs in real-time and appears on the care plan adjacent to the item generating the score. This offers feedback to the nurse that the item has indeed been accounted for in the total score. The total PRN score is calculated.

3.1.3 Workload Scheduling

The workload described by the care plan will be scheduled by the Nursing Workload Manager module. A schedule will be automatically generated or updated on creation or modification of the care plan. The scheduler will use an expert system to understand the rules employed in scheduling the tasks. It will act as a checklist or reminding mechanism, and generate a warning message if the task was not carried out at the assigned time. There will be a direct feed from the nursing care plan portion of the module to the scheduler portion to avoid duplication of data entry and inadvertent omissions.

3.1.4 Fluid Balance Link

With integration to the Fluid balance module, the Nursing Workload Manager will be able to set up Fluid Balance charts with the information entered in the nursing care plan, such as the administration of medications and specimen procurements. The medication administration times from the scheduler will appear too. When a verification of administration is made or a fluid level is entered in the Fluid Balance module, the item will be automatically checked off on the schedule.

3.2 OS/2 and Presentation Manager

The Nursing Workload Manager runs under the OS/2 operating system using the Presentation Manager environment. OS/2 Presentation Manager is an object oriented multitasking windowing environment with a graphical user interface OS/2 was developed to support personal computers with Intel 80286 and 80386 processors. It exploits the hardware by providing program isolation, memory management, task management, interprocess communications and timer services [IBM, 1988].

OS/2 supports the concepts of logical consoles with Presentation Manager following the visual desktop metaphor. Multiple windows on the screen act as many pieces of paper on a desktop. Windows are a means of sharing, sub-dividing and organizing the screen. A window hierarchy can exist of parent, child and sibling windows.

System Application Architecture (SAA) is a collection of guidelines aimed at setting standards for an application's programming interface and user interface [Dror and Lafore, 1990, IBM, 1988]. Common Programming Interface (CPI) facilitates program portability to other IBM environments. In theory a program built on an IBM PS/2 should be able to run on an IBM System 370. Adherence to the Common User Access (CUA) standards produces applications with consistent interfaces, enabling users to learn a new application more easily. CUA guidelines describe the components of a common user interface and how to navigate program flow through dialog boxes, help facilities and messages.

Presentation Manager uses a system of queues and application window procedures to process messages. Input events originating from the mouse or keyboard are delivered to an application as messages. The system queue which is shared by all applications in the system receives these messages and other messages from the system, the timer or other applications. An input router directs the messages to the appropriate application message queue [IBM, 1988].

A window procedure message is made up of four parameters. The first identifies which window the message is for, the second indicates which type of message has been sent, and the remaining two parameters contain data associated with the message.

The Graphics Programming Interface (GPI) is device independent and allows the programmer to use the same function calls to display text and graphics on any output device, such as a video display monitor or a printer. The GPI function calls are translated by the operating system into displayable images [Petzold, 1990].

OS/2 uses a spool queue to intercept data directed to a printer or plotter. The data is written to a file on disk and printed when the selected printer is available. The spooler synchronizes print jobs, so that data is not interleaved from different sources. The print spooler is called the Print Manager.

With the Print Manager, jobs can be reordered, suspended, cancelled or restarted. The spool queue enables foreground applications to continue to interact with the user, while relatively slow printing jobs take place in the background. The default printer name is stored in a system file, OS2SYS.INI. An application can query this file for the printer name. From the printer name, the driver name and logical device address can be obtained. The driver file can supply information on the printer such as page size, font support, colour support, etc. In this way an application can be written to work automatically with any printer. Dimensions of objects to be printed and the font size of characters can be derived from the page size.

To print under Presentation Manager, the program must create a presentation space, open a device context and then associate the presentation space to the device context. The presentation space is a memory segment that holds specifications on the drawing environment such as current colour, cursor position, fonts, and page size [Dror and Lafore, 1990]. The device context describes a physical output device and its driver. The presentation space, which is device independent, and the physical device, which is device specific, are connected through the device context.

When an application in OS/2 takes more than one-tenth of a second to process a task, multiple threads should be used. A thread is an entity that receives a slice of CPU time [Dror and Lafore, 1990]. Using one thread to process messages and a second to process a lengthy task allows the user to continue using the system The additional thread is able to run concurrently with the main thread as it does not create a message queue [Petzold, 1990]. If a second thread was not used, the system would be locked up until the lengthy task procedure was finished. A special multithread library is provided with Microsoft C which allows a program up to 32 threads [Petzold, 1990].

Synchronization of threads can be achieved by the use of semaphores. A semaphore is an OS/2 kernel mechanism that acts as a traffic light or stop-and-go switch [Dror and Lafore, 1990]. It can be set, cleared and tested. In addition to

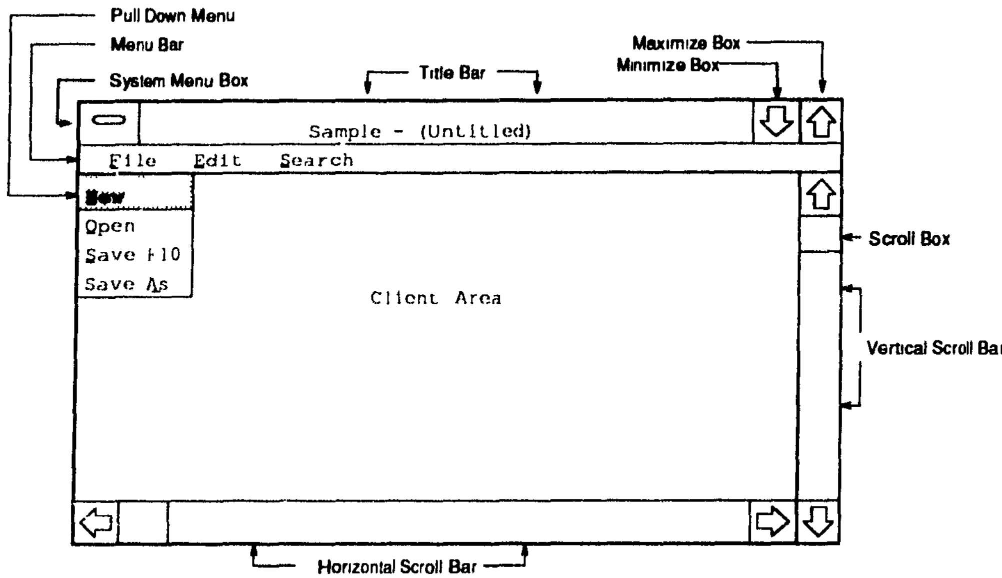

Figure 3.1: Sample Window

signalling a defined event between two threads it can also efficiently control access to serially reusable resources [IBM, 1988].

The Dynamic Data Exchange protocol provides a way for an application to access another's data. It uses a series of messages between the server program that controls the data and the client program that needs it [Dror and Lafore, 1990]. Large quantities of data may be passed among applications. The data to be transferred is stored in a shared memory segment available to designated applications or all applications in the system [IBM, 1988].

A sample window is annotated in Figure 3.1. At the top left hand corner of the window is the **system menu** box. The system menu is a called **a pull down menu.** The menu items in the system menu pertain to system level commands. The user can use the system menu to minimize the sample window, restore it, move it, close it or switch to another window.

One of the commands in the system menu is **Minimize**. This command shrinks the window into its icon. An **icon** is a small box usually placed at the bottom of the screen used to represent an application. A window is minimized

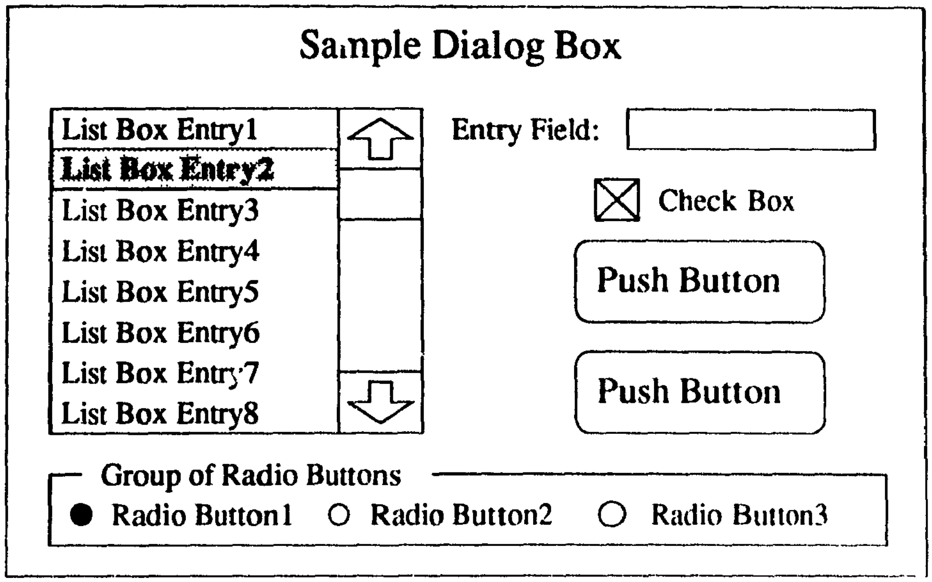

Figure 3.2: Sample Dialog Box

into its icon when the application is to continue running, but occupy minimum screen space. The **Restore** command is used to expand the icon back to the original window. There is also a command, **Maximize,** that expands the window to occupy the whole screen.

At the top right corner are the **Minimize** and **Maximize** boxes. By clicking on these, the window is immediately resized to occupy its minimal space, an icon, or its maximal space, the whole screen.

Along the right hand edge of the sample window is the **vertical scroll bar** The contents of the client area can be scrolled vertically by clicking on the arrows or by moving the **scroll box**. The **horizontal scroll bar** lies at the bottom of the sample window. It is used to scroll the contents of the client area horizontally

Along the top of the window is the **menu bar**. This menu bar contains the names of all the menus in the window. Next to the menu item may be a function key designation. This function key is called a **keyboard accelerator**. The user can access the command without going through the menu bar by just pressing the function key.

A **dialog box** is a special pop up window, see Figure 3.2. It may contain entry fields, check boxes, list boxes, push buttons or radio buttons. These items are called **controls** and are used by the application to interact with the user.

An **entry field** is a rectangular box in which the user can type a single line of text or numbers. In an entry field <Backspace> is used to delete text. Movement through the entry field is achieved with the arrow keys, and the <Home> and <End> keys.

Check boxes allow the user to select one of two states. An "X" appears in the check box to indicate that it is selected. A **push button** is a rounded rectangle that usually contains text. A push button can be assigned default status, so that pressing <Enter> when the focus is not on a push button, but is in the dialog box will automatically select it.

A **list box** is a rectangular box containing a list of items. If there are more items than can be shown in the box at once, there will be scroll bars along the right hand side of the list box. The scroll bar contains an $\Uparrow$, a $\Downarrow$ and a scroll box. The user can select one or more items in the list.

Radio buttons permit the user to select one of a number of choices. They are often grouped together. Only one radio button in a group is on at a time, and one radio button in the group is always turned on. A black circle appears within the radio button to indicate it is selected.

3.3 User Interface

The nursing care plan generation and automated PRN workload measurement scoring portions of the Nursing Workload Manager have been implemented. The user interface of these portions is described in this section.

The Nursing Workload Manager module is run by either entering the program at the command prompt, or by selecting the application from the list of available programs in the Presentation Manager Desktop Group menu. When it is not in use, the application can be shrunk to its icon.

When the Nursing Workload Manager is executed the summary window appears. Figure 3.3 shows the summary window of the Nursing Workload Manager module. It is the top level window of the module from which the user enters and exits. The summary window contains a subset of the features shown in the sample window, Figure 3.1. The summary window has a system menu in its top left corner. The title of the window is shown along the top and in the top right hand corner of the window is the minimize icon. The menu bar runs along the top of the window under the title bar. The summary window does not use vertical or horizontal scroll bars.

The module can be operated via the keyboard or the mouse. Each line of the summary window, or the client area of the window, is sensitized A mouse click on the line will invoke the next window layer. Alternately the next window layer can be accessed via the menu bar. Colour is used to highlight the headings

3.3.1 Menu Bar

A menu tree of the top level menus in the Nursing Workload Manager module is shown in Figure 3.4. The menu bar of the summary window is made up of the following menu items.

- File - this menu item invokes a submenu offering commands to create a new care plan, to open an existing care plan, to print a care plan worksheet, to save a care plan and to save a care plan under another name.
- Patient Info. - this menu item invokes a submenu offering commands to enter or edit patient information such as name, age or diagnosis.

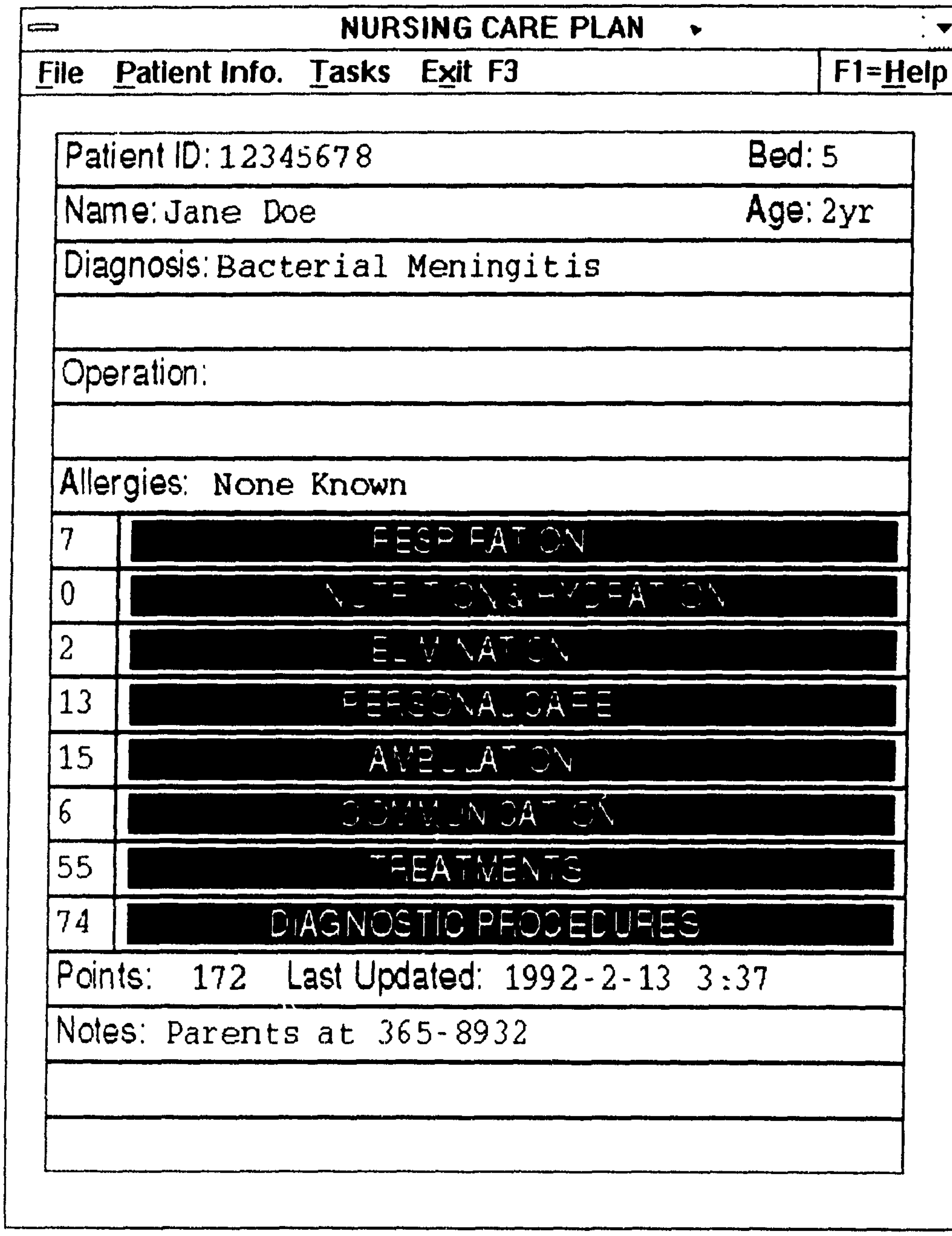

Figure 3.3: Summary window of Nursing Workload Manager module

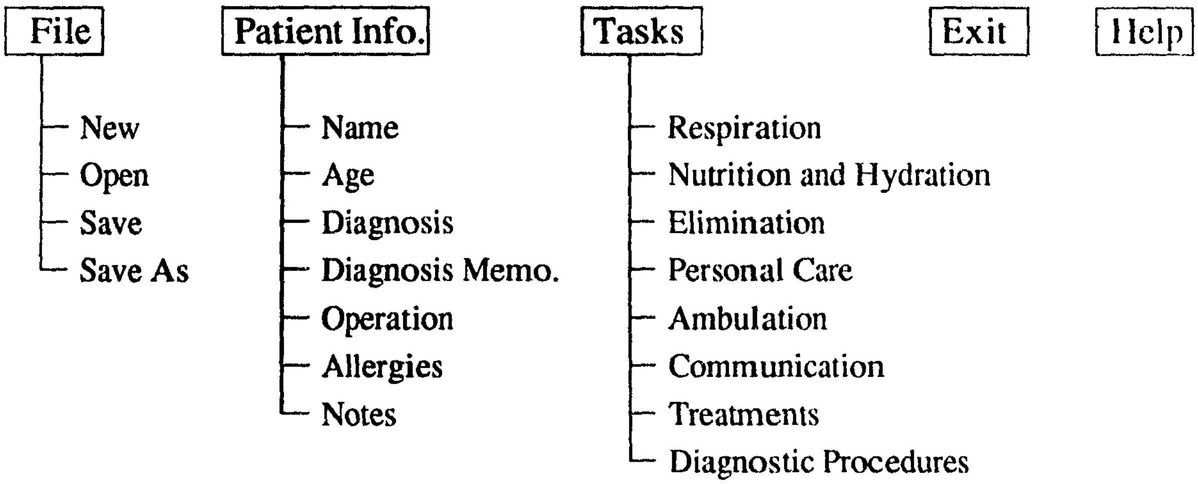

Figure 3.4: Menu layout of Nursing Workload Manager module

- Tasks - this menu item invokes a submenu offering commands to enter or edit task information in any of the eight task categories.
- Exit - this menu item exits the application.
- Help - this menu item invokes the on-line help facility.

3.3.2 Lines of Summary Window

The user creates a new care plan or opens an existing one by pulling down the bf File menu and selecting **New or Open**. Once a care plan has been created or opened, the user can enter information on any line of the summary window The summary window is the main window of the module. When the user selects a line to edit, a dialog box appears. The dialog box may be very simple containing only a heading and entry field, or may contain many controls such as those in Figure 3.5 When the dialog box is closed, the user returns to the summary window The lines from top to bottom are as follows. Figure 3.3 shows the summary window

- Name - the name of the patient.

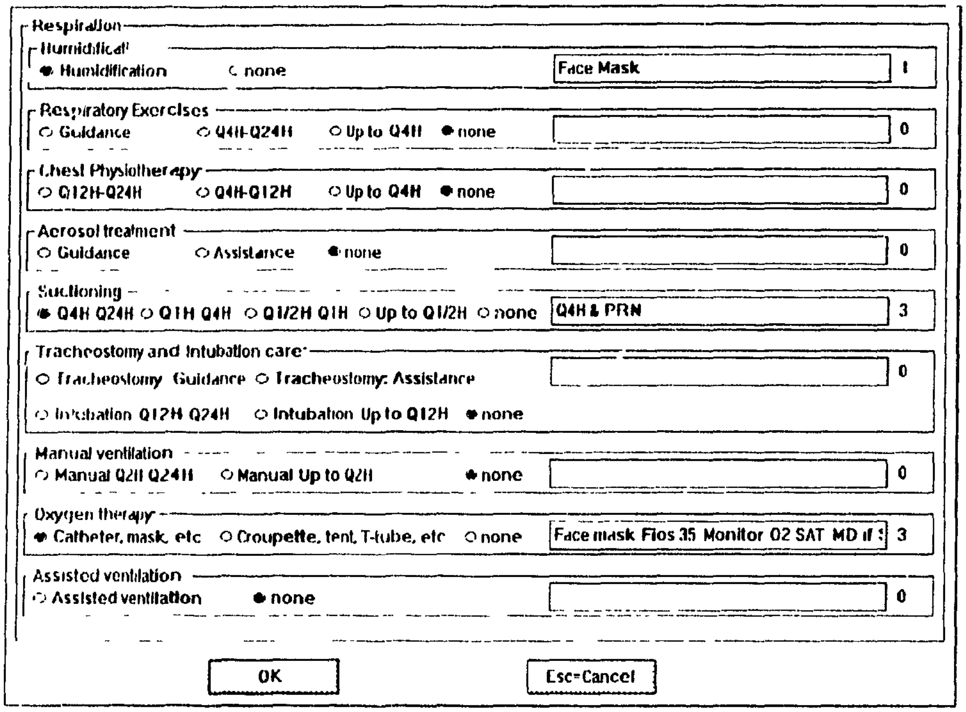

Figure 3.5: Respiration dialog box

- Age - the age of the patient.

- Diagnosis - the medical diagnosis of the patient. This can be entered or selected from a list box. The list box displays the most common diagnoses. At this point the user can elect to load a standard care plan. A general standard care plan or a diagnosis-specific care plan can be loaded. The dialog box used to load a standard plan is shown in Figure 3.27. Under the diagnosis line on the summary window is a free line for a memo note concerning the diagnosis.

- Operation - the operation(s) performed on the patient. Two lines may be used.

- Allergies - the allergies of the patient.

- Respiration - the PRN point total for all respiration tasks appears in the column to the left of the Respiration heading. All the tasks associated with

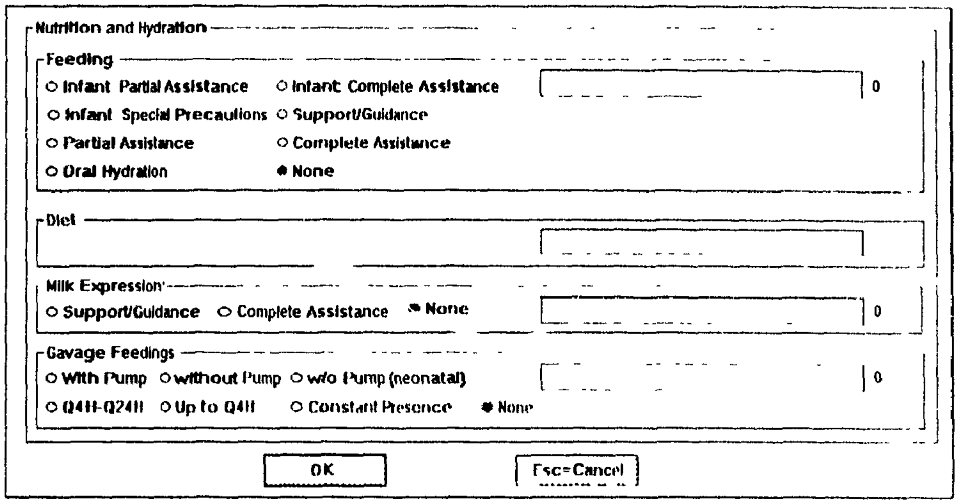

Figure 3.6: Nutrition dialog box

the respiration category are collected in a dialog box. The Respiration dialog box is shown in Figure 3.5. A memo may be entered for each task Depending on the length of the memo, it may not all be shown at once The user uses the arrows keys to travel through the memo field. The PRN points associated with the tasks appear next to the memo field. As radio buttons representing task detail are selected, the PRN point field is updated immediately. The user accesses the dialog box by clicking with the mouse on this line or by using the Tasks menu. Before exiting from the dialog box, the user may accept changes made or may cancel the changes.

- Nutrition and Hydration, Elimination, Personal Care, Ambulation, and Communication - task information in these categories is set up in a similar way to the Respiration dialog box. These dialog boxes are shown in Figures 3.6 to 3.10.

- Treatments - the PRN point total for all treatments appears in the column to the left of the Treatments heading. Task information on treatments is accessed through this line by an intermediate dialog box, shown in Figure 3.11. The intermediate dialog box lists eight sub-categories of Treatments:

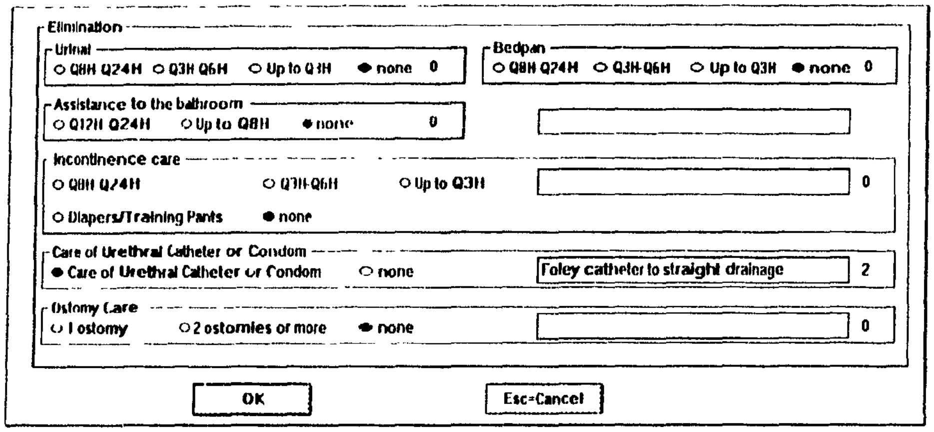

Figure 3.7: Elimination dialog box

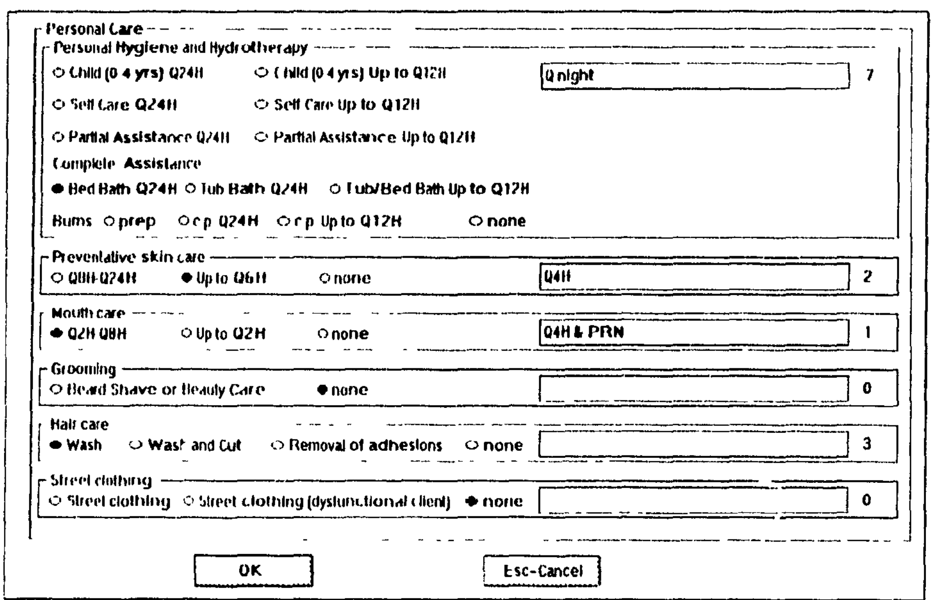

Figure 3.8: Personal Care dialog box

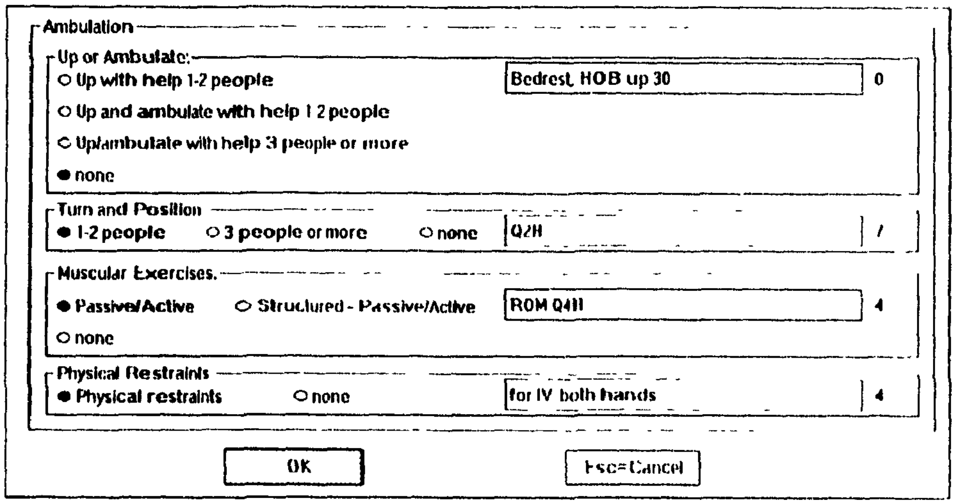

Figure 3.9: Ambulation dialog box

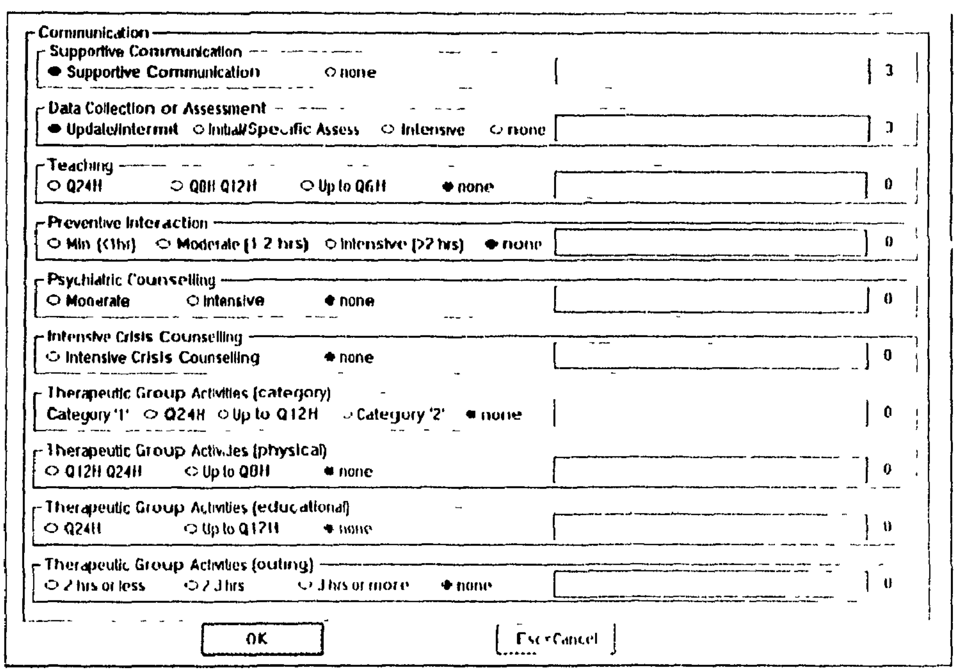

Figure 3.10: Communication dialog box

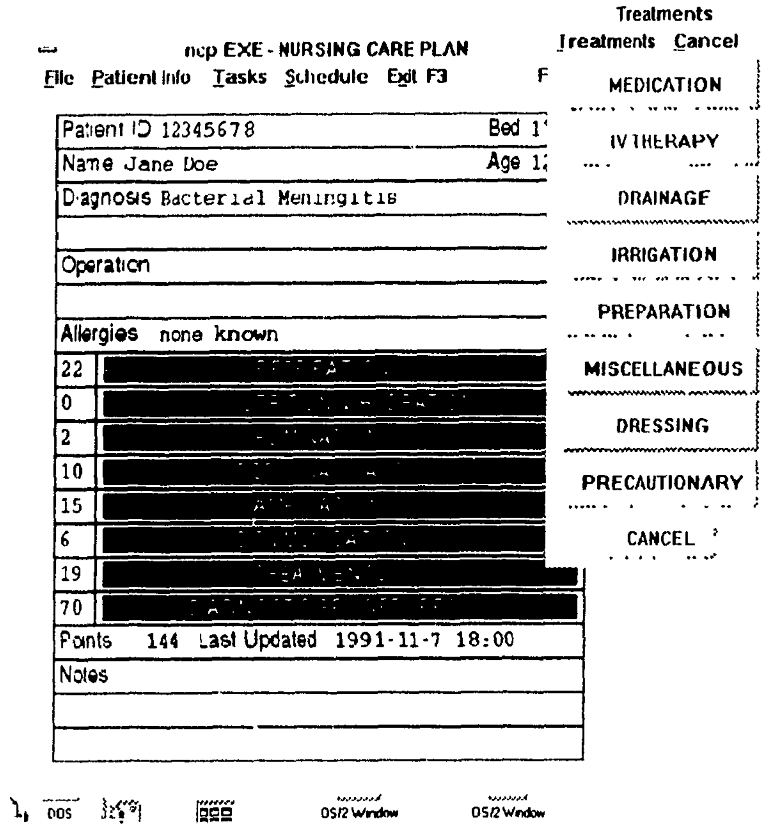

Figure 3.11: Treatments dialog box

Medications, Intravenous Therapy, Drainage, Irrigation, Preparations, Miscellaneous, Dressings and Precautionary Techniques. The user accesses the intermediate dialog box by clicking with the mouse on the Treatments line or by using the Tasks menu. The sub-categories can be invoked by clicking on one of the sub-category push button, or by pulling down the Treatments menu and selecting one of the sub-category menu items. On exiting the sub-category dialog box, the user is returned to the intermediate Treatments dialog box. Figure 3.12 illustrates the sequence of windows that appears in accessing the dialog box "Precautionary Techniques" in the Treatments category. A common memo block of six lines appears in each of the sub-category dialog boxes and it can be edited from any of the Treatments dialog boxes.

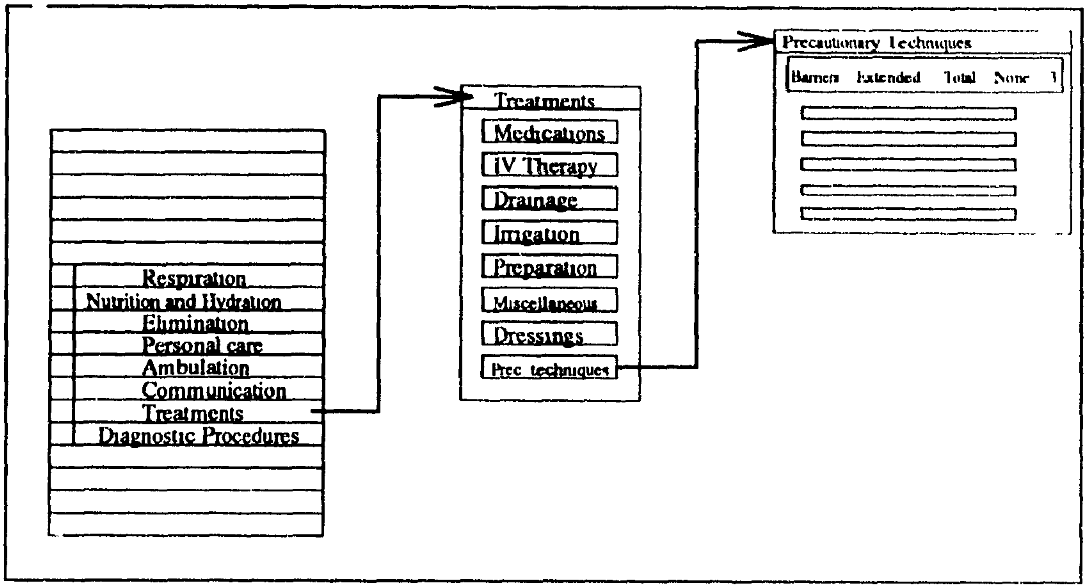

Figure 3.12: Sequence to access dialog box "Precautionary Techniques"

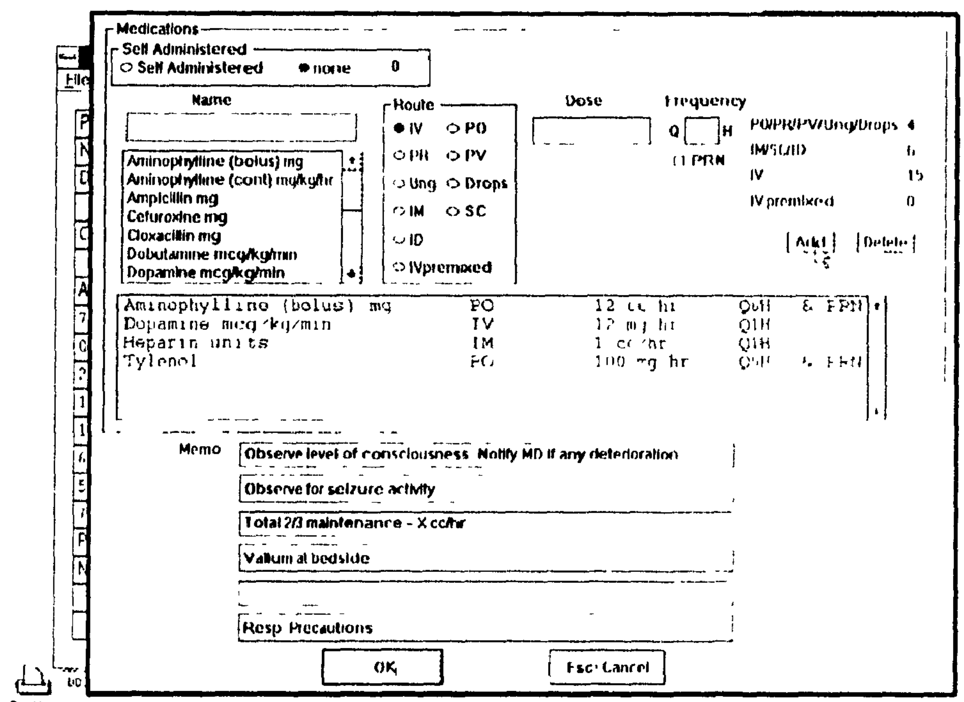

Figure 3.13: Medications dialog box

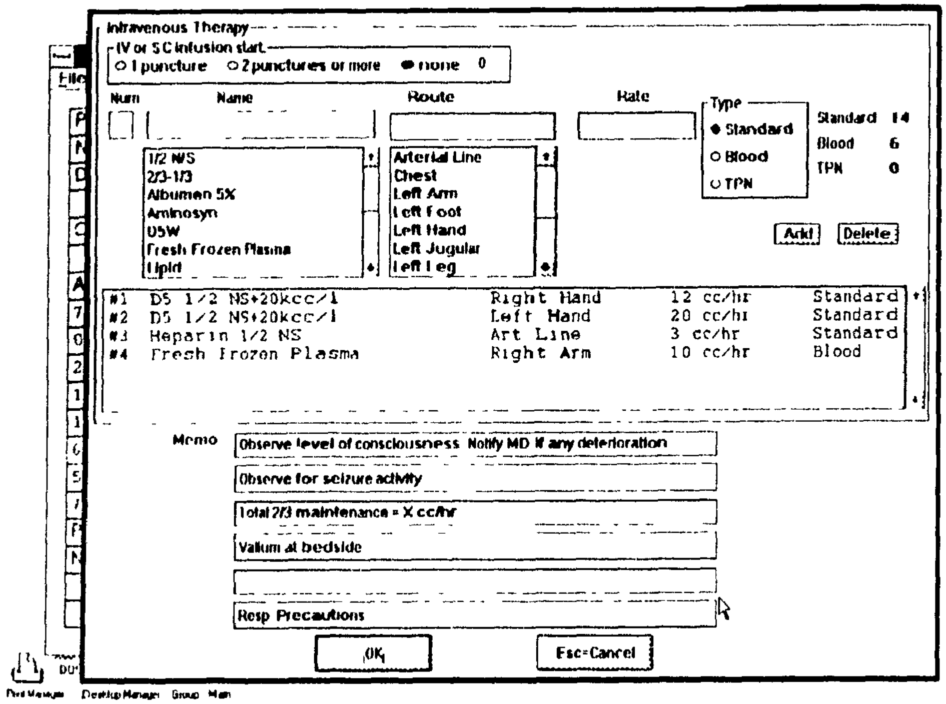

Figure 3.14: Intravenous Therapy dialog box

Medications - the Medications dialog box is shown in Figure 3.13. A medication line is built up by entering the medication name or by selecting one from the name list box, by selecting the route, by entering the dose and by entering the frequency of administration. Once each of the components is specified, the user clicks on the Add push button. The complete line appears in the medications list box. A medication can also be deleted from this list box. To delete, the user highlights the desired line in the medications list box and clicks on the Delete push button.The common memo block is shown below the medications list box. The PRN points for each medication type are shown on the right above the Add and Delete push buttons. They are updated as lines are added to and deleted from the medications list box.

Intravenous Therapy, Drainage, Irrigation, Preparations, Miscellaneous Dressings, and Precautionary Techniques - task information in these categories is set up in a similar way to the Respiration and Medications dialog boxes. The Treatments dialog boxes are shown in Figures 3.14 to 3.20.

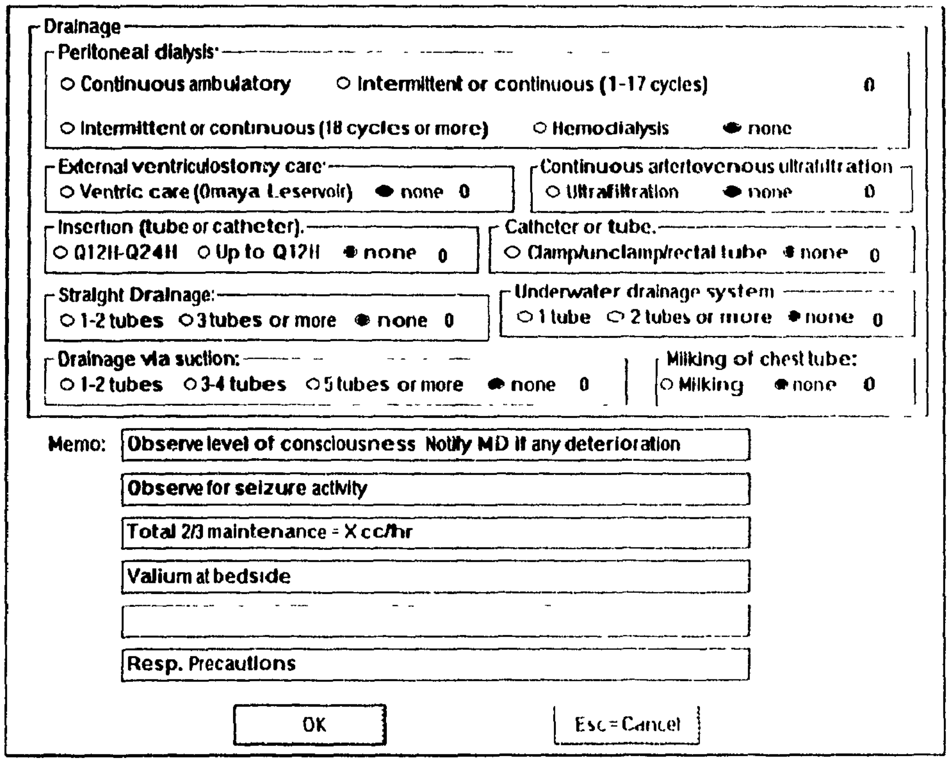

Figure 3.15: Drainage dialog box

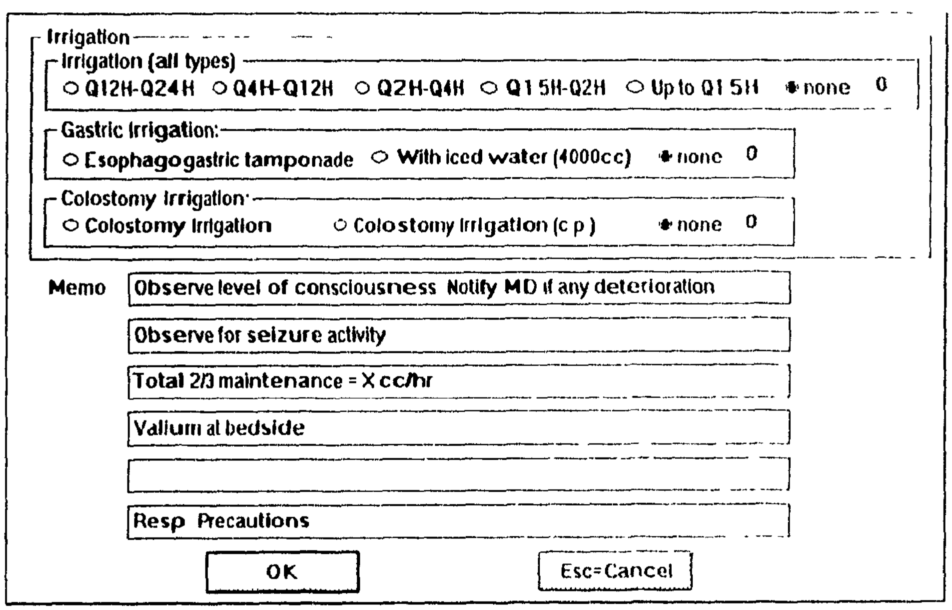

Figure 3.16: Irrigation dialog box

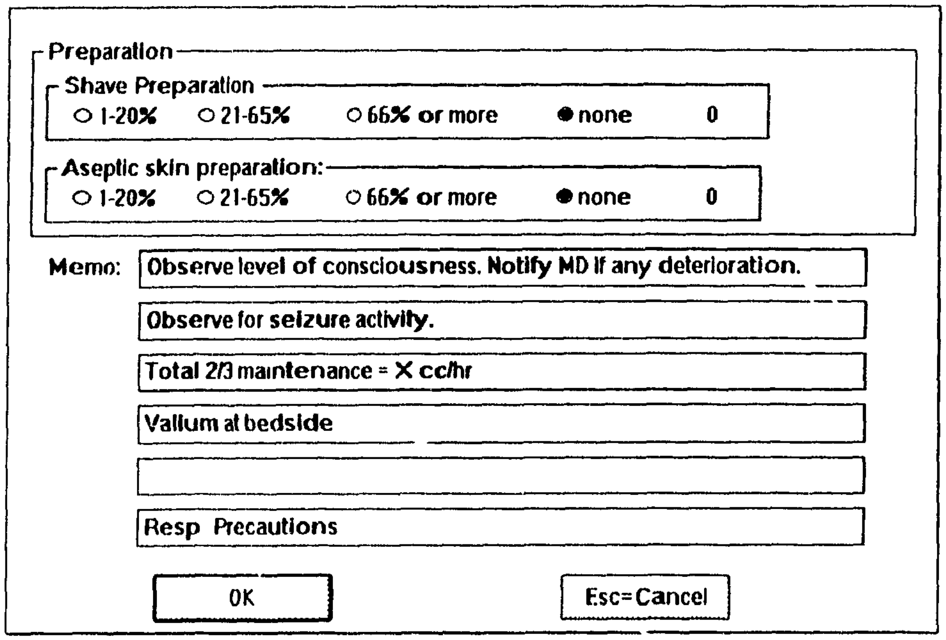

Figure 3.17: Preparations dialog box

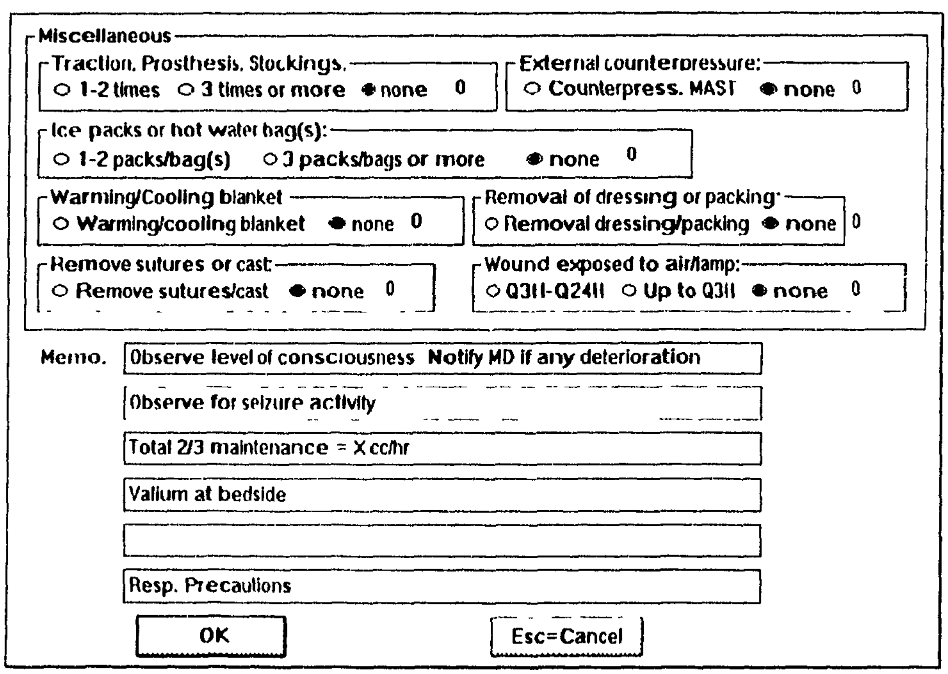

Figure 3.18: Miscellaneous dialog box

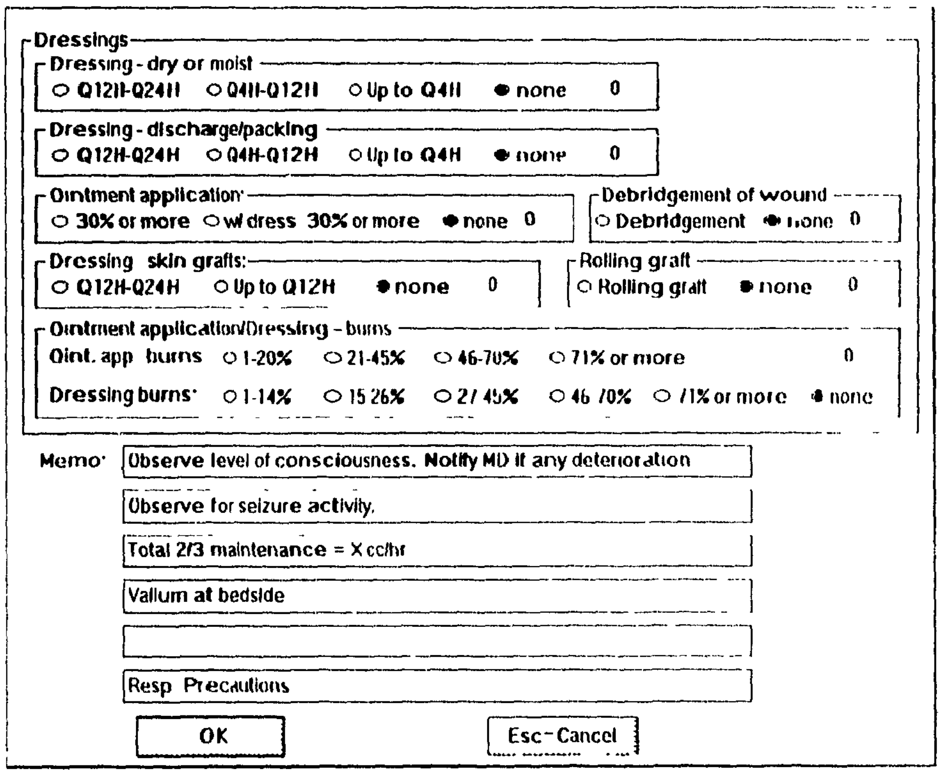

Figure 3.19: Dressings dialog box

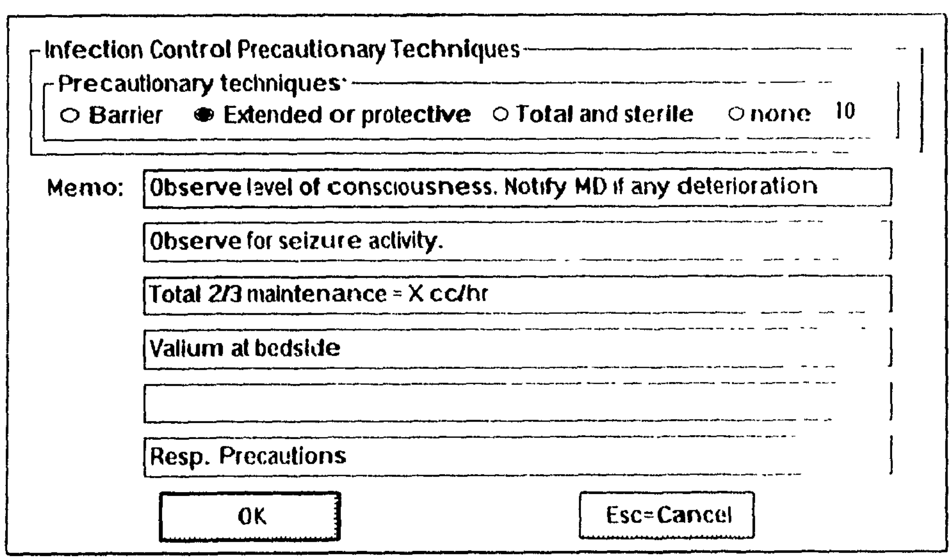

Figure 3.20: Precautionary Techniques dialog box

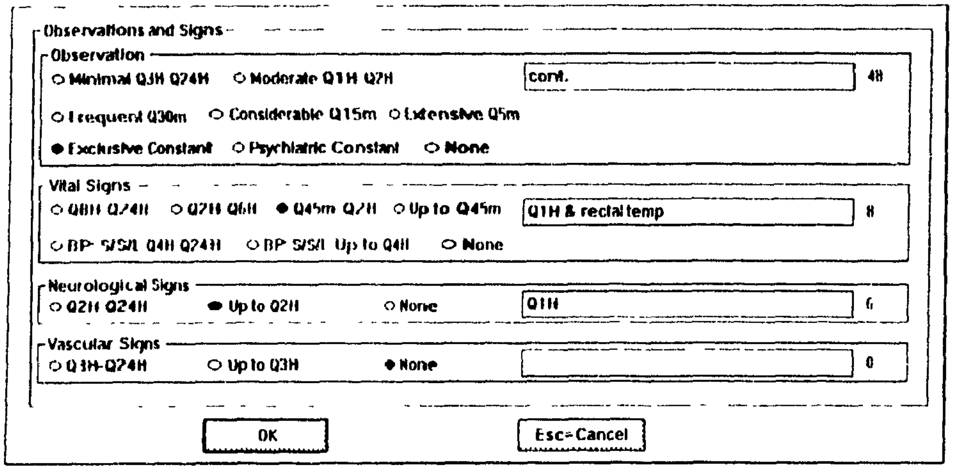

Figure 3.21: Observations and Signs dialog box

- Diagnostic Procedures - diagnostic procedures task information is accessed through this line by an intermediate dialog box. The intermediate dialog box lists four sub-categories of Diagnostic Procedures: Observations and Signs, Pressure Monitoring, Fluid Balance and Investigations.

  Observations and Signs, Pressure Monitoring, Fluid Balance, and Investigations - task information in these categories is set up in a similar way to the Respiration dialog box. These dialog boxes are shown in Figures 3.21 to 3.24.

- Points - the total points derived from the PRN workload measurement system.

- Last Updated - the date and time that the care plan was last saved.

- Notes - free form notes.

3.3.3 Opening and Saving Care Plans

Information entered into the nursing care plan can be saved to disk and later loaded. Text information and the status of the controls, such as radio buttons and check

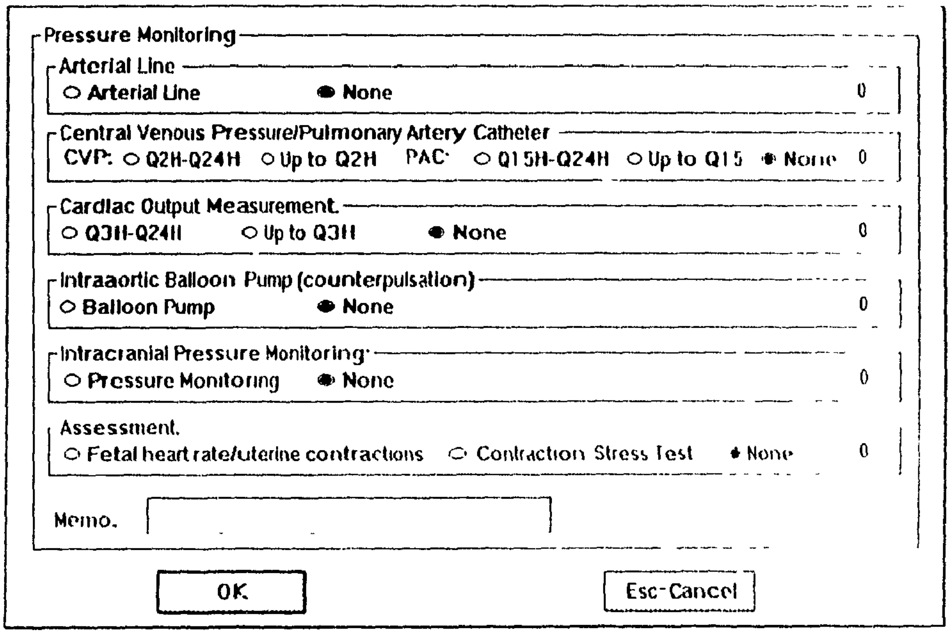

Figure 3.22: Pressure Monitoring dialog box

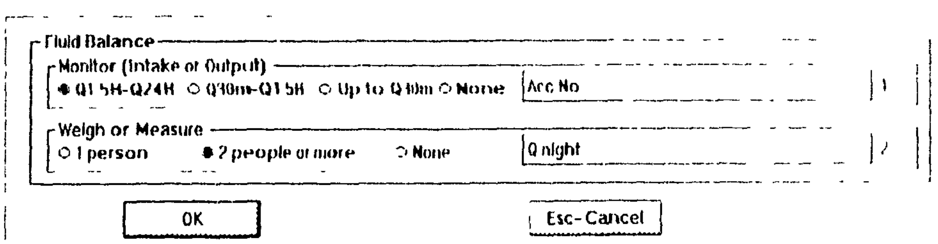

Figure 3.23: Fluid Balance dialog box

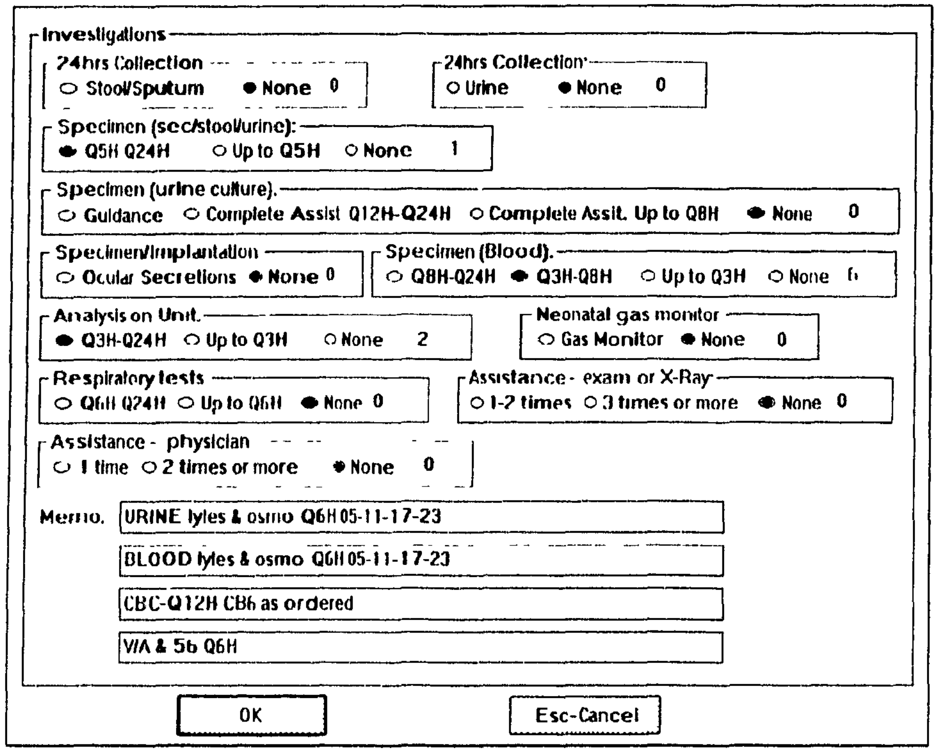

Figure 3.24: Investigations dialog box

boxes are saved. When a user selects the **Open** menu item from the **File** menu, a list of all care plan worksheets on the system is shown. The user can type the name of the care plan into the entry field or select the care plan from the list box. The care plan worksheets are listed alphabetically in the list box. By convention, the filename used to save the care plan is the patient identification number. When a user selects the **Save** menu item from the **File** menu, the care plan is saved under the filename that it was given on its creation or its most recent opening. The user is asked to confirm the save procedure. The care plan may be saved under another filename by selecting the **Save As** menu item from the **File** menu.

3.3.4 Printing

The care plan worksheet can be printed out along with a separate sheet listing the medications and intravenous solutions entered onto the care plan. A sample nursing care plan worksheet has been printed out and is shown in Figures 3.25 and 3.26. Figures 3.25 shows the standard worksheet and Figure 3.26 shows the Medications and IV Solutions list. A task is printed out on the worksheet if it has been selected, or if a memo has been entered. PRN points are printed in the column to the left of the heading. The memo is printed on the same line as the heading. All the Treatment memos are printed in a block at the end of the Treatments section. The Investigation memos are printed in a block at the end of the Diagnostic Procedures section.

3.3.5 Library of Nursing Care Plans

In the Nursing Workload Manager, standard nursing care plans are available for loading and customization. These standard plans represent the usual activities carried out to treat a patient in the PICU. The standard practices are automatically incorporated into the care plan. There is a general plan which lists the typical care provided for every patient in the PICU, regardless of diagnosis. For example, most patients require their vital signs checked every hour, turning and positioning every two hours, skin and mouth care every four hours, and a bed bath every night.

In addition to general activities, there are activities that are standard for certain diagnoses. The nurse may load the general plan or a diagnosis-specific plan. Figure 3.27 shows the dialog box that appears when the user has requested a standard care plan. The diagnosis-specific plans contain the activities required to care for a patient with that medical diagnosis and also the general activities. There is a library of diagnosis specific plans which contains the most common diagnoses. The standard plans can be used as an educational aid to novice nurses. By loading

NURSING CARE PLAN WORKSHEET

Name: Jane Doe **Age:** 2yr
Diagnosis: Bacterial Meningitis
Operation:
Allergies: None Known

RESPIRATION

1 Humidificatn Face Mask

1 [illegible]ctioning Q4H & PRN

1 Oxygen Face mask FiO2 35 Monitor O2 SAT MD if SAT<97

NUTRITION & HYDRATION

[illegible] P.O

ELIMINATION

1 Urethral Care Foley catheter to straight drainage

PERSONAL CARE

1 Hygiene Q night
2 [illegible]kin Care Q4H
1 Mouth care Q4H & PRN
1 Hair care

AMBULATION

[illegible]p with help Bedrest HOB up 30
[illegible]/Position Q2H
1 [illegible] Exercise ROM Q4H
1 Re[illegible]ints for IV both hands

COMMUNICATION

1 [illegible]pportive
1 [illegible]

TREATMENTS

Medications:

4	PO/PR/PV/Ung/Drops	15	IV
6	IM/SC/ID		

Intravenous:

14	IV Therapy (continuous)	6	Blood & Derivatives

10 Precautionary techniques
Observe level of consciousness Notify MD if any deterioration
Observe for seizure activity
Total 2/3 maintenance = X cc/hr
Valium at bedside

Resp Precautions

DIAGNOSTIC PROCEDURES

48	Observation cont
8	Vital Signs Q1H & rectal temp
6	Neuro Signs Q1H
1	Intake/Output Acc No.
2	Weigh/Measure Q night
1	Sec,Stool,Urine
6	Blood
2	Analysis on unit

URINE lytes & osmo Q6H 05-11-17-23
BLOOD lytes & osmo Q6H 05-11-17-23
CBC-Q12H-CB6 as ordered
V/A & 56 Q6H

PRN Points: 172 **Last Updated:** 1992-2-13 3:37
Notes: Parents at 365-8932

L'HOPITAL DE MONTREAL POUR ENFANTS - THE MONTREAL CHILDREN'S HOSPITAL NURSING

Figure 3.25: Print-out of Nursing Care Plan Worksheet

MEDICATIONS AND IV SOLUTIONS

MEDICATIONS

Name	Route	Dose	Frequency	Pts
Aminophylline (bolus) mg	PO	12 cc/hr	Q6H & PRN	1
Dopamine mcg/kg/min	IV	12 mg/hr	Q1H	15
Heparin units	IM	1 cc/hr	Q1H	6
Tylenol	PO	100 mg/hr	Q5H & PRN	3

INTRAVENOUS SOLUTIONS

No.	Name	Route	Rate	Type
#1	D5 1/2 NS+20kcc/1	Right Hand	12 cc/hr	Standard
#2	D5 1/2 NS+20kcc/1	Left Hand	20 cc/hr	Standard
#3	Heparin 1/2 NS	Art Line	3 cc/hr	Standard
#4	Fresh Frozen Plasma	Right Arm	10 cc/hr	Blood

L'HOPITAL DE MONTREAL POUR ENFANTS - THE MONTREAL CHILDREN'S HOSPITAL NURSING

Figure 3.26: Print-out of Medications and IV Solutions chart

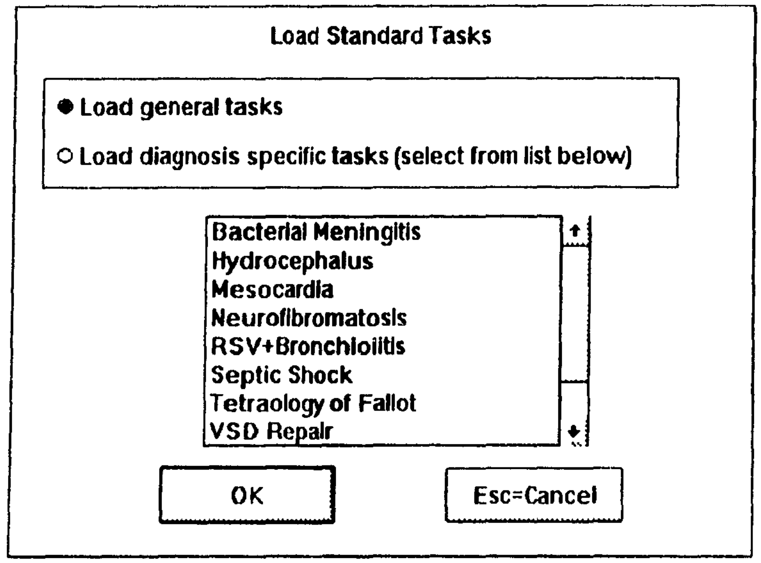

Figure 3.27: Dialog box to load a standard care plan

a standard plan the patient has access to institutional standards of care.

Chapter 4 Implementation, Results and Future Work

This chapter begins with a description of the implementation of the Nursing Workload Manager module. The file layout, the Help utility, error messages and the printing procedure will be briefly outlined. The second section discusses the evaluation process applied to the module and presents results of an on-site user group evaluation. In the final section, ideas for future work on the module will be discussed.

4.1 Implementation

4.1.1 Files

The Nursing Workload Manager module was implemented under the OS/2 Presentation Manager environment version 1.3 using the Microsoft C compiler, version 6. The source code is made up of 22 C program files with a total of approximately 8000 lines of code. The code is broken into functional blocks. Figure 4.1 shows a layout of the files. The size of the executable file is 130 kilobytes.

- **ncp.c** contains the main procedure. It creates the message queue and sets up the summary window. It controls program flow through menu selections or cursor position. It tracks the cursor or mouse pointer over the summary window. When the mouse is clicked, it determines where the mouse is and which dialog box is being invoked.
- **ncpmenu.c** contains procedures to handle the specifics of the menu selections
- **ncputil.c** contains general utility procedures.

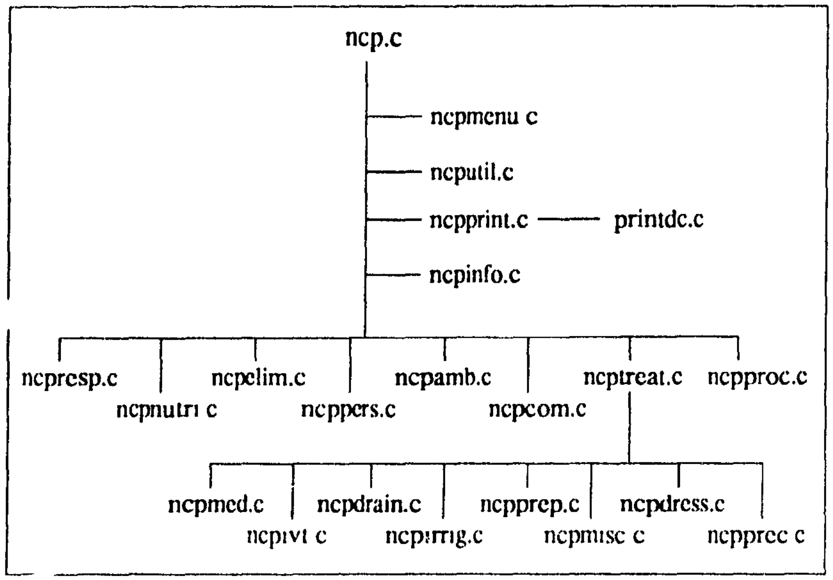

Figure 4.1: C program files

- **ncpprint.c** and **printdc.c** contain procedures to set up the printing routines and to print the Nursing Care Plan Worksheet and the Medications and IV Solutions chart.

- **ncpinfo.c** contains procedures to create the patient information dialog boxes and to process data entered into them.

- **ncpresp.c** contains procedures to create the respiration task dialog box and to process data entered into it.

- **ncpnutri.c, ncpelim.c, ncppers.c, ...,ncpprec.c** contain procedures to create their respective task dialog boxes and to process data entered into them.

In addition to the C files, the application is made up of resource files, dialog files and header files. Resource files are not part of a program source code They occupy read-only data segments and help to improve memory efficiency. A resource file is a separate text file that is compiled into binary form by a resource compiler and added to the application's executable file. An advantage to placing data in a resource file is that changing the resource does not require recompilation of the source code. Typical information stored in a resource file is static window text, dialog box text, menu items and text that is language specific. Dialog files are resource files containing a description of a dialog box. They are included either inside the resource files or are called from it. As much as possible, the dialog boxes were designed to conform to CUA guidelines.

Care plans saved to disk have an extension of ".wks". The data is stored in the file in a structured way. Tables 4.1 and 4.2 show the file structure. There are utility procedures to open the file and read the contents into the variables and data structures used in the care plan application. Likewise there are utility procedures to save the care plan by writing to a file the contents of the variables and data structures. Library files are saved with an extension of ".lib".

4.1.2 Help and Error Messages

An on-line help system has been implemented. The help system follows the CUA guidelines and uses the IPF facility of the Presentation Manager. The Help menu has the following menu items: Help for Help, Extended Help, Keys help, and Help index. Figure 4.2 shows the help system being accessed from the summary window. The Help window can remain open throughout the operation of the application. It can be moved around the screen, be resized and be iconized. The user views the information in the help window by scrolllling the text with the vertical scroll bar.

Safeguards have been implemented to prevent the user from entering information until a new or existing care plan has been opened and to prompt the user to save the care plan if changes were made since the last save. The prompt appears when another care plan is to be opened, or the application is being exited.

The user's input is monitored for errors where necessary. In the Medications and Intravenous Therapy dialog boxes, shown in Figure 3.13 and 3.14, the user must enter a valid input into all the fields to build up a medication line or an

Line No.	Description	No. of chars.
1	Patient ID	8
2	Bed No.	2
3	Name	30
4	Age (including: m or yr)	4
5	Diagnosis	36
6	Diagnosis memo	44
7	Operation line 1	36
8	Operation line 2	44
9	Allergies	36
10*	Treatments-Medications Points	1,2 or 3
10*	Treatments-IV Therapy Points	1,2 or 3
10*	Treatments-Drainage Points	1,2 or 3
10*	Treatments-Irrigation Points	1,2 or 3
10*	Treatments-Preparation Points	1,2 or 3
10*	Treatments-Miscellaneous Points	1,2 or 3
10*	Treatments-Dressings Points	1,2 or 3
10*	Treatments-Precautionary Techniques Points	1,2 or 3
11*	Diagnostic Procedures-Observations and Signs Points	1,2 or 3
11*	Diagnostic Procedures-Pressure Monitoring Points	1,2 or 3
11*	Diagnostic Procedures-Fluid Balance Points	1,2 or 3
11*	Diagnostic Procedures-Investigations Points	1,2 or 3
12	Respiration Points	1,2 or 3
13	Nutrition and Hydration Points	1,2 or 3
14	Elimination Points	1,2 or 3
15	Personal care Points	1,2 or 3
16	Ambulation Points	1,2 or 3
17	Communication Points	1,2 or 3
18	Treatments Points	1,2 or 3
19	Diagnostic Procedures Points	1,2 or 3
20	Total PRN Points	1,2,3 or 4
21	Date and Time of Last Update	16
22	Notes line 1	38
23	Notes line 2	44
24	Notes line 3	44
25*	Task ID	3
25*	Task PRN Points	1 or 2
26	Task memo	47
	(lines 25 and 26 are repeated for each task)	

* = more than one item in the line. Each item is separated by a blank space

Table 4.1: File Structure

Line No.	Description	No. of chars
223*	Task ID	3
223*	Task PRN Points	1 or 2
224	Task memo	47
225	Treatments memo line 1	65
226	Treatments memo line 2	65
227	Treatments memo line 3	65
228	Treatments memo line 4	65
229	Treatments memo line 5	65
230	Treatments memo line 6	65
231	Diagnostic Procedures-Investigations memo line 1	65
232	Diagnostic Procedures-Investigations memo line 2	65
233	Diagnostic Procedures-Investigations memo line 3	65
234	Diagnostic Procedures-Investigations memo line 4	65
235	Number of Medications = m (Number of lines to follow is equal to number of Medications)	1 or 2
236*	Medication name line 1	30
236*	Medication route line 1	10
236*	Medication dose line 1	12
236*	Medication frequency line 1	5
236*	Medication PRN tag line 1	5
236*	Medication points line 1	2
236+m	Number of IV Solutions	1 or 2
237+m	Number of IV Solutions - continuous	1 or 2
238+m	Number of IV Solutions - blood products	1 or 2
239+m	Number of IV Solutions - TPN	1 or 2
	(Number of lines to follow is equal to number of IV Solutions)	
240+m*	IV Solution number	3
240+m*	IV Solution name	30
240+m*	IV Solution route	15
240+m*	IV Solution rate	12
240+m*	IV Solution type	8

* = more than one item in the line. Each item is separated by a blank space

Table 4.2: File Structure, cont

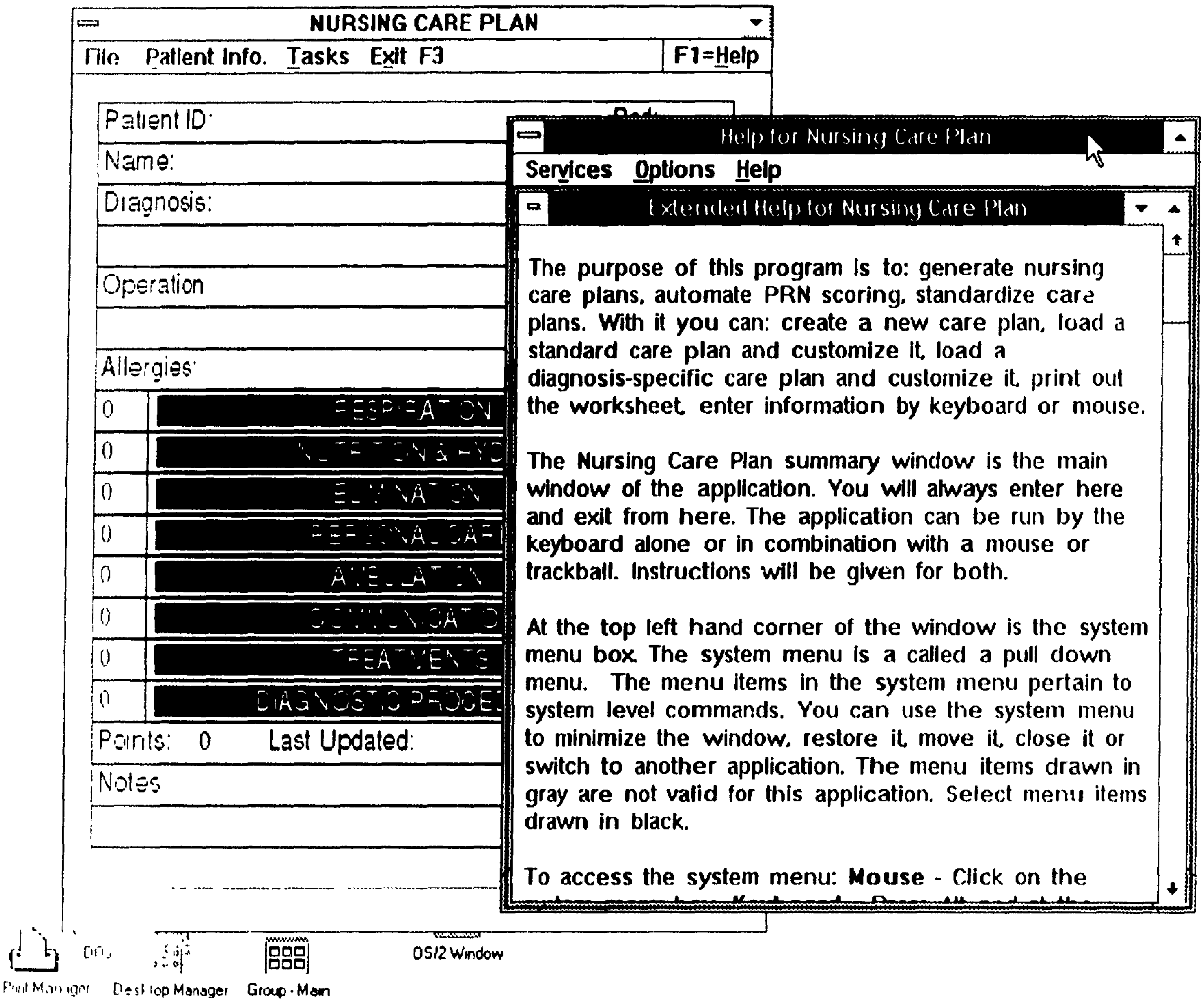

Figure 4.2: Help Utility

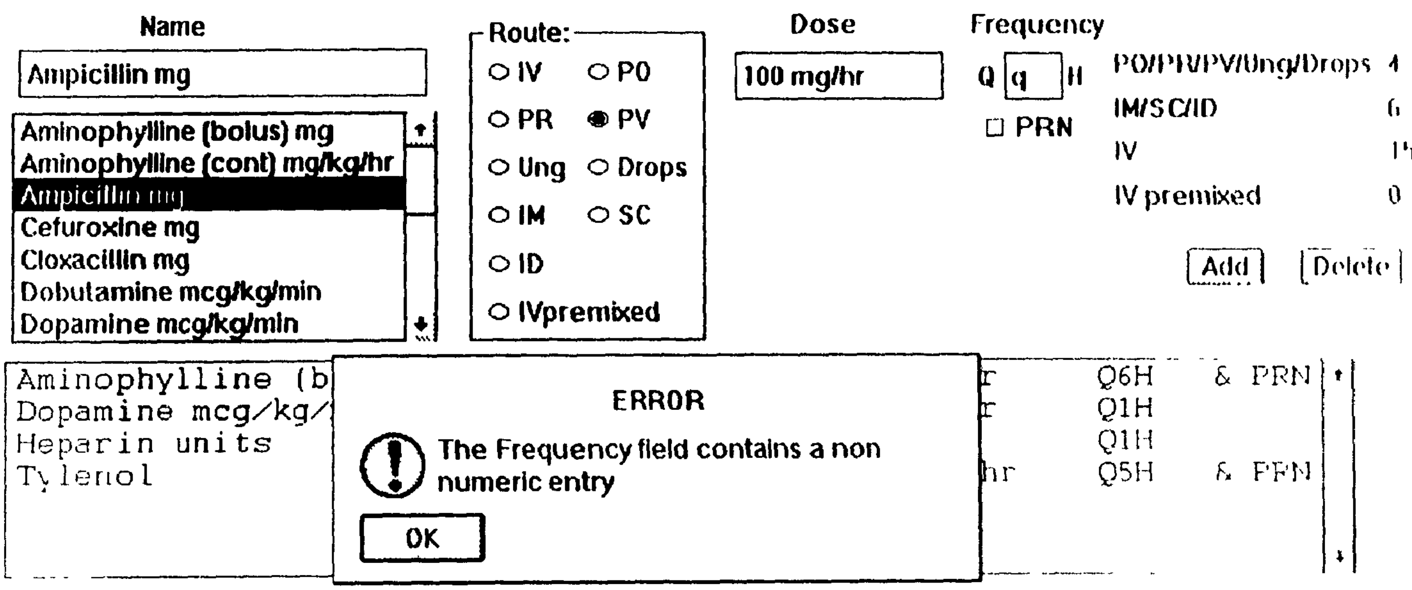

Figure 4.3: Frequency error message in Medications dialog box

intravenous solution line. An error message will appear if the user has not entered a value into one of the medication line component fields or if the frequency is non-numeric. For example, the user would receive an error message upon entering the letter "q" in the frequency field. Figure 4.3 shows this error message

4.1.3 Printing

The application uses a second thread to print the nursing care plan worksheet The second thread is created so that the user can continue to interact with the system during printing. The special multithread library of Microsoft C is used. On an IBM PS/2 Model 80 (80386 based machine with 8 MBytes of RAM) with the Nursing Workload Manager running it takes about 5 minutes to print the worksheet on an EPSON 24 pin letter quality printer.

The print routine queries the OS2SYS.INI file (described in section 3.2) for the name of the default printer, and subsequently extracts the specifications of the printer from the printer driver. The print-out is divided into cells. For instance, the nursing care plan worksheet is divided up into a matrix of 2 by 50 cells. The cell size is used to set the size of the character font and to position text. The page size of the printer is used to calculate the cell size. The font type and size vary according to the function of the text. the headings are in bold proportional font with a character height of 90% of the cell height. The task information is printed in smaller fixed font. By basing the cell size and font size on the dimensions of the printable area of the page, the application can print to any printer with an IBM OS/2 print driver. The nursing care plan worksheet was printed on an EPSON 24 pin letter quality printer and an Apple LaserWriter II postscript printer. The only difference in the outputs was in the font size. The change in appearance was minimal. With the Graphics Programming Interface of OS/2 the printer graphics routines can be tested on the display prior to printing.

4.2 Evaluation

The first implementation of the Nursing Workload Manager module (designed and developed by the author) consisted of a full screen replica of the Nursing Care Plan Worksheet, see Figure 2.3. The user scrolled through the care plan to access the different sections of it. It was approximately two and a half screens long. The section or category headings were sensitized to invoke their respective dialog boxes. For example, the Respiration category heading invoked the Respiration tasks dialog box. At that time, only the Respiration dialog box was fully implemented. The tasks in the dialog box were set up as described in the PRN scoring sheet. The task selected, along with points and memo, appeared on the screen line when the dialog box was closed.

This preliminary version was demonstrated to a nurse (Assistant Director of Nursing and Coordinator of PICU and Nursing Information Services) and a physician (Acting Director of the PICU) in the research lab at the University The nurse and physician are both collaborators on the PDMS research project, and the nurse is also a collaborator on the Nursing Workload Manager module research. Their evaluation was positive, but pointed out shortcomings of the application They found travelling through the care plan cumbersome and found it difficult to navigate. Also the keyboard could not be used to fully operate the module; a mouse was necessary for some operations The inability to view the whole care plan at one time made it difficult to assess the patient and identify omissions in the care plan.

They liked the concept of clicking on a sensitized category heading to open up to the details in a dialog box. Though, the nurse did not feel comfortable with the way the tasks had been described in the Respiration dialog box. It seemed that the nurses describe the tasks in another manner on the care plan, and then when scoring the care plan with the PRN scoring sheet find the appropriate match

Subsequently, the second version described in this report was developed to address these issues. A small summary window was created that occupies less than 50% of the screen Pull down menus with mnemonics, keyboard accelerators and control keys were fully employed to allow the user to operate the module without a mouse, if desired. The summary window allows the user at a glance to evaluate the state of the patient care and the severity of the illness and condition by showing the PRN category sub-totals and PRN total

In the implementation of the second version, there was a focus on evaluating the application concurrently with its development. A Presentation Manager screen capture facility made it possible to capture all or selected portions of the screen In this way, printed copies of the user interface screens could be shown to the staff at the hospital without the burden of them visiting the research lab In the final few months, it was possible to present demonstrations of the module due to an upgrade in software at the Hospital. Both the printed version and the demos were very valuable for eliciting feedback and fine tuning the application. The final evaluation was conducted by a team of potential users who had not been part of the application's design or development, and the head nurse. Results of this evaluation are presented in section 4.3.

In implementing the second version, goals were set for delivering a working system. The first goal was to present a system in which a care plan could be manually created. This offered the benefits of easier editing and automated scoring. It was possible to print out the worksheet. The second goal was to automate the generation of the care plan for common diagnoses. This improved the speed of creation of care plans, improved the quality of the care plan and acted as an educational aid to novice nurses. All these goals were met.

4.3 Results

An evaluation session was held at the hospital and attended by the author, the collaborating nurse, the assistant head nurse and two staff nurses. The assistant head nurse and the two staff nurses all have approximately the same number of years of experience. The assistant head nurse had a Bachelor's degree in nursing and the staff nurses had CEGEP degrees. The youngest was 32 years old and the eldest was 36 years old. An overview of the goals of both the PDMS research project and the Nursing Workload Manager research project was presented. The prototype of the module was then demonstrated.

During and after the demonstration, there were a lot of questions and discussion. Problems were pointed out and improvements suggested. Issues concerning the logistics of installing such an application in the PICU were brought up. Physical problems, resistance to change and computer illiteracy were mentioned. Though the PDMS has been in development for a number of years it runs in the hospital as a prototype and is installed outside the PICU in an adjacent room. Most of the nursing staff have not been exposed to it. Prior to the end of the evaluation session a user evaluation form was handed out. The user evaluation form is shown in Figure 4.4. The evaluation form is made up of multiple choice questions and free-form answer questions. The first three questions were designed to assess the evaluator's attitude towards computers in nursing. The next four were designed to assess the evaluator's comfort and knowledge of computers, and the remaining three multiple choice questions were designed to assess the evaluator's opinion of the application.

All of the three evaluators had positive attitudes towards computers in nursing. Only one of the evaluators felt comfortable using a computer, and was familiar with word processing. They were uncertain of the usefulness or ease of use of the Nursing Care Plan (NCP) application, but all agreed that with some practice they would be comfortable using the application.

When asked, "What seemed the most complicated or confusing in the NCP application?", all evaluators mentioned the Respiration and similar dialog boxes The Respiration dialog box is shown in figure 3.5. They felt that there was too much information shown at one time. Another criticism was the lack of instruction in the dialog box itself. Any experience the two novice computer users had had with computers was form fill-in where instructions were written next to the entry field and the user had to follow an order of entry. Having a separate help facility did not satisfy them. Also, the menu bar along the top of the window did not coincide with their exposure to main-frames with function keys along the bottom of the screen The print-out prompted comments about the use of colour or bolding to highlight subheadings and important information. For instance, they thought it would be good to have allergies appear in red.

In answer to, "What seemed the easiest to learn and perform in the NCP application?", the unanimous reply was the entry of medications and intravenous solutions in the Medications dialog box (Figure 3.13) and the Intravenous Therapy

NCP - USER EVALUATION FORM

SA = Strongly Agree, A = Agree, U = Uncertain, D = Disagree, SD = Strongly Disagree.

Computers will allow nurses more time for the professional tasks for which they are trained.	SA	A	U	D	SD
Computers make nurses' jobs easier.	SA	A	U	D	SD
Computers take jobs away from nurses.	SA	A	U	D	SD
I am comfortable using a computer.	SA	A	U	D	SD
I am comfortable using a word processor to generate documents.	SA	A	U	D	SD
I am comfortable using a database package.	SA	A	U	D	SD
I have knowledge of the basic components of the computer's operating system.	SA	A	U	D	SD
The NCP application was easy to use.	SA	A	U	D	SD
The NCP application produces correct results.	SA	A	U	D	SD
After some practice I would be comfortable using the NCP application.	SA	A	U	D	SD

What seemed the most complicated or confusing in the NCP application?

____

____

What seemed the easiest to learn and perform in the NCP application?

____

____

Which entry method did you like best or use the most in the NCP application?

____

____

Additional Comments:

____

____

Age ______ Sex: Female ________ Male ________

Years worked as a nurse: ________ Highest degree obtained in nursing: ______________

Figure 4.4: User Evaluation Form

dialog box (Figure 3.14). The list box showing the names of common medications and intravenous solutions was liked. They suggested the other dialog boxes be redesigned to look more like the Medications and Intravenous Therapy dialog boxes. They felt that the procedures to verify data were important, and liked the idea of having an escape mechanism in case of error.

Two entry methods can be used to operate the NCP application. The demonstration was first done using only the keyboard. The evaluators found it difficult to navigate through the dialog boxes and found the cursor hard to follow. In Presentation Manager the cursor appears as a gray outline over push buttons, list box items, radio buttons, menu items and check boxes, and as a straight vertical line in entry fields.

The mouse was used in a second demonstration after comments on the first demonstration had been recorded. Operating the application with the mouse was much preferred to operating it solely with the keyboard. Mouse operation was found to be more intuitive as less time was spent planning operations

4.4 Discussion and Future Work

The most interesting aspect of the Nursing Workload Manager to these evaluators was the ability to integrate information from different applications In the manual method they have to duplicate much information. To be able to enter the information once and have it appear in all necessary charts appealed to them

A point to consider with these evaluators was their nursing experience Loading standard plans seemed a limited benefit. They can generate a manual care plan very quickly and know the standards very well. With evaluators with less nursing experience, the care plan generation feature would be more important. They found the automated PRN scoring valuable. They resent the time they spend manually scoring their care plans.

The comments by the evaluators on colour coding the print-out of the NCP application implied that once they had entered a care plan on the computer, they would use the paper version as their working copy. This highlights the culture change that is required for nurses to work with computers. They view the personal computer as a device used to produce documents, not as a partner in patient care.

Using the keyboard alone does not do justice to the Presentation Manager graphical user interface. Although, the NCP application can be operated by the keyboard alone, its most natural and easy interaction is with the keyboard-mouse combination. A user with knowledge of computers and of the application can perform operations very quickly by using the keyboard to access menu items and invoke dialog boxes, but slows down considerably when using the keyboard to perform operations inside the dialog boxes, such as changing the state of a radio button or selecting an item from a list box. These operations are performed more quickly by using the mouse By providing both entry methods in the user interface, users can choose the entry method most comfortable to them and most appropriate for the operation they are performing. A user uncomfortable with a keyboard can use the mouse for all operations except for the entry of alphabetical information, such as the patient's name.

Ideally the Nursing Workload Manager module should have more than one interface or allow for variations of a single interface. As discussed in the section on user interaction in chapter 1, section 1.1.4, the novice user has different preferences and needs than the frequent or expert user. When the module is first installed in the unit, most users will be novices. This will have an impact on the design of the user interface. The user will want to be lead through the application and be asked to perform fully defined actions. As the user's computer skills grow and the user becomes familiar with the application, a tight structure or flow will no longer be necessary. The desire for speed will outweigh concerns over lack of control. The level of computer anxiety will have decreased and users will have learnt how to manage errors. At this stage it would be advantageous to have a less directional interface, giving the user more freedom and choice.

Evolving the user interface as the user skills develop has benefits, but would be difficult to manage in the PICU environment. As a teaching hospital, student nurses rotate through the unit as do float nurses. Float nurses temporarily fill a vacant position for as little time as one shift. There would always have to be a novice user interface for these nurses. A solution is to provide a user interface with different modes or levels. The user could select one of three modes: novice, intermediate or expert. The novice mode would offer the user less choices at one time and structure the flow through the application. Feedback on the user's actions would inform the user, and error messages would be more detailed The expert mode would allow the user more freedom and would be less verbose in its feedback. The evaluation session emphasized the importance of not overestimating the computer aptitude of a group nor the intuitiveness of the interface

Future work in the Nursing Workload Manager module will consist of building the workload scheduler and creating links to the other modules of the PDMS The challenge lies in building a scheduler that can update its schedule dynamically and reflect on-going changes in the care plan The dynamic data exchange capabilities of OS/2 will make linking to other modules possible The results of the evaluation session showed there is merit to revising the user interface of the nursing care plan generator.

An on-line reference system would be a useful addition to the Nursing Workload Manager module. It could store information about medications, such as weight dependent drug dosages, interactions and appropriateness of prescriptions. A CD-ROM (compact disc read only memory) drive unit can be attached to the IBM PS/2 and reference compact disks are widely available

The library of nursing care plans described in section 3.3.5 is fairly small. Adding plans to the library requires some knowledge of operating system functions, such as editing and renaming, and some knowledge of Presentation Manager and C to update the library calling procedure. The user of the Nursing Workload Manager module though able to operate the module, may not be able to carry out the tasks required to put a new plan in the library. A library utility would be useful.

The library utility would allow the user to create a care plan as usual in the Nursing Workload Manager and then import it to the library with the required modifications automatically done. The difference between a patient care plan and a one in the library is the block of patient information. For example, the library plan does not contain the patient id, bed number or patient name fields. Implementation of a library utility would also entail the generalization of the library calling procedure.

It would be valuable to add a preview option to the library of nursing care plans. This would allow the user to preview a care plan in the library prior to loading it into the care plan being edited. Also, the ability to merge care plans from the library would be very useful in the cases of multiple diagnoses At this time, the user can only load one library care plan. A subsequent selection from the library clears the task portions of the care plan being edited and loads the newly selected care plan.

The help facility does not include hypertext indexing. This would enhance the help facility. Hypertext is a class of software that provides the capability to browse documents through a network of links [Haan *et al.*, 1992]. These links can be defined by the program developer or dynamically by the user.

The existing file structure is unwieldy and requires some acquaintance with the file saving and loading procedures. The loading and saving are fast, but in consideration of long term software maintenance there are advantages to using a relational database. Future work envisages a relational database to store all the care plan information. This would allow the information to be easily used by other applications, and offers some protection from inadvertent deletions and directory movement.

Care plans can be saved to disk and later loaded. There is no audit trail recording changes made to the care plan. This may lead to legal problems One solution is to use the print-out of the nursing care plan worksheet as the official copy. When a change is made, the care plan worksheet would be printed out and would supersede the previous print-out The worksheet shows a date and time stamp. A field could be added to hold the name or initials of the person who made the change. This solution, though, takes away from the idea of having the nurses use the screen version of the worksheet as their reference. It encourages the proliferation of many print-outs. Another solution would be to archive the care plan after each save operation. Backup copies would be available for reference if required, but could be downloaded to a mass storage device.

Chapter 5 Conclusion

In this thesis a Nursing Workload Manager module for a patient data management system was presented. The module is part of a system under development in the pediatric intensive care unit at the Montreal Children's Hospital. Current literature in the fields of patient data management systems, nursing care plans, nursing workload measurement systems and system evaluation is surveyed and discussed. The literature survey is followed by an overview of the functioning of an intensive care unit. The functionality of the Nursing Workload Manager is presented. The IBM OS/2 operating system and the Presentation Manager graphical user interface are described. This is the environment under which the module was developed. The user interface is described with figures illustrating the screen displays and print-outs.

The software implementation of the module is summarized. The file layout and structure is explained, along with the on-line help utility and error messages. The evaluation procedure applied to the module is described, and results of a user evaluation session are discussed. Finally, future work on the Nursing Workload Manager module is suggested.

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