A Computerized Nursing Workload Management System in a Pediatric ICU

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Abstract

This thesis presents a computerized nursing workload management system developed as part of the Patient Data Management System (PDMS) for the Pediatric Intensive Care Unit of the Montreal Children's Hospital. The objective of the Nursing Workload Management System (NWMS) is primarily to reduce the workload of nursing staff by automating the preparation of nursing care plans, generating schedules for the tasks in the plan of care, and providing an audit trail facility to annotate the care delivered to a patient.

The thesis begins with a literature review of contemporary computerized medical information systems followed by an overview of the PDMS. A description of the design and implementation of the Nursing Workload Management System of the PDMS is followed by evaluation and performance results of the system. The evaluation of the performance results is encouraging and further on site testing of the NWMS is recommended. Finally, an outline of future extensions for the system is included.

Sommaire

Cette thèse présente un système de gestion informatisé de quantité de travail d'infirmières, développé comme partie du "Système de Gestion de Données Des Patients" (SGDP) pour l'Unité de Soins Intensifs de Pédiatrie de l'Hôpital des Enfants de Montréal. L'objectif primaire du Système de Gestion de Quantité de Travail (SGQTI) est de réduire la quantité de travail des infirmières en automatisant la préparation des plans de soins de puériculture, en générant des emplois du temps pour les tâches du plan de soins, et en fournissant un moyen de vérification pour annoter les soins délivrés au patient.

Cette thèse commence par une revue de la littérature des systèmes contemporains informatisés d'information médicale, suivi par une vue d'ensemble du SGDP. Une description de la conception et de la réalisation de SGQTI du SGDP est suivie par une évaluation et des résultats de performance du système. L'évaluation des résultats de performance est encourageant et plus de tests sur le site sont recommandés. À la fin de la thèse, un aperçu des extensions futures du système est compris.

Acknowledgments

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Thanks must also go to Dr. Franco Carnevale of the Pediatric Intensive Care Unit of the Montreal Children's Hospital for all his good thoughts and opinions and for providing the PDMS work team with a picture of the ICU environment and what a computer system like the PDMS can provide for the staff and patients of the ICU.

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Chapter 1 Introduction

A hospital's intensive care unit (ICU) is an environment where a large amount of patient data is continuously acquired, analyzed and processed by the physicians and nurses in order to assess the patient's condition and deliver the appropriate care.

Computers can rapidly and accurately record and manipulate large volumes of data useful to the staff of the ICU, and thus can be a helpful tool in an ICU .

Computerization can automate the collection of some of the patient data, such as the vital signs data, which in turn can relieve the burden of its collection. This would leave the nurses and physicians more time to perform other patient care related tasks.

The increased complexity of nursing care as well as the increased legal challenges have increased the need for timely and accurate forms of documentation.

In the practice of nursing, the nurse systematically assesses the health needs of the patient, develops and modifies a nursing plan of care, and implements the plan by performing appropriate nursing actions. As well, the nurse carries out a systematic and continuous evaluation, to determine whether patient's needs are being met. Computerizing the generation of nursing care plans, scheduling the plan of care, and providing a facility to automatically save the plan of care and actual care delivered would make the plan of care more accessible to the care provider. As well, it would more accurately document the history of care delivered and make it more accessible for quality monitoring and quality improvement studies.

In this thesis, a computerized Nursing Workload Management System in a Pediatric Intensive Care Unit will be presented. In this chapter, benefits of computerization in hospitals are described. This is followed by an outline of the functionality of patient data management systems, as well as a mention of some commercial medical systems. Then, issues of user-computer interaction and software performance and reliability are mentioned. A discussion on the relationship between nursing documentation in the ICU and quality of care is presented. This is followed by a description of the Nursing Workload Management System. And at the end of the chapter, an outline of the remainder of the thesis is presented.

1.1 Benefits of Computerization

Providing high-quality health care services is an information-intensive process. The practice of medicine is described to be dominated primarily by how well information is processed and reprocessed, retrieved, and communicated [Bernett, 1990].

In a critical care environment, a large amount of patient data becomes available to the clinician which must interpret this data. Some of this information may be overlooked or improperly integrated with the other information in the patient database. This may result in a potentially dangerous situation which may not be recognized by staff. Computers, once programmed to do a task will tirelessly perform the task of processing what ever new information it receives, comparing it to other available data and to what it has in its knowledge base [McDonald, 1976].

Nursing practice applications for computerized information systems include bedside measurement of heart rate, blood pressure, blood gases, and intracranial pressure; computer-controlled fluid, nutrient, and drug infusions; computer-generated medicine-administration records; automated nursing care plans; automated nursing notes; and automated monitoring of quality indicators [Adams, 1989, Cox *et al.*, 1987, Grobe, 1984, Larrabee *et al.*, 1991].

Herring and Rochman [Herring and Rochman, 1990] note favorable effects of bedside computers. They note decreased time spent in documenting nursing care (a saving of 20-30 minutes per nurse per shift); fewer charting omissions; and more up-to-date patient care plans.

Barry and Gibbons [Barry and Gibbons, 1990] note that up to 30% of the nurse's time is spent on collecting and processing information.

In a study by Minda and Brundage [Minda and Brundage, 1994] on difference in time required for handwritten and computer recorded nursing assessment, they report a significant decrease in the time required for documentation using the computerized documentation, as well as an increase in the number of observation recorded.

According to Soontit [Soontit, 1987] benefits of computer systems include a decrease in documentation time, improved accuracy of care documentation, accessibility of patient data at the bedside for all care givers, speedier implementation of physician's treatment orders, elimination of errors due to illegible handwritten orders, decreased time spent in graphing vital signs and input and output data, and efficient retrieval of medical record information for care-quality, and risk-management purposes.

Trofino [Trofino, 1993] reports the advantages of using a voice-activated system for creating nursing notes as having decreased documentation time and improved the quality of documentation.

In summary, advantages of beside computers include: decreased time spent in documentation; increased accuracy in documenting care measures; greater accessibility of patient information to all care givers; faster implementation of physician's orders; efficient retrieval of medical record information for quality monitoring; and finally more up-to-date patient care plans.

1.1.1 Other Computer Applications in Medicine: Virtual Reality

An important field of computerization, which has a wide range of applications in medicine is Virtual Reality (VR). VR is a combination of human interface, graphics, sensor technology, high performance computing, and networking. This technology has been used in medical education to improve physician training, to better understand human anatomy, and to teach new advances and procedures in surgery. VR can also aid in medical diagnosis, treatment and aiding the physically disabled. Kuhlen and Dohle have developed and advanced visualization system that incorporates computer graphics technology in the diagnosis of movement disorders [Kuhlen and Dohle, 1995]. VR can aid in surgical planning [Dumay, 1995]. Dumay [Dumay, 1995] states that a virtual environment can aid in micro surgery planning, and to improve surgical protocols, as well reduce the need of animal studies which are often performed prior to actual interventions in man. Another research area where VR technology is fertile is Telesurgery and telemedicine. Telesurgery (or remote surgery) will help solve issues that can complicate surgery [Greenleaf, 1996], among those: the patient is too ill or injured to be moved for surgery, a specialist surgeon is located at some distance from the patient, and if an accident victim has better chance of survival if immediate on-the-scene surgery can be performed.

1.2 Functions of PDMS

Several studies have pointed out benefits of utilizing computers in a hospital environment.

DeBrota [DeBrota, 1994] states that computers may assist in many aspects of patient care including :

1. collection of historical information from patients
2. acquisition of information from diagnostic equipment

3. storage of information

4. provision of clinical information summaries

5. prediction of clinical outcomes

6. sharing of information among decision makers

7. clinical decision analysis and decision making

In a study on the benefits of bedside terminals in several hospitals, Herring and Rochman [Herring and Rochman, 1990] report that bedside terminals resulted in better work organization and efficiency. They also report that quality of care improved due to 1) fewer errors or omissions, 2) more accurate and complete documentation, 3) increased accountability for charting and scheduling IVs, 4) more accurate and up-to-date care plans.

1.2.1 Decision Support Systems

A function of the PDMS includes the ability to assist in making decisions . This is done using Artificial intelligence.

Artificial intelligence is "the effort to develop computer-based systems (both hardware and software) that behave as humans" in terms of language, visual and oral perception, and logical reasoning. Expert systems use artificial intelligence to automate decision-making processes and solve problems that usually require human thought [Laudon and Laudon, 1991].

Some examples of expert systems designed for nurses include the following: The HELP Patient Care Information System, used to assist nurses with scheduling and care planning [Bradshaw *et al.*, 1988]. A Research Knowledge System (ARKS) is another expert system developed to store, manage, and restructure the knowledge from nursing's scientific literature into a more useful form for easy access and application [Graves, 1990].

Chang et. al. [Chang, 1988] describes the CANDI (Computer Aided Nursing Diagnosis and Intervention) system, a PC based system which collects data that uniquely describe the patient's current state, upon which the system produces a diagnosis.

Expert system development used to be complicated, expensive and time consuming because they had to be developed using special programming languages, and covered a broad rather than specific domains [Fonteyn and Grobe, 1994]. With the use of expert system shells and the trend to focus on specific areas of nursing practice has provided a means to expedite and facilitate the growth and development of expert systems for use in nursing practice.

Two systems that have been already developed using experts shells are Urological Nursing Information System, a system designed to assist nurses in planning care for incontinent patients, and CARE PLAN, designed to assist nurses caring for postpartum patients [Petrucci and Petrucci, 1991].

1.3 Concerns Regarding PDMS Usage

Many issues are of importance in using Patient Data Management Systems. In the following paragraphs, two of those concerns are discussed.

1.3.1 Data Integrity

A high degree of data accuracy and reliability is a must for any ICU system. This may be partially achieved by allowing the user to edit the pieces of data entered before saving it into the database. Editing parameters can be useful in providing high-quality data. These include, as a first-level checking: automatically rejecting values which are outside the range possible for a particular data element and asking the user to enter another value. A second-level, and more sophisticated editing procedure is assessing anatomic variables and physiological compatibility. Anatomical edits check the appropriateness of sequential data. And yet another level called, delta checking compares sequential data for the same variable. As an example, if there is a dramatic change in a physiological variable, the user is queried to confirm this change [McDonald *et al.*, 1988, Milholland, 1988, Andre and Eckerty, 1990].

Henderson et. al. [Henderson *et al.*, 1990] states that controlling the quality of data best is by *using* the data often, which means that the more the computerized data is used by the health care team, the greater the likelihood that errors will be found. He recommends that data be used but also corrected when errors are found. He adds that modern health care systems provide "audit trail" of corrected data, thus saving the prior entries as well the the time and identification of the person making the change permanently for legal reasons.

1.3.2 Speed of Data Entry

Data may be entered by various input devices and systems. Preference of one device over the other is governed by the speed with which data may be entered using that device.

Data about patients in the ICU includes such items as : medication information, nursing tasks information, and bedside patient assessment. Entering such data in a structured, list-driven manner would provide a fast and more uniform means. This may be accomplished by using such popular point-and-click systems as : 1) the use of a mouse, 2) track ball, 3) light-pen, and 4) touch screen. A draw back of those systems is that the user has to wait for the screen to appear before pointing again, which may slow down the process.

1.4 User-computer Interaction

The lack of good user interfaces has been the major deterrent in the acceptance and long-term use of a medical system. Data entry by the staff is a burden and it is one of the biggest issues when it comes to interaction with computers. While many of the input pointing devices such as a mouse or a track ball function well on the desktop, the mobility of the care givers limits the desirability of these popular pointing devices [Tang and Patel, 1994].

Tang and Patel [Tang and Patel, 1994] explain that in contrast to communication between humans, communication between a computer and human generally lacks context, so that the user needs to 'refresh' the context of a computer session constantly by entering information about a patient, or a task, etc, over and over. He explains that for efficient interaction between the user and computer, the context of the interaction must be taken into consideration.

For enhancing user-computer interaction, Tang and Patel [Tang and Patel, 1994] recommend improving pen-based technology, developing knowledge-based techniques that support contextual presentation of information, and to develop new strategies and reliable metrics to evaluate user interfaces of health-care givers workstations.

One of the most promising methods in the research on human-computer interaction involves "think-aloud" protocols. This involves recording subjects as they verbalize their thoughts while interacting with computer systems. Researchers have applied variations of this technique to collect rich qualitative data. The think-aloud method has also been used by many other researchers such as [Joseph and Patel, 1990, Kuipers and Kassirer, 1987, Corcoran *et al.*, 1988, Fonteyn, 1991] in studies to capture the reasoning processes of expert nurses, for the purpose of developing prototype expert systems.

Another means for interacting with the computer is through speech. Automatic speech recognition systems have been successfully implemented for data input to the computer [Petroni *et al.*, 1991, Kuhn *et al.*, 1990, Shiffman *et al.*, 1991].

Trofino [Trofino, 1993] describes a voice-recognition system for creating complete printed nurse's notes by voice.

Automatic speech recognition systems are becoming more affordable, however their current error rates, speaker dependence, and controlled vocabulary makes their usage limited [McDonald *et al.*, 1988].

From IBM comes OS/2 Warp Version 4 which is the first Intel-based PC operating system with built-in speech recognition. With the introduction of this system, it takes a simple spoken phrase to navigate through the different applications on the PC [IBM, 1996].

1.5 System Reliability and Performance

Due to routine time pressures on staff and the occurrence of life threatening situations, the performance of a medical system is critical. The major concern in medical software is reliability [Reupke *et al.*, 1988]. Johnson and Aylor [Johnson and Aylor, 1988] state that the most important factors in medical software applications are reliability, availability, and safety. Reliability is the probability that a particular device will function as expected in a specified environment for a particular period of time. Safety is the property that a device will not cause harm by operating incorrectly [Johnson and Aylor, 1988, Kight, 1990]. Andreoli [Andreoli, 1985] outlines that development of a computer program is a continuous process, and that tracing the actual point at which a defect occurs is difficult, and often impossible. He adds that the nurse and physician have the responsibility to use their professional judgment in evaluating such information before doing what the computer suggests.

1.6 Nursing Documentation vs. Quality-of-Care Improvement

Gillies [Gillies, 1994] discusses the relationship between quality of care improvement and nursing documentation. In discussing the principles underlying quality-of-care improvement efforts, Gillies [Gillies, 1994] asserts that the key to quality improvement of patient care is accurate evaluation of care, and that the key to successful evaluation of care lies in adequate documentation of care.

To automate studies of quality-monitoring requires that process and outcome standards and critical problem indicators for targeted diagnoses, problems, or incidents be stored in computer memory, together with criteria for selecting patient records to be analyzed. Standards with relevant measurement criteria, are cross-referenced alphabetically, by relevant clinical specialty, and relevant medical and nursing diagnoses [Edmunds, 1983].

McCormick and McQueen [McCormick and McQueen, 1988] note that "diagnosis and prognosis based on systematically collected and collated data are more accurate than those based on clinical judgment and intuition alone". They add that this results in more scientific based decision making, as the outcomes of alternative means of treatments can be compared.

1.7 Commercial PDMSs

Success has been realized with commercially developed Patient Data Management Systems as well as in-house hospital systems (developed at universities or medical schools) [Bradshaw *et al.*, 1989, Brennan, 1991, Hasman *et al.*, 1988, Kuhn *et al.*, 1990, Soontit, 1987].

Some commercial PDMS include:

- The Hewlett Packard PDMS/CareNet System [Hammond *et al.*, 1991, Nolan-Avila and Shabot, 1987].

- The EMTEK system [EMTEK, 1988].
- The MedTake system [Pesce, 1988].
- The Marquette.
- The Health Care Solutions by TDS HealthCare Corporation.
- The Clinibase by Logibec.
- The CliniCare system [Hughes, 1988].
- The Mediplan system by IST, a nursing care plan system.

Influencing the choice of PDMS to use are such factors as the ability to customize, functionality, cost, user interface, modularity and multi-vendor equipment support [Paganelli, 1989].

1.8 Nursing Workload Management

1.8.1 Nursing Workload Measurement

Nursing workload measurement systems have been designed to measure the estimated time required for delivering patient care. Measuring the workload required to care for patients aids the nurse managers in scheduling, allocating resources and staff.

The purpose of the nursing workload measurement systems, as described by some authors, is to provide time estimates for staff allocation and scheduling, productivity monitoring, cost and billing for nursing services [Bradshaw *et al.*, 1989, Karshmer, 1991, Keenan, 1991, van Slyck, 1991].

Among the nursing workload measurement systems used in Canada are: GRASP, MEDICUS, and PRN [O'Brian-Pallas *et al.*, 1989, Thibault, 1990].

There are different approaches to measuring nursing workload. Carr-Hill and Jenkins-Clarke (Great Britain) [Carr-Hill and Jenkins-Clarke, 1995] list four different approaches to measuring nursing workload:

1. Dependency driven, where workload requirements depend on the need of ward patients of a certain amount of nursing care to perform the daily activities of living.
2. Task oriented, based on the recording and predicting nursing interventions for individual patients.
3. Care plan driven: where producing a care plan is used to predict workload.
4. Ward based: where ward overviews of staffing requirements are produced based on patient through-put/bed occupancy.

Lepage et. al. [Lepage *et al.*, 1995] describe a system designed for care workload measurement using SIIOS (Soins Infirmiers Individualises à la Personne Soigneé) in conjunction with a DRG (Diagnosis Related Groups). They report that after analysis of the data entered by the users into the system, information on the representation of daily workload for each category of care can be given to the user.

Edwardson and Giovannetti [Edwardson and Giovannetti, 1994] review Nursing Workload Management Systems. They discuss approaches to workload measurement, and identify four issues related to workload measurement:

1. **Classification.** They mention that many classification systems use information about needs of bathing, feeding, ambulation, observation, special treatments, and psychosocial support and teaching. Recently Workload Measurement Systems (WMS) that include almost all of the activities performed

by nurses have become very popular because of a belief that including more variables will provide more accuracy. This assumption behind this approach is that the whole of nursing care is equal to its sum [DeGroot, 1989].

2. **Quantification**. There are two types of quantifications required in measuring nursing workload: the amount of time required for patient-specific care activities and the amount of time required for all other work.

3. **Reliability** Reliability of measurement is a major concern. There are three major types of reliability: stability, homogeneity, and equivalence [Edwardson and Giovannetti, 1994].

4. **Validity** Validity of workload measurement systems is generally assessed at the time a system is implemented in a setting. Content validation is the most common validation method used. In this method, clinical experts are enlisted to identify or verify the care activities most important for the care of a group of patients. Since the purpose of the WMS is to forecast workload for some time in the future, then logically, the most important evidence of validity is predictive validity [Edwardson and Giovannetti, 1994]. Predictive validity is usually established during implementation of a system by comparing the workload predicted by the system with the actual workload observed by time studies [Edwardson *et al.*, 1990, Giovannetti and Johnson, 1990, Whitney and Killien, 1987].

Scheduling solves problems of resource allocation, and predicts conflicts. Weil et. al. [Weil *et al.*, 1995] introduce constraint programming as a successful solution to the nurse scheduling problem. By specifying compulsory and optional constraints, it can generate different schedules. They add that the tool they have developed using this method saves much time for the head nurse in generating nursing schedules.

1.8.2 Nursing Care Plan

A nursing care plan is a plan for the care that is required to a patient based on patient's age, diagnosis, operation performed, allergies, in addition to possibly other individual circumstances.

Albrecht and Lieske [Albrecht and Lieske, 1985] describe an automated care planning system installed at the Milwaukee County Medical Complex.

Automation of care plan preparation has resulted in added benefits as noted by a decrease in time spent in creating and updating a care plan [Bailey, 1988, Edmunds, 1982, Allen, 1991], increased legibility [Allen, 1991, Hendrickson *et al.*, 1991], increased productivity [Bailey, 1988, Brider, 1991], and job and moral improvement [Bailey, 1988].

1.9 Thesis Overview

In this thesis, a Nursing Workload Management System (NWMS) of the Patient Data Management System (PDMS) for a Pediatric Intensive Care Unit (PICU) will be presented.

Chapter 2 describes the different modules that comprise the PDMS, as well as its hardware and software configuration. A description of the current developments to the system is outlined at the end of that chapter.

In chapter 3, an outline of the OS/2 environment, Presentation Manager, and the Database Manager is included. This is followed by a description of the different components of the NWMS, their functionality, and how they integrate together.

Chapter 4 describes the NWMS in operation. This is achieved by running the system using real medical test cases from patients in the PICU of the Montreal Children's Hospital. Results of the test cases and evaluations of the NWMS is included. The last section of that chapter describes future functionality to be added and improvement to the NWMS. That is followed by the conclusion in chapter 5.

Chapter 2 The Patient Data Management System

This chapter presents the Patient Data Management System (PDMS) which is in development at the department of Electrical Engineering at McGill University for the Pediatric Intensive Care Unit (PICU) of the Montreal Children's Hospital. The first section of this chapter describes the design objectives of the PDMS. This is followed by the system hardware configuration and the system software architecture. A description of the system's software modules is then followed by an overview of the current state of development and future functionality to be added to the PDMS.

2.1 PDMS Design Objective

The PDMS is a real time computer-based medical information system for the management of patient data in the PICU of the Montreal Children's Hospital. The main objective of the PDMS is to provide a facility for the acquisition, storage, processing and retrieval of the large amount of incoming data from bedside physiological monitors, to present this data in the form of graphical trends on a color video display for review and interpretation, and to reduce the time spent on paper work and documentation by nursing staff by enhancing the preparation of clinical records in a computerized form.

The PDMS also provides a friendly user interface for the entry of various types of data from numerous sources. These sources may include nursing notes in a narrative style, nursing observations, laboratory data, nursing plan of care to be carried out, in the form of a checklist. In addition, the system provides a speech recognition interface for entry of the readings of fluid infusion pumps using voice input.

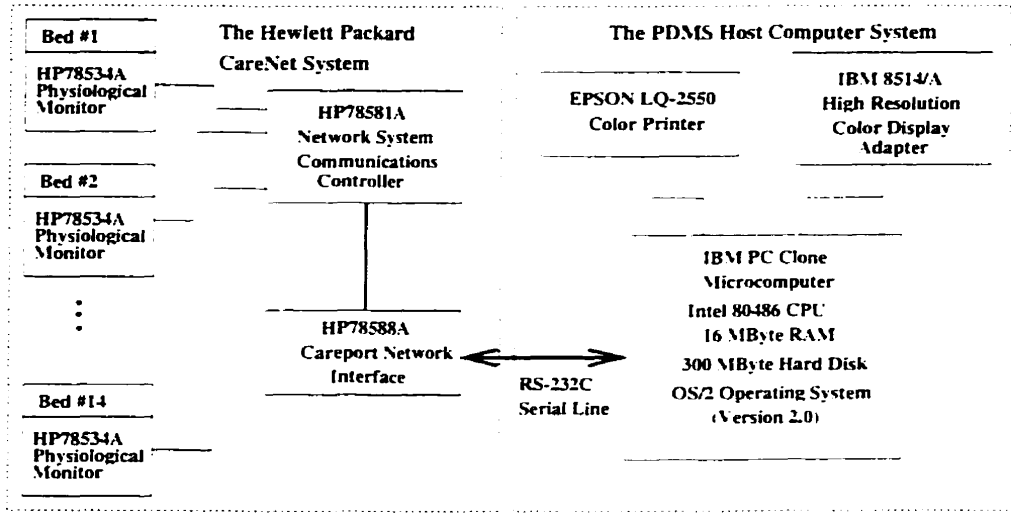

Figure 2.1: PDMS Hardware Configuration

2.2 System Hardware Configuration

The primary component of the PDMS hardware environment is the Hewlett-Packard CareNet System. It consists of fourteen bedside HP 78534A Physiological Monitor/Terminals linked by a local area network (LAN) in a star configuration to the HP 78581A Network System Communications Controller. These bedside monitors are capable of smoothing and displaying measured real time parameters and generating alarm signals.

The communication between the host computer and the network is performed by the HP 78588A Careport Programmable Interface. It permits the translation of formatted messages of the network communications controller into RS-232C messages to the host computer. Figure 2.1 shows this hardware configuration.

The host computer is an Intel 80486-based IBM PC with 16 Megabytes of RAM and a 300 Megabytes hard disk. The display consists of a high resolution 8514/A color display adapter which provides a high resolution of 1024 X 768 pixels.

2.3 System Software Architecture

The PDMS software runs under the OS/2 operating system. The choice of OS/2 was made because it is truly a multitasking operating system. The principle of modularity is adopted in the design and implementation of the PDMS. A modular design allows developing more efficient software as separate programs implementing only the necessary functions rather than designing one program for performing all the different tasks. Thus, with a modular design such as this one, new modules can be easily added or updated to rapidly follow system development plans. It also makes debugging and troubleshooting the system more manageable.

OS/2 was chosen as the operating system for implementing and building the system. It is a truly multi-tasking operating system with which multiple tasks and threads can and were implemented. The interprocess communication between these modules is achieved by using operating system structures such as pipes, semaphores and shared memory segments. Furthermore, the PDMS uses OS/2's Presentation Manager to present a consistent, easy to program and easy to use windowing user interface. Figure 2.2 show the software configuration of the system. The figure shows how the different modules interface with each other, with the Careport, and the shared memory buffers.

2.4 PDMS Software Modules

The original version of the PDMS was developed under OS/2 1.0. The upgraded development of the PDMS continued using OS/2 version 1.3 and each module is currently running under OS/2 version 2.1. The implemented modules of the PDMS include:

- The Data Link Controller module.

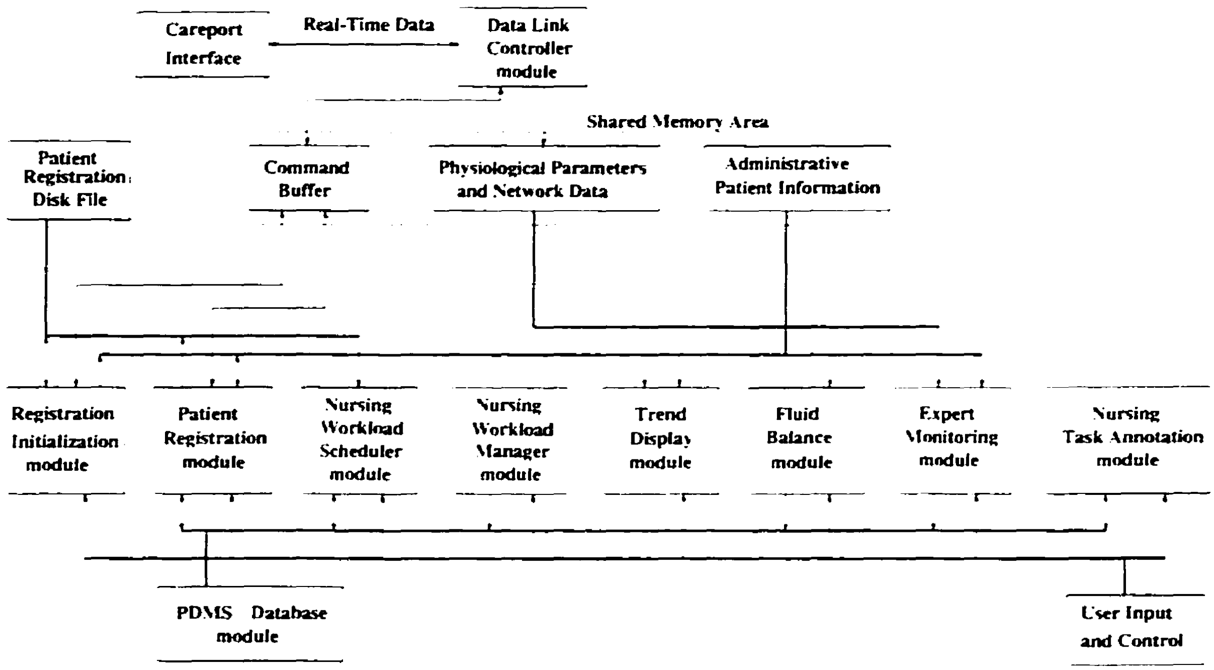

Figure 2.2: PDMS Software Architecture

- The Registration Initialization module.
- The Patient Registration module.
- The Expert Monitoring System module.
- The Trend Display module.
- The Fluid Balance module.
- The Nursing Workload Manager module.
- The Nursing Workload Scheduler module.
- The Nursing Care Delivery Annotation module.

Each module can be considered as a single process, and all the modules may run concurrently under the OS/2 environment. Figure 2.2 shows the software modules of the PDMS.

2.4.1 The Data Link Controller module

The primary function of the DLC is to acquire and store the physiological parameter values transmitted by the network of bedside monitors in real time and to place them into queues for each of the fourteen beds. These parameter values are acquired every two seconds and placed into a "seconds" queue structure. Then these "seconds" data are averaged every minute and stored in minute queues. Then, what are called "minutes" data are averaged every thirty minutes and stored in the "half hour" queues. All these values are stored in shared memory and are accessed by the Expert Monitoring module and the Trend Display module, which will be described shortly.

This physiological data acquisition is done through the serial RS- 232C link to the Careport. The DLC module also acts as a coordinator between processes that wish to read the physiological parameter data found in the shared memory queues by using semaphores, and coordinates the use and access of system resources between many processes running at the same time.

2.4.2 The Registration Initialization module

The Registration Initialization module is the first module run by the PDMS system when booting the host computer. The module simply queries the user for the mode of registration initialization, and then automatically initializes the system to the mode chosen by the user. There are two initialization modes:

- Passive Initialization
- Active Initialization

The Passive Initialization mode initializes all ICU beds and therefore all the corresponding structures and parameter data queues in shared memory are empty.

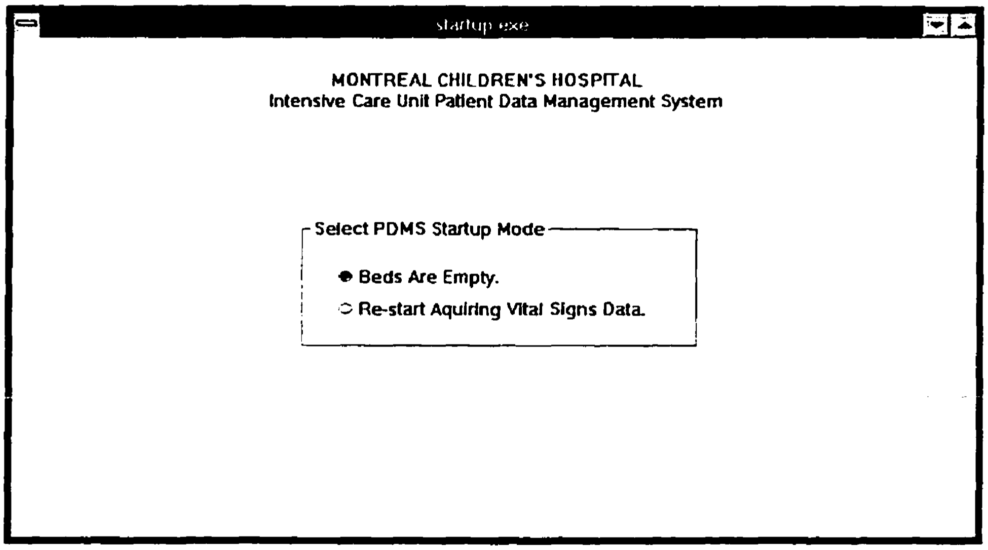

Figure 2.3: Main Window of the Registration Initialization Module

In the Active Initialization mode, the Registration File, which contains information about the patients currently registered is read, the corresponding data is put in shared memory structures and all patients in that file are connected to the CareNet one after the other so that vital sign data acquisition is started. The module also provides a time-out value during which the user is expected to enter a response. When the time-out value has expired, the module starts up the system with the default mode. The default mode is Passive Initialization . Figure 2.3 shows the Registration Initialization module window.

2.4.3 The Patient Registration module

The Patient Registration module stores the administrative patient information in the shared memory for editing and viewing. It can also retrieve and suspend patient information by generating signals to the Data Link Controller module to indicate events of addition, suspension, or discharge of a patient, using semaphores and shared memory. Figure 2.4 shows main window of the Patient Registration module while figure 2.5 shows the dialog box used for admitting a patient.

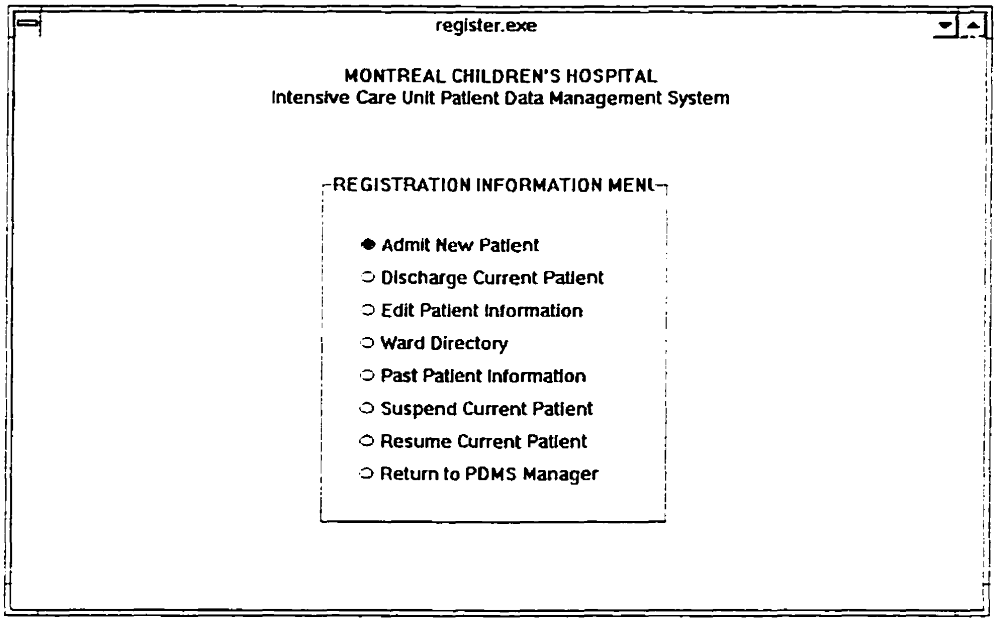

Figure 2.4: Main Window of the Patient Registration Module

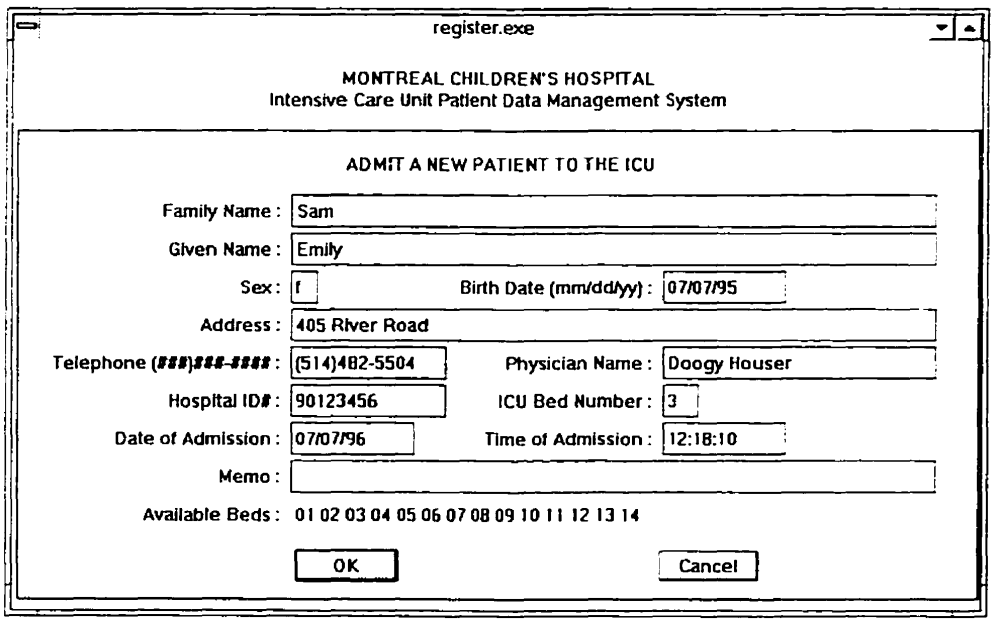

Figure 2.5: Patient Admittance Dialog Box

It is also through the Patient Registration module that the acquisition of the patient's vital sign data according to the admission and discharge of patients in the intensive care unit ward is initiated or done. The patient information entered into this module includes such data as patient's name, date of birth, patient id, bed assignment, treating physician, date of admittance to the ICU, etc. This information is automatically stored in the PDMS Database. The patient's personal information is stored in one table called the 'Patients' table, and this is done once per patient and is updated only if a change in this information occurs, while the admittance and discharge dates are stored in another table called the "Admittance" table and this data is stored per patient per visit to the ICU. Figure 2.4 shows the main window of the Patient Registration module, as well as the "Admittance' and "patients" database tables in which the registration information is stored.

The shared memory structure storing the administrative patient information is indexed by bed number, and can be accessed by the Trend Display module, the Fluid Balance module, and the Expert Monitoring System module to obtain administrative patient information.

2.4.4 The Expert Monitoring System module

The Expert Monitoring System module is a monitoring system whose primary function is to provide automated physiological trend analysis and interpretation in real time. It can also give a warning signal in a form of a color code on the display to alert the clinical staff in case a life-threatening event is detected at any time for each critical patient in the intensive care ward. As a result, the patient can be treated in time before irreversible damage occurs. Figure 2.6 shows the main window of the Expert Monitoring System module. The beds are color coded green, yellow, or red, to indicate normal, alarming, or critical conditions. An empty bed is colored black.

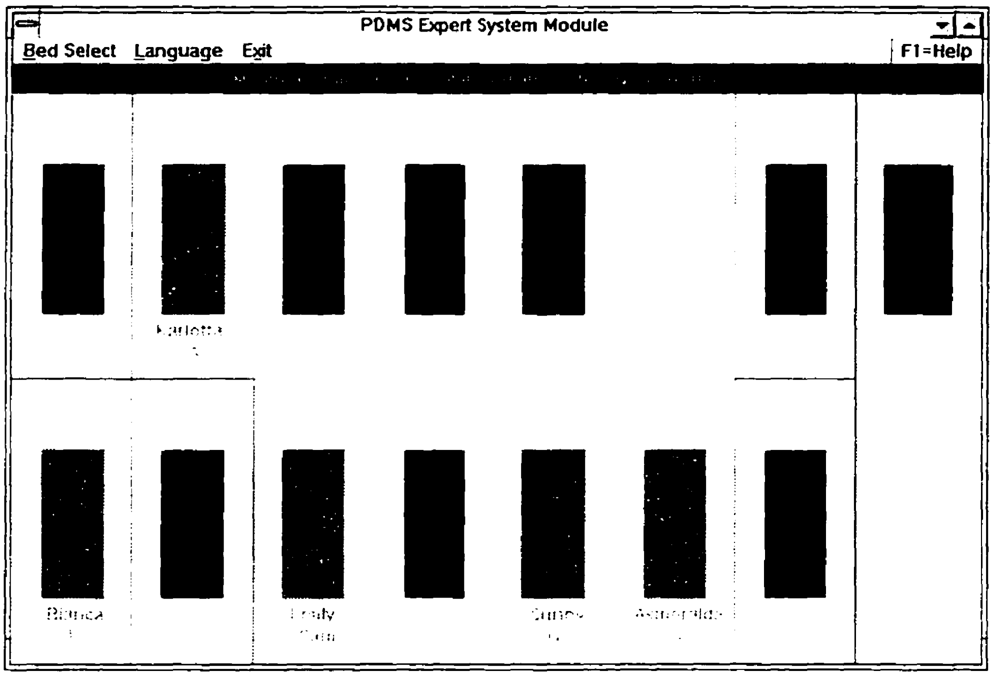

Figure 2.6: Main Window of the Expert Monitoring System Module

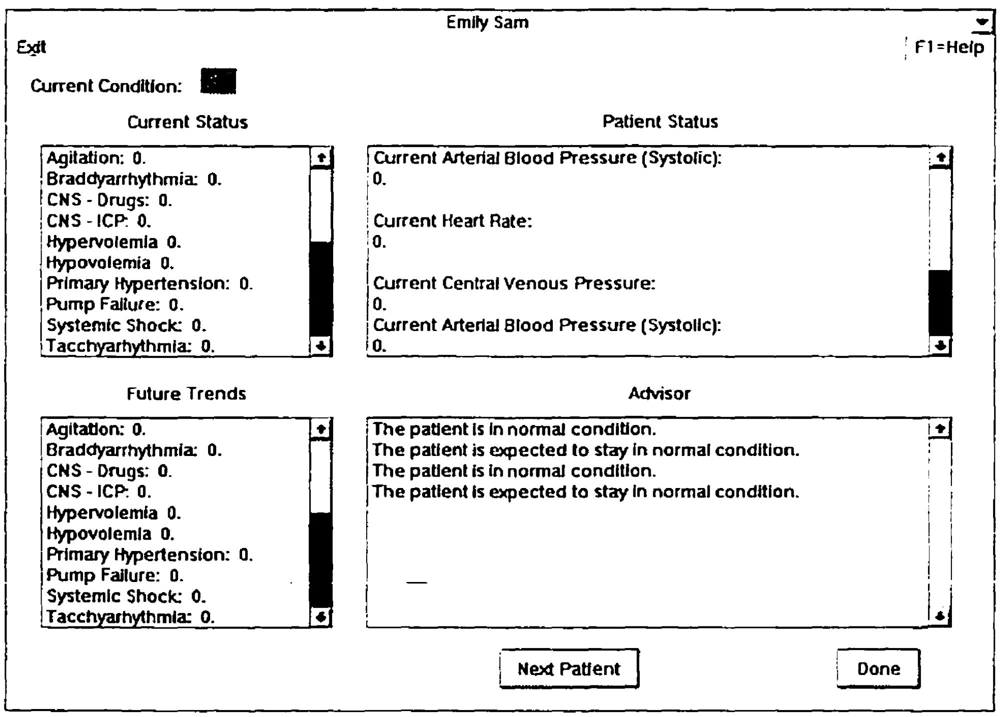

Figure 2.7: Interpretation Window of the Expert Monitoring System Module

The Expert Monitoring System module consists of median filters and a multi-level expert system. It receives the physiological data of each patient from shared memory through the Data Link Controller module and filters it to remove irrelevant values and to extract the linear trends. The processed data then goes through the rule- based expert system for diagnosis. The rule-based expert system then analyzes and predicts the patient's condition based on this linear trend and generate the alarm signals in different colors on the user interface. Alarms are generated for current and future expected critical conditions. In addition, the linear trend is saved in the PDMS Database for future reference. By clicking on any bed, an interpretation window shown in Figure 2.7 generated by the Expert Monitoring System presents the patient diagnosis. Further details are given in [Lam, 1993].

2.4.5 The Trend Display module

The Trend Display module allows the user to review the physiological parameter values in a graphical form. The module has the capability of displaying the trends in three different resolutions or modes, namely: second data resolution, minutes data resolution, and half-hour data resolution. It also has the capability of displaying more than one patient at the same time by creating a separate window for that patient. The module allows the user to specify a time interval, or display range of the data and allows the user to assign each physiological trend a distinct color and symbol pattern combination. The physiological parameter data are obtained from the shared memory through the Data Link Controller module. The graphical trends provide a clearer way of viewing simultaneously several parameter data and thus may assist health care professionals in making their medical decisions [Yien, 1993]. Figure 2.8 shows the main window of the Trend Display module.

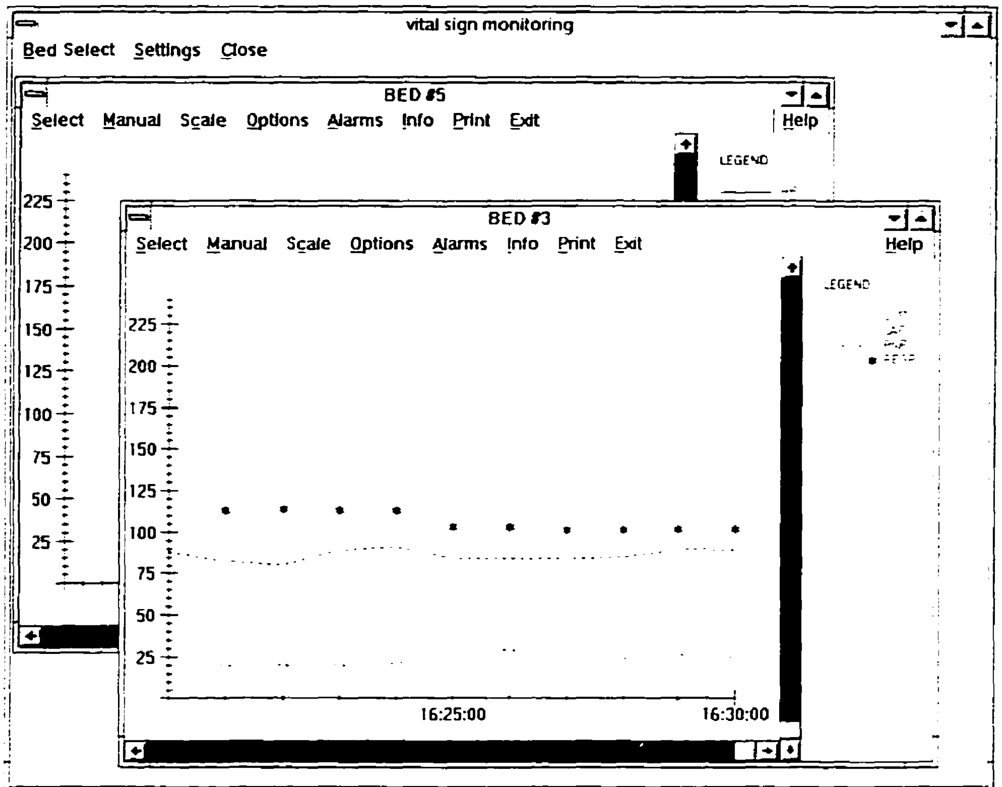

Figure 2.8: Main Window of the Trend Display Module

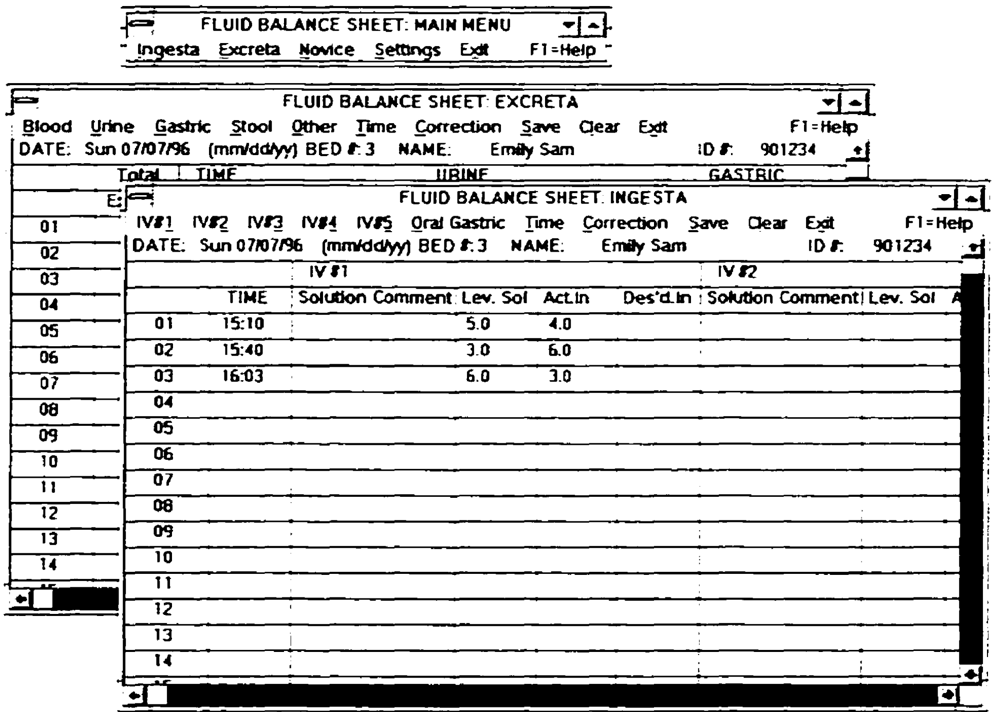

Figure 2.9: Main Window of the Fluid Balance Module

2.4.6 The Fluid Balance module

The Fluid Balance module manages the recording of the fluid intake (ingesta) and fluid output (excreta) information of each patient in a spreadsheet form. The nursing staff periodically takes measurements from infusion pumps or urine bags and enters the readings and makes the required data calculations to determine the overall balance of fluids. Figure 2.9 shows the main excreta, and ingesta windows of the Fluid Balance module.

The Fluid Balance module can be operated by keyboard and mouse, and it also has a speech interface which allows the nurse to directly enter data by the use of voice input. The speech interface is comprised of the speech recognition system for speech input, and a speech generation or speech synthesis system for speech output. Such an interface provides an "eyes-free" and "hands-off" capability and enhances the mobility of the users while entering the data [Petroni *et al.*, 1991].

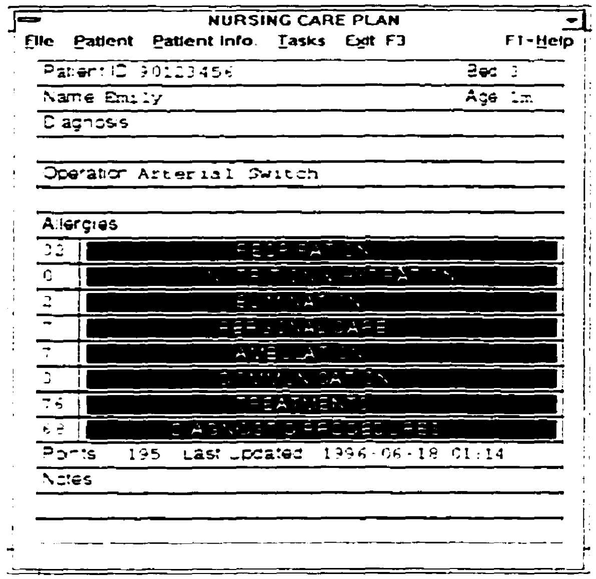

Figure 2.10: Main Window of the Nursing Care Plan Preparation Module

When using the voice recognition method, the input data is echoed back at the user using the speech synthesis system of the interface for confirmation in order to avoid errors. The data entered into the spreadsheet by any of these means are automatically saved into the appropriate PDMS Database tables.

2.4.7 The Nursing Workload Manager Module

The purpose of the Nursing Workload Manager (NWM) module is to generate nursing care plans, automate the measurement of nursing workload in real time, and set up fluid balance charts through integration with the Fluid Balance module. The NWM constitutes one of the parts of the NWMS and will be discussed in detail in the chapters 4 and 5. Figure 2.10 show the main window of the NWM module.

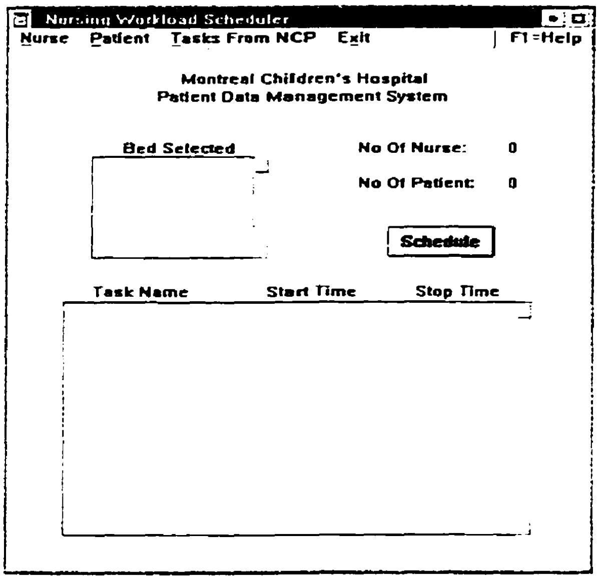

Figure 2.11: Main Window of the Nursing Workload Scheduler Module

2.4.8 The Nursing Workload Scheduler Module

The Nursing Workload Scheduler (NWS) module generates nursing care plan schedules. It is designed to support the Nursing Workload Manager module by reducing the workload of the nurse which must manually generate a schedule and hence contributes to the enhancement of the quality of patient care. The NWS module is part of the NWMS and will be discussed in detail in the chapters to follow. Figure 2.11 show the main window of the NWS module.

2.4.9 The Nursing Task Annotation Module

The objective of the Nursing Task Annotation (NTA) module is to relieve the nurse from the burden of documenting the execution of the nursing plan of care by computerizing this task and it is designed as an extension to the Nursing Workload Manager module and the Nursing Workload Scheduler module. The NTA module constitutes part of the NWMS and its design and implementation is presented in the chapters to follow. Figure 2.12 show the bed layout window of the NTA module.

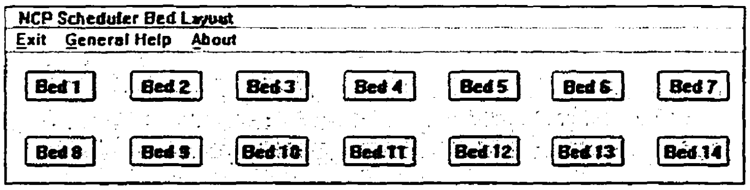

Figure 2.12: Main Window of the Nursing Task Annotation Module

2.4.10 The PDMS Database

The PDMS Database contains the tables used for storage of data from the Patient Registration module, the Nursing Workload Manager module, the Fluid Balance module, and the Nursing Task Annotation module. It also acts as the source of data input to the Nursing Workload Scheduler module.

The PDMS Database module is implemented using the relational database management services available from OS/2 Extended Edition Database Manager. Interaction with the Database Manager is done by embedding SQL statements in C source code. The embedded SQL statements serve as a database programming language for creating database elements, submitting SQL queries, editing and entering table data.

2.4.11 Current Development

Current development of the PDMS includes the addition of the Nursing Task Annotation facility which is designed as an extension to the work performed by the Nursing Workload Manager module and the Nursing Workload Scheduler module. The Registration Initialization module was also added recently to the PDMS. This module allows for a cleaner and more timely initialization of the system when rebooting the host computer after a power shutdown. Most recently, the Expert Monitoring System underwent an evaluation to further refine the knowledge-base rules of this system. The results of this evaluation can be found in [Abu-Shihab, 1996]. Also, work was implemented to apply new database design specifications for the PDMS according to [Saab, 1995], the implementation of which is described in chapter 3.

Chapter 3 The Nursing Workload Management System

In this chapter the Nursing Workload Management System is presented. The first section of the chapter describes the OS/2 environment, Presentation Manager, and OS/2 Database Manager. The purpose and functionality of the NWMS, its software design, and the integration of its modules is explained.

3.1 The OS/2 Environment, Presentation Manager, and Database Manager

3.1.1 OS/2 and Presentation Manager

Presentation manager (PM) is an OS/2 Graphics Programming Interface (GPI) that enables the user to create, display and print graphic images in a PC-based environment. In a PM application, the user uses the graphics functions to program the desired graphics output. The applications written by the user receive window messages about the images to be created; the programmers task is to write how to process this input into output.

The major advantage of the GPI is device-independence, which is achieved through the linking of presentation spaces with device contexts, and the use of a wide selection of graphics primitives. A *presentation space* is a data structure; equivalent of a blank piece of paper on which graphic images are created before being sent to an output device. An output device can be, for example, a printer or plotter, memory bit map, display screen, or even a facsimile card. A PM application must direct all drawing to a presentation space.

The graphics engine and device drivers are responsible for getting output from a presentation space to an output or hardcopy device. The mapping from the presentation space to the hardcopy device is handled by a device context that is associated (linked) with the presentation space.

A *device context* also is a data structure, its purpose is to translate graphics commands made to its associated presentation space into commands that the physical device can convert to displayed information.

Graphics programming is influenced by the underlying operating system. OS/2 supports the following concepts, which play an important role for programming in GPI.

An OS/2 *session* is one or more processes with its own virtual console. A virtual console is a virtual screen-either a character-based full screen or a PM window and buffers for keyboard and mouse input.

A *process* is an OS/2 program that has been loaded into memory and prepared for execution. A process consists of code, data and other resources such as file handles, semaphores, pipes, queues, and so forth, in memory. The operating system considers every application it loads to be a process.

An OS/2 *thread* is a dispatchable unit of execution that consists of a set of instructions, related CPU register values, and a stack. Every process has at least one thread and can have many threads running at the same time. The application runs when the operating system turns over control to a thread in the process. A user may choose to program an application with multiple threads, for the purpose of speeding up a program, by allowing the application to perform different actions simultaneously. For example, a process may perform computations and be processing I/O at the same time.

Some threads and processes may be sharing the same resources, thus synchronization between them is necessary. To synchronize the actions of multiple threads

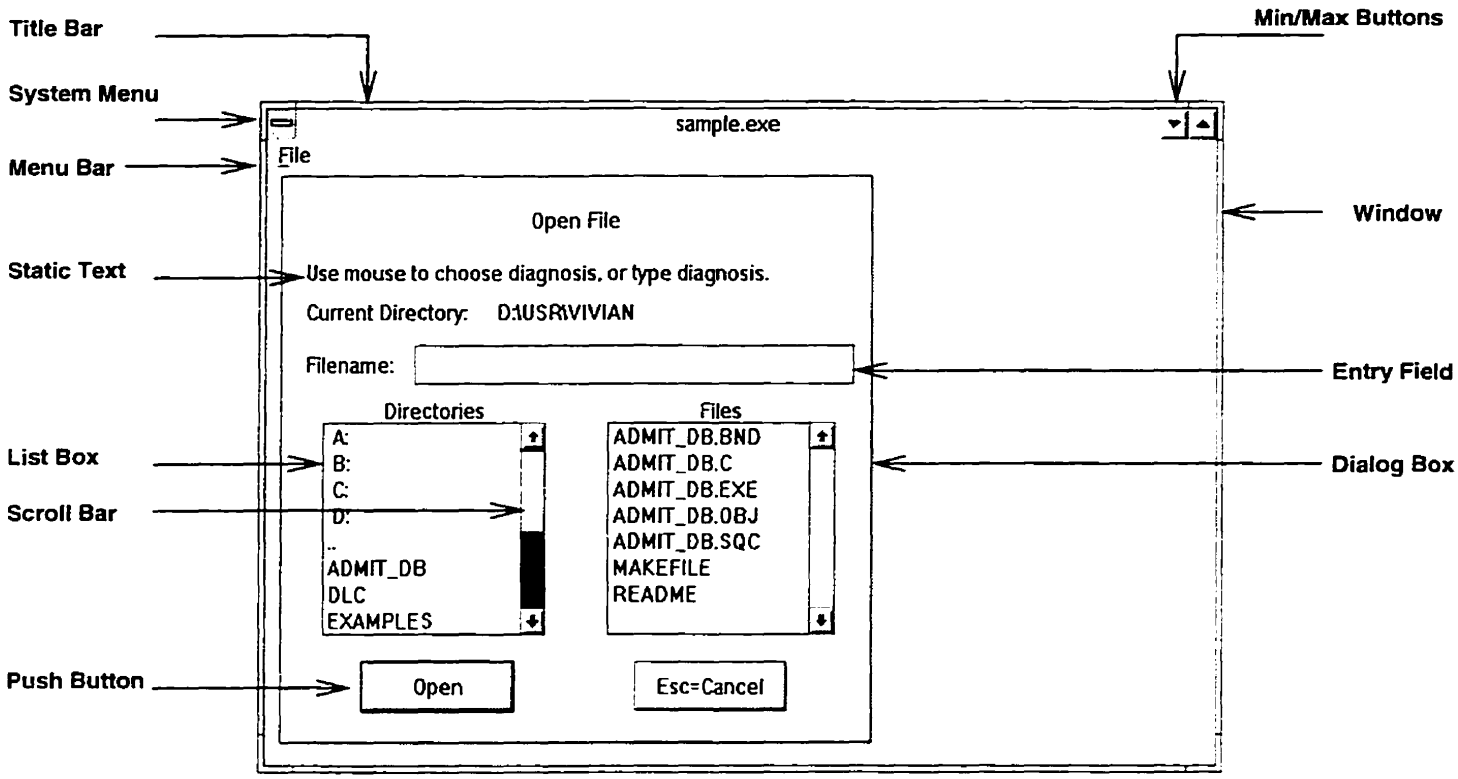

Figure 3.1: Sample OS/2 Window and Dialog Box

or processes, OS/2 uses *semaphores*. Semaphores are OS/2-managed software flags used to coordinate the actions of concurrent processes and threads.

Figure 3.1 shows a sample OS/2 window and a dialog box.

OS/2 supports creating resources other than a PM window, such as icons, user defined fonts, and dialog boxes. PM tools that create such resources are available in the OS/2 Toolkit.

For example, a tool for creating dialog boxes creates WYSIWYG (What You See Is What You Get) dialog boxes that use PM's built-in control windows.

Thus, a PM resource is a file that contains data, bitmaps, or other independently created resources that will eventually be used by the user program. These resources get added to the user's executable program, or are placed in DLLs (Dynamic Link Libraries).

DLL contain executable functions which may be linked to an application at program load time, or at run time, instead of at compile time. Dynamic linking solves two problems: first, it allows functions to be added to the program without having to relink the entire program, second, it removes the need to store on disk and load in memory multiple copies of the same code. Without dynamic linking, each program would have to load its own copy of the system library in memory.

The items in the resource files are loaded in memory using special PM API (Application Programming Interface) calls.

The advantages of creating these resources separately from the user application is two fold: it allows changes to be made to these resources without having to recompile the source code, and second, multiple instances of the application can share the same resources without reloading them into memory.

Unlike traditional applications which take complete control of the computer's mouse, screen and keyboard, PM applications share these resources with other applications that are running concurrently. This is achieved by the operating system, by using *messages*. A message is information, a request for information, or a request for an action to be carried out by a window in an application. Each message has an identifier which indicates the action required by the window.

3.1.2 OS/2 Database Manager

The OS/2 Database Manager is based on the relational model of data. The information in the database is presented in tables, which are simple tabular forms of rows and columns. Data is defined and accessed using tables and operations on these tables. This allows the user to design, create, and access databases without having to understand the underlying complex physical data structures and access methods. The Database Manager consists of *Database Services* and *Query Manager*.

Query Manager is a front-end interface that allows the user to create databases, define tables in the database, enter, or alter data in the database, and issue queries about data in the tables.

OS/2 Database Manager is primarily a Structured Query Language processor. It implements the SQL command set as defined by the ANSI standard.

SQL statements may be issued from a prompted user interface in the Query Manager or *embedded* into other programming languages such as C, COBOL, or FORTRAN. A program (written in C-language for example) with embedded SQL statements is precompiled during the program preparation process, during which the SQL statements are replaced with calls that are recognized by a C-language compiler. This precompilation is supported by the Database Services.

3.2 The Nursing Workload Management System

3.2.1 Conceptual Description

The Nursing Workload Management System provides the following functionality:

1. automate nurse care planning.
2. automate measurement of nursing workload.
3. automate scheduling of patient care related tasks.
4. computerize the documentation of care delivered to patients.
5. documentation involves saving all this data permanently into the database for easy access to it later.

The Nursing Workload Management System consists of three separate modules namely

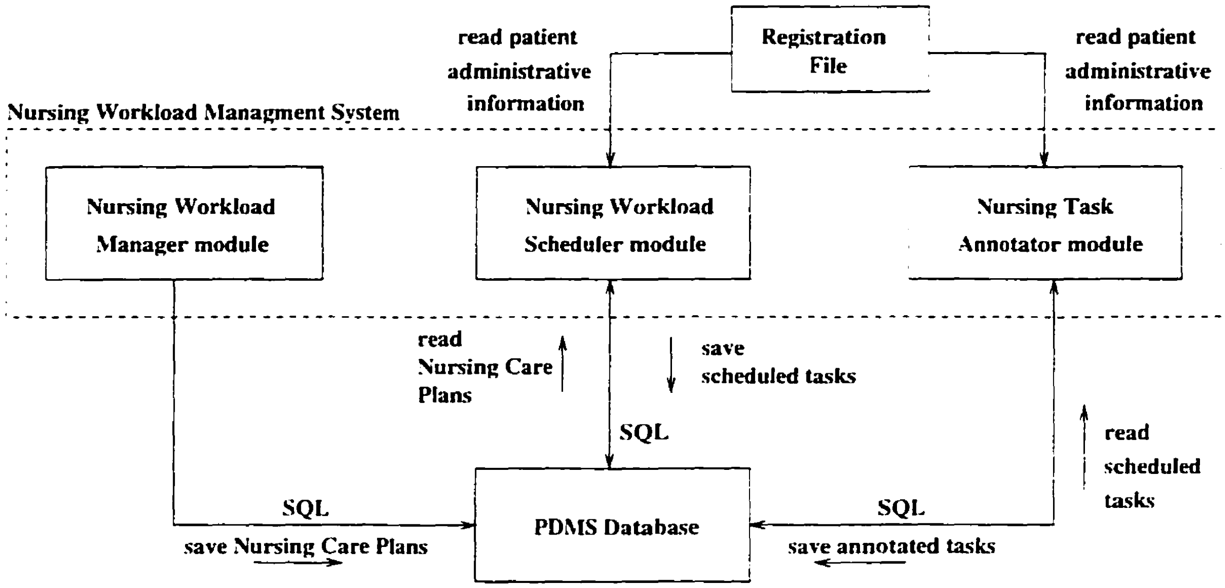

Figure 3.2: Components of the Nursing Workload Management System

1. The Nursing Workload Manager module
2. The Nursing Workload Scheduler module
3. The Nursing Task Annotation module

Figure 3.2 shows the different components of the Nursing Workload Management System and the interconnections between these modules.

3.2.2 Database

The PDMS Database is implemented using OS/2 Database Manager. It stores the various data from the different PDMS modules. The PDMS Database design was proposed by Saab [Saab, 1995] and has now been implemented. In the current implementation, the patient data handled by the PDMS is divided into four different classes: first, administrative data such as patient name, age, home address, etc; second, the real time parameter data which are automatically acquired; third, the data that comes from the care planning and execution by the nursing staff; fourth, intake and output data (or fluid balance). Refer to table 3.1. Data is the ICU comes

Table Name	PDMS module	Type of data stored
Patient	Registration	Administrative data such as patient name, age, etc.
Admittance	Registration	Admission and discharge dates, etc.
EMSDATA	EMS	Vital sign data.
NCP	NWM	Nursing Care Plans' headers.
Task	NWM	Tasks belonging to different Nursing Care Plans.
Medication	NWM	Medication information from different Nursing Care Plans.
Solutions	NWM	Solution information from different Nursing Care Plans.
Done_Tasks	NTA	History of what nursing tasks got done.
FluidBal	Fluid Balance	Fluid intake and output information.

Table 3.1: PDMS Database

from a multitude of sources, such as data gathered from the vital signs monitoring equipment, laboratory results, nursing observations, and intake and output fluids. Storing each piece of data represents a challenge for the staff ICU, because not only does this include capturing the appropriate clinical data, but it also involves making sure that data that gets stored is edited for accuracy.

The registration information is kept in two database tables, namely the Patient table and the Admittance tables, and also in a file, called the Registration file. Tables 3.2 and 3.3 show the contents of these two database tables. The registration file is used as the reference for scheduling purposes since its contents are interrogated when a bed is selected to see if a patient really exists there.

3.2.3 Data Archiving

Several Database Utility Service commands may be used to store entire databases or tables into a specified location, say a disk. For example, the command **BACKUP DATABASE** may be used to create a copy of a database. The user must specify the

Column Name	Data Type	Number of Bytes	Comment
Patient_ID	string	9	Unique in this table.
First_Name	string	25	
Last_Name	string	25	
Date_of_Birth	string	10	
Gender	string	2	
Address	string	50	
Phone_Nbr	string	15	

Table 3.2: Contents of the Patient Table

Column Name	Data Type	Number of Bytes	Comment
Patient_ID	string	9	
Date_In	string	10	Database Date type.
Time_In	string	8	Database Time type.
Bed_Nbr	numeric	4	
Doctor	string	30	
Date_Out	string	10	Database Date type.
Time_Out	string	8	Database Time type.

Table 3.3: Contents of the Admittance Table

name of the database to backup as well as the drive on which the backup files are to be placed. Using this command the user may specify whether the entire database needs to be copied or just the incremental changes made since the last backup. Once the database has been backed up, its contents may may be deleted, to allow for new data to be stored. The contents of a previously backed up database may be restored by using the database utility command **RESTORE DATABASE.** Other utilities may be used to copy data from a database table into a file. The commands **EXPORT TABLE** and **IMPORT TABLE** may be used to copy data from a database table, and copy data from a file to a database table, respectively. Once the data of a table has been saved, the user may then delete the data from that database table to save new data.

3.3 Patient Registration

Patient registration is done using the Registration module, as mentioned in chapter 2. Using the registration module, the user may add a new patient, discharge, edit patient information, suspend and resume a patient. When a patient is added, discharged, or when the patient information is edited, the Database, Registration File, and Shared memory buffers are all updated to reflect the current status of the ICU. As well, when a patient is newly added, vital sign acquisition is started automatically through the DLC module. Vital signs are automatically saved into the PDMS Database. When a patient is discharged, vital sign acquisition is terminated. The Suspend function is designed to halt vital sign acquisition while the patient is not in the ICU, for example when the patient has to undergo an operation in the Operating Room, etc. The Resume function is designed to resume vital sign data acquisition for a patient.

What follows is a description of the three components of the NWMS and their functionality.

3.4 Nursing Workload Manager module

3.4.1 Functional Description

The purpose of the Nursing Workload Manager (NWM) module is to generate nursing care plans, automate the measurement of nursing workload in real time, and set up fluid balance charts through integration with the Fluid Balance module. Nursing care plans can be generated in two different ways. The entire plan can be entered manually by clicking on different categories in the care plan window, or a standard care plan can be called-up from a library of plans and customized for the patient. The library of the Nursing Workload Manager module contains a standard care plan containing the general tasks required to care for most patients in the Pediatric Intensive Care Unit and many diagnosis-specific care plans. Figure 2.10 shows the main window of the Nursing Workload module [Roger, 1992].

The Nursing Workload Manager module measures the nurse workload in real time based on the Progressive Research in Nursing (PRN) workload measurement scoring system. The output of the measurement provides feedback to the administration of the Pediatric Intensive Care Unit to determine staffing allocations, monitoring productivity, and cost of nursing services.

Data entered into the nursing care plan is automatically saved into the appropriate PDMS Database tables and is also saved to a debug file whose contents are read when opening the care plan corresponding to the specified name it was saved under. A hard copy of a care plan worksheet can also be printed out with a separate sheet listing the medications and intravenous solutions entered onto the care plan.

Basically the NWM module has 3 styles of dialogs: 1) all the nursing tasks, except intravenous therapy and medication, can be entered using a dialog box of the form shown in figure 3.3. The IV solution information may be entered using the IV Therapy dialog box shown in figure 3.5, and the medication information

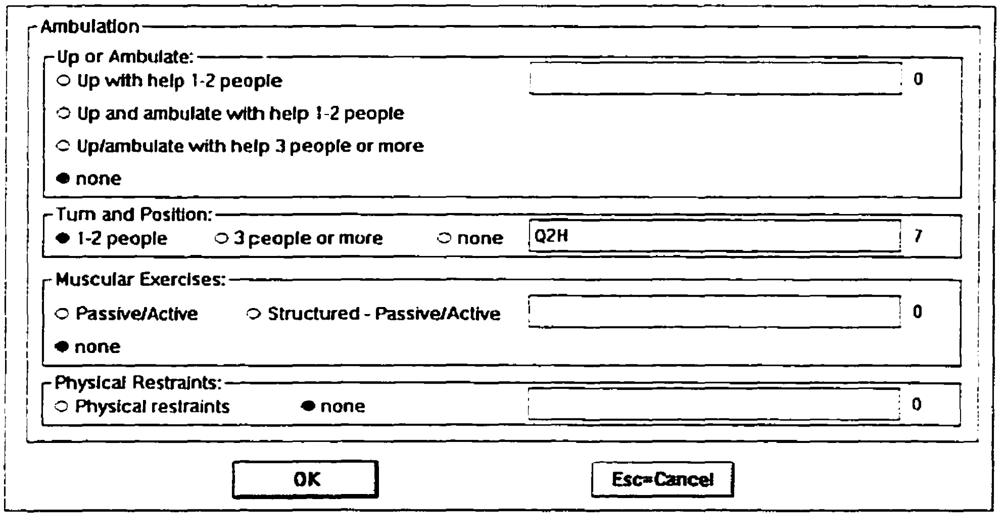

Figure 3.3: Ambulation Tasks Dialog Box

may be entered using the Medication dialog box shown in figure 3.4.

3.4.2 Nursing Care Plans

The user interface of the of the NWM module is very flexible, and allows creating care plans and automatically calculating the PRN score for the care plan. This current design allows the user to create many care plans per patient. To have more control over this process, the system developers would need to change the interface to accommodate one-to-one plan creation. For each bed, a file dedicated to nursing care plan may be kept. Then, the user would need only to select the bed number, and the corresponding file which is assigned to the specified bed may be opened. This eliminates the need for archiving the collection of nurse care plans, but it also means that once a care plan is edited for changes, the changes will overwrite the original, which may not be desired by the user. The interface is designed such that a care plan may be created for a patient even if a patient is not currently registered in the ICU. This makes the NWM module interface more flexible and is particularly useful when the nurse needs to prepare a care plan for a patient that will be admitted in the ICU at a future time.

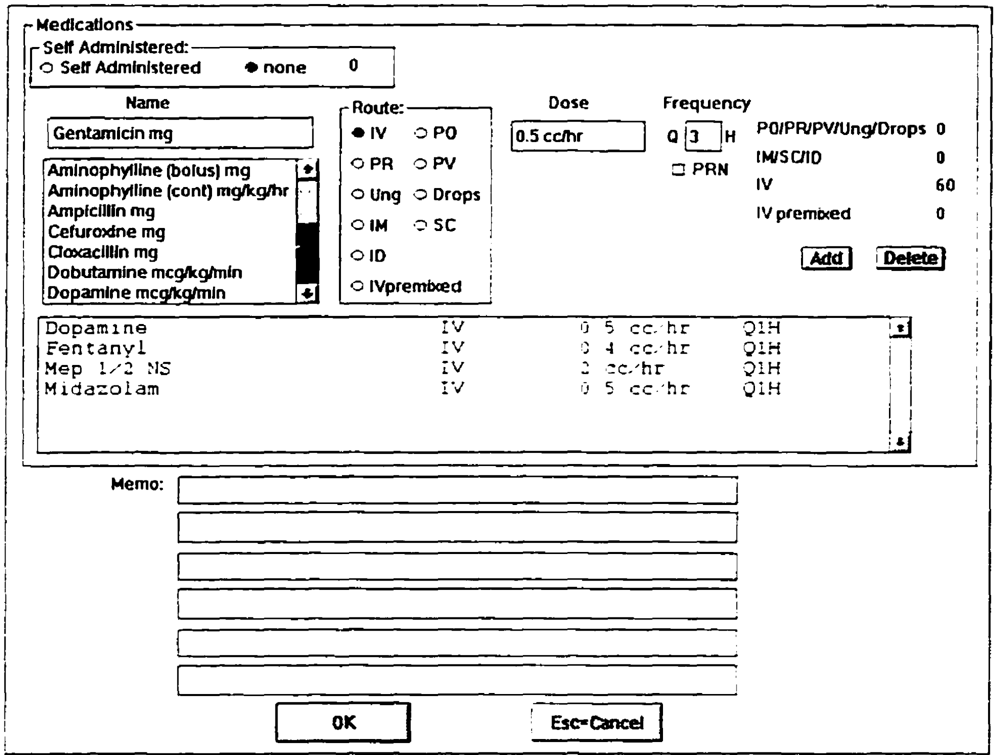

Figure 3.4: Medication Dialog Box

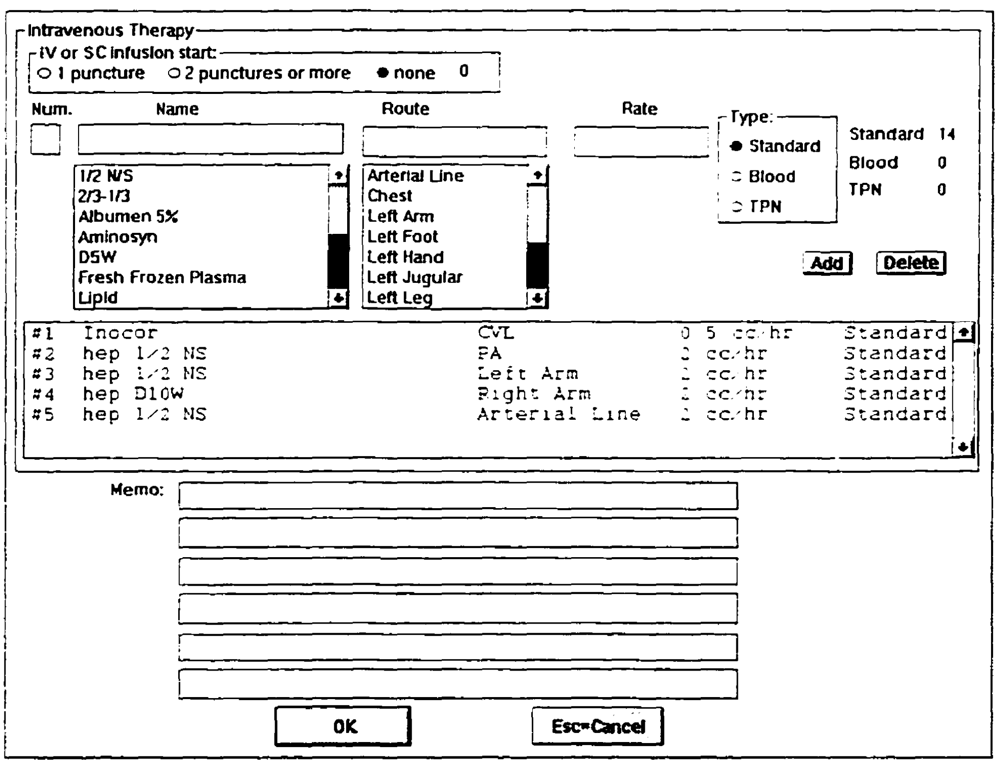

Figure 3.5: Intravenous Therapy Dialog Box

Column Name	Data Type	Number of Bytes	Comment
Patient_ID	string	9	
NCP_ID	string	26	Nurse Care Plan ID.
Diagnosis	string	40	
Diagmemo	string	40	
Allergies	string	30	
Notes	string	256	
Operations	string	120	
Total_Points	string	4	Total PRN points for the Nurse Care Plan.

Table 3.4: Contents of the NCP Table

Column Name	Data Type	Number of Bytes	Comment
NCP_ID	string	26	
Task_ID	numeric	4	
Frequency	string	15	Times per day task performed.
Points	string	4	PRN points.
Memo	string	30	

Table 3.5: Contents of the Task Table

Column Name	Data Type	Number of Bytes	Comment
NCP_ID	string	26	
Name	string	30	Medication name.
Route	string	20	
Dosage	string	15	
Frequency	string	15	
PRNTag	string	6	
Points	string	4	PRN points.

Table 3.6: Contents of the Medication Table

Column Name	Data Type	Number of Bytes	Comment
NCP_ID	string	26	
Number	string	4	
Name	string	32	Solution name.
Route	string	15	
Rate	string	15	
TypeTag	string	9	
Points	string	4	PRN points.

Table 3.7: Contents of the Solutions Table

Saving and Retrieving Care Plans

When the user has edited the care plan, and is satisfied with the changes and wishes to save the care plan, the save item of the pull-down menu in the NWM's main window may be used to do so. Once this item is pressed, the application saves the nursing care plan under the file name specified by the user and also automatically into the PDMS Database. The database representation of a nursing care plan is shown in figure 3.7. The data from the nursing care plan is saved in the database in different database tables, depending on the type of data. Information such as the patient identification number, diagnosis of the doctor, allergies information, nurse's comments, etc, is referred to as the care plan header and it is saved into the 'NCP' table, whose contents are described in table 3.4. The medication and solution information are saved separately in the 'Medication' and 'Solutions' database tables, whose description is included in tables 3.6 and 3.7, respectively. And lastly, all the remainder of the tasks are saved in the 'Task' table, described by table 3.5. The current design of the NWM module is such that new data is appended to the old data in the database table.

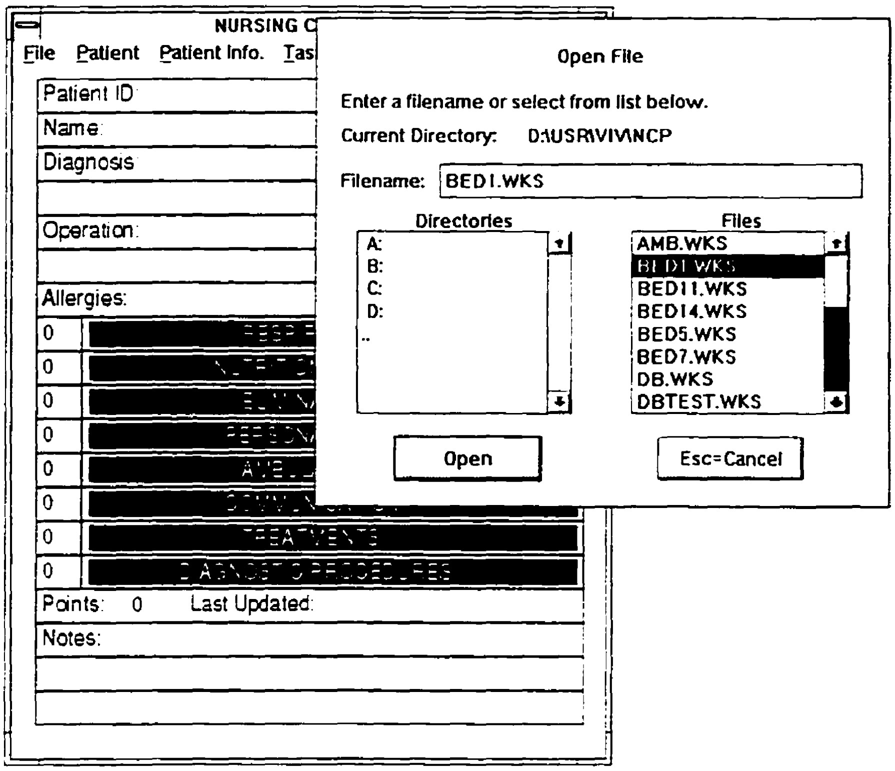

Figure 3.6: Open an Existing Care Plan Dialog Box

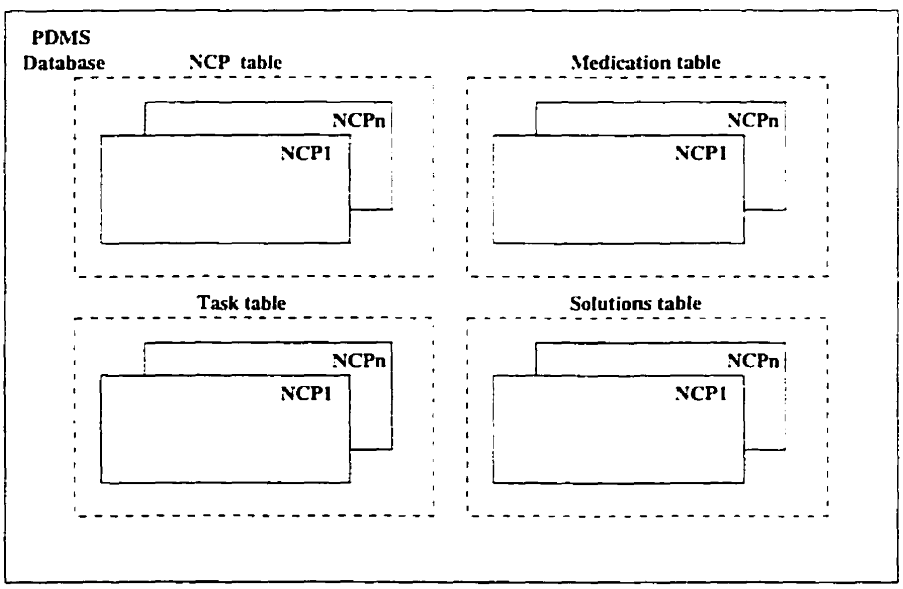

Figure 3.7: Database Representation of Nursing Care Plans

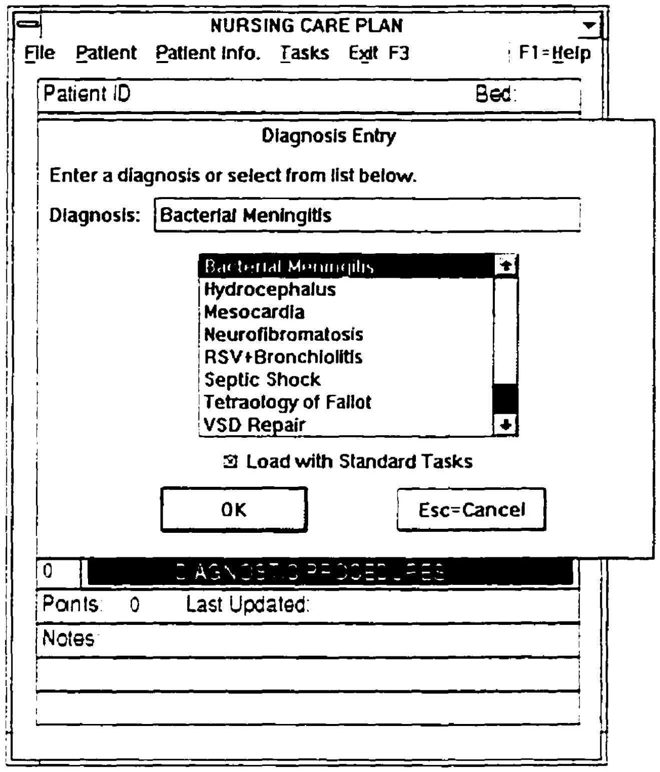

Figure 3.8: Diagnosis Selection Dialog Box

Library of Standard Nursing Care Plans

The standard nursing care plans library is a collection of pre-prepared care plans. These care plans exist in the nursing care plan working directory.

By clicking on the 'Diagnosis' field of the NWM window, the user may select to load the tasks that are specific to a diagnosis that appears in the window, or load the general tasks. Figure 3.9 shows the dialog from which the nurse may select diagnosis specific tasks.

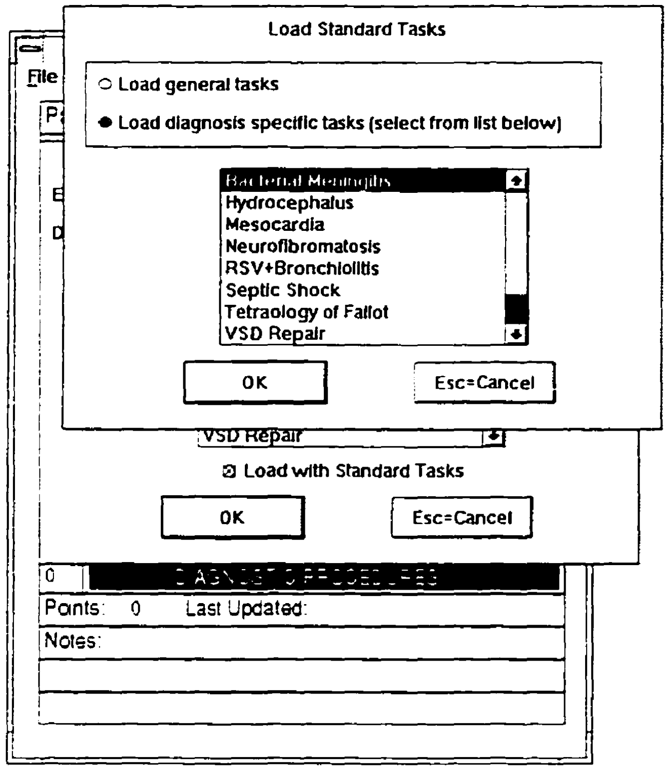

Figure 3.9: Loading Diagnosis Specific Tasks Dialog Box

3.5 The Nursing Workload Scheduler module

3.5.1 Functional Description

The Nursing Workload Scheduler module generates nursing care plan schedules. It is designed to support the Nursing Workload Manager module by reducing the workload of the nurse which must manually generate a schedule and hence contributing to the enhancement of the quality of patient care. The Nursing Workload Scheduler module consists of an expert system which can perform a general schedule once sufficient information is provided. The tasks submitted to the Nursing Workload Scheduler module for the scheduling process come from the eight categories in the nurse care plan: respiration, nutrition and hydration, elimination, personal care, ambulation, communication, treatments, and diagnostic procedures. However the user may enter another task that is not in one of the above categories by specifying its priority with respect to the other tasks so that the scheduler algorithm may find the appropriate time slot for it.

The Nursing Workload Scheduler module accesses the PDMS Database to retrieve the data of the nursing care plans. It presents each task on a user interface permitting the user to modify, delete, or add new tasks, as mentioned above. Once the tasks submitted to the expert system are properly initialized, the Nursing Workload Scheduler automatically resolves time conflicts and generates one or more complete schedules [Sun, 1994]. Figure 2.11 shows the main window of the Nursing Workload Scheduler module with a listbox displaying the schedule for a "selected bed" which becomes highlighted in that window. The NWS consists of the user interface, and the expert system. The user interface allows the user to select beds for scheduling, and edit the scheduling parameters, such as the priority of tasks, starting time, frequency of tasks, and so on.

The expert system is behind the actual scheduling process, or assigning time slots for the tasks submitted for scheduling. The expert system of the NWS module has been implemented using Nexpert Object, which is a commercially available knowledge-based program that is used to build expert systems.

The objective of the NWS module is to provide support for the Nursing Workload Manager module by automatically generating nursing schedules of tasks in the ICU for multiple patients and multiple nurses. The schedules generated by the scheduler are patient-oriented. The scheduler simply assigns a time for each task for a selected patient without any reference to a specific nurse who should perform the task.

3.5.2 Scheduling Parameters

The scheduler program requires certain parameters to be known and fixed. These parameters are:

1) the number of nurses, 2) for each task, the priority of the category to which the task belongs to, the priority of the task on that category, the time duration of time the task is performed, the frequency of executing the task during the day, and the period of time between successive times to perform that task, and finally the starting time of the task. To carry out the scheduling procedures, the NWS module utilizes three additional tables shown in table 3.8, 3.9, and 3.10.

Table 3.8 shows the hierarchy of Nursing Interventions. These tasks constitute the bulk of the nursing interventions. This table was adopted from recommendations by nursing staff manager at the Pediatric Intensive Care Unit of the Montreal Children's Hospital.

Other default scheduling parameters are kept in the Scheduling_Info database table whose contents are described in table 3.9. This table contains information such as the task duration, default task frequency, as adapted from the PRN System Scoring Form.

All the other parameters are specified by the user at the time of nursing care plan creation or through the NWS user interface, after loading the tasks of the nursing care plan from the database but before scheduling.

3.6 History Keeping

History will be entered and kept in the database using the NTA module, which is described in section 3.8. Table 3.11 lists the contents of the table that will contain the history of what got done from the scheduled plan of care for any patient. The table contains Patient_ID as the primary search key into the database, schedule date and time, the time the task was done, and identification of the person who carried out the nursing intervention.

Hierarchy of Nursing Interventions
(From High Priority to Low Priority)

Hierarchy	Task	Comment
1	Medications (all types)	
2	Specimens (all types) Vital Signs Neurological Signs Pulmonary Artery Catheter Monitor Intake or Output	All equal priority
3	Suctioning	
4	Chest Physiotherapy	
5	Turn and Position	
6	Care of urethral catheter Dressing (all kinds) Weigh or measure Bed bath (personal hygiene)	All equal priority
7	All other tasks	Equal in priority

Table 3.8: Priority of Nursing Interventions

Column Name	Data Type	Number of Bytes	Comment
Task_ID	string	20	
Task_Name	string	60	
Task_priority	numeric	4	Priority of the task.
Task_Length	numeric	4	Task duration.
Task_Frequency	numeric	4	
Period	numeric	8	

Table 3.9: Contents of the Scheduling_Info Table

Column Name	Data Type	Number of Bytes	Comment
Patient_ID	string	20	
Schedule_Time	string	10	Date when schedule produced.
Schedule_Date	string	10	Time when schedule produced.
Bed_Nbr	numeric	2	
Task_Description	string	20	Task specific title string.
Task_Index	numeric	2	
Task_Priority	numeric	2	As defined in table 3.8.
Start_Time	string	10	Task starting time.
End_Time	string	10	Task ending time.

Table 3.10: Contents of the Scheduled_Tasks Table

Column Name	Data Type	Number of Bytes	Comment
Patient_ID	string	20	
Schedule_Time	string	10	As in Scheduled_Tasks.
Schedule_Date	string	10	As in Scheduled_Tasks.
Task_Description	string	20	As in Scheduled_Tasks.
Start_Time	string	10	As in Scheduled_Tasks.
End_Time	string	10	As in Scheduled_Tasks.
Done_Time	string	10	Annotated done at time.
Nurse_ID	string	20	Nurse identification.

Table 3.11: Contents of the Done_Tasks Table

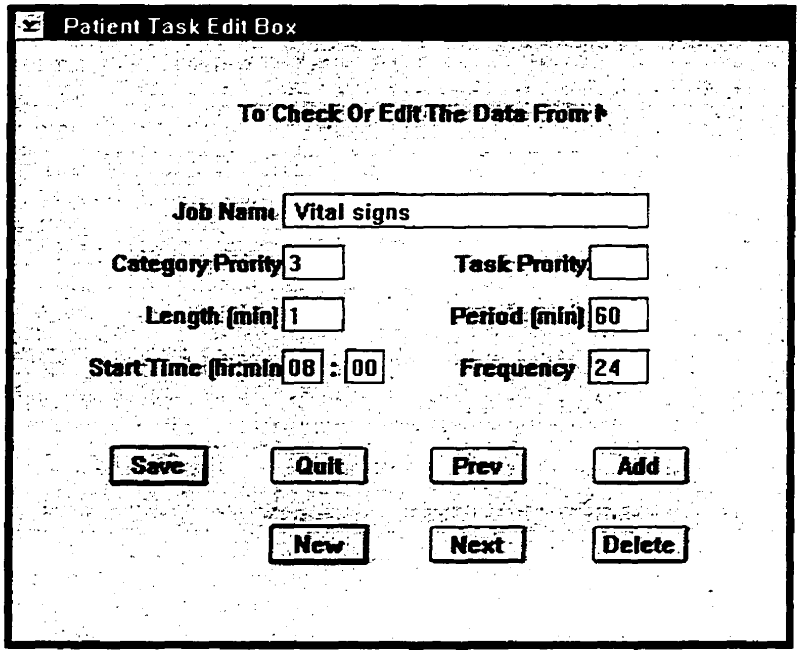

Figure 3.10: The Patient Task Editing Dialog Box

Retrieving Nursing Care Plans for Scheduling

When the user selects a bed (or a combination of beds) to schedule, the patient identification number is determined from the Registration file, and is used as the search key in the NCP table, from which the tasks belonging to the latest created Nursing Care Plan are fetched from the PDMS database. Refer to table 3.4 to view the contents of the NCP table. The tasks belonging to the latest created Nursing Care Plan for the specified patient id may be identified as having the latest NCP_ID. As the NCP_ID consists of the patient id along with the date and time of the Nursing Care Plan, the latest NCP_ID is determined using the SQL **MAX** function, which returns the maximum value in a set of values. Then all the tasks from the Medication, Solutions, and Tasks table having that NCP_ID are fetched for scheduling.

3.6.1 Saving the Schedule

The scheduled tasks are automatically saved into the database table dedicated for that purpose. Refer to table 3.10 to view the contents of that table. In this table, the Task_Description is a string which describes the task scheduled, and is it is such that:

- For a medication task, the Task_Description is a string consisting of the medication name, the dosage, and the route by which it is given.
- For a solutions task, the Task_Description is a string consisting of the solution name, and the dosage, and the rate.
- For any other task, the Task_Description is a string consisting of the default task name, as in table 3.9.

The schedule is also saved to a text file, for debugging purposes. This Scheduled_Tasks table is essentially a transient table, which contains the tasks that are to carried out, some of which will be left undone, others will be carried out and will be then placed in another table and may then be removed from the Scheduled_Tasks table or a flag may be added to this table to mark those tasks as done.

3.7 Un-scheduled Tasks Category

These tasks are the result of the scheduler not finding the proper time slot for a certain task. These un-scheduled tasks may be automatically dumped into a file, that may be sent to the printer, or the tasks in this category may be re-submitted by the user to the scheduler to put them in a separate schedule, which may be carried out by the same nurse or handed to another nurse to carry out.

3.7.1 Printing a Schedule

The schedule may be printed to a file or directly to a printer using Query Manager. With the scheduled tasks having been saved into the database, the user may run a SQL query using the **Queries** panel. Query Manager displays the result of the query in the Report panel, from which the user may choose to print the report to a file or to printer using the **Print** menu. Before running the query, the user can determine the format or the appearance of the report. For example, the report may have a header, the date or time, if the user chooses to.

3.7.2 Issues Related to Re-Scheduling

Many issues arise when the schedule generated by the nurse needs to be updated during the shift, for the purpose of incorporating a new nursing task into the current schedule, for example.

This may be done by fetching all the tasks scheduled after the current time from the 'Scheduled_Tasks' table, and fitting the new task(s) within those scheduled tasks. The user may simply add the information relevant to the new task(s), such as the task name, its priority, the time it is to be started, and then hits a specific key or button in the scheduling window, which indicates to the scheduling program that re-scheduling is required, and hence attempts to fit the new tasks within the tasks already scheduled. Once this new portion of the schedule has been generated, it could then replace the old portion of the schedule, which consisted of the tasks scheduled after the current time.

If the new task(s) cannot fit in within the currently scheduled tasks, the scheduling program would notify the user, who may decide to manage the new task(s) independently from the currently scheduled tasks.

This process of re-scheduling is almost invisible to the user, who needs only to enter the information about the new task(s) required for a particular patient, and specify to the scheduling program that re-scheduling is required.

An alternative way to achieve re-scheduling is to allow the user to alter the time of the tasks scheduled after the current time, before re-scheduling with the new task(s). However, the user must be cautious since, for example, altering the time of a scheduled medication may not be a safe thing to do, especially given that instances of the medication were given at a specific scheduled time.

Re-scheduling may also be designed to take into account and re-schedule all the tasks that were left undone. In this case, these tasks may be tagged to the user as undone, who may decide to increase or decrease their priority before re-scheduling them.

3.8 The Nursing Task Annotation module

3.8.1 Purpose

The objective of the Nursing Task Annotation (NTA) module is to relieve the nurse from the burden of documenting the execution of the nursing plan of care by computerizing this task, and it is designed as an extension to the Nursing Workload Manager module and the Nursing Workload Scheduler module. In this module, a list of nursing tasks generated by the Nursing Workload Scheduler is displayed in a form of a schedule which will be carried out during the nurse shift. In the window, the tasks are displayed as well as the time they are supposed to be carried out, the time they were carried out and the identification number of the person who has performed the task. The latter two items, namely time of task execution and nurse identification number are entered by the nurse. Each time the nurse logs a task being executed, the corresponding line of data is saved automatically into the PDMS Database. Since all this data is saved in the Database, it provides easy access to valuable information for quality assurance studies, which may be needed for health care quality improvement. Statistics on this data may be very easily generated by running simple database queries using SQL language.

3.8.2 Conceptual Description

The Nursing Task Annotation module is an interactive graphical user interface for displaying, monitoring and logging the execution of tasks produced with the NWS module. The NTA module can produce a visual as well as a sound alarm when the time of the nearest task time is within a certain predefined time tolerance.

3.8.3 User Interface

Figure 3.12 shows the Schedule Display window of the NTA module when a particular bed is selected from the bed layout window. As can be seen, the window contains an area for the patient scheduled tasks, in which each row contains the task name, start and end time, done time and signature. In the window there are three push buttons. The 'Started' button is used when a tasks is being started. The 'Completed' button is used when a task is completed, and the 'Help' button provides some help about how to use the NTA module windows.

Once the user clicks on the 'Completed' button in the Schedule Display window, the dialog box shown in figure 3.14 appears. The user can then fill in the information pertinent to the tasks that was executed, which includes the time the task was carried out, as well the identification of the user who carried it out. The 'Time' field of the tasks is pre-filled with the current time, which may be altered by the user. As well, the nurse is required to enter an identification number in the 'Nurse ID' field, and an optional "remark" may be entered in the 'Remark'. This data pertaining to the done task may then be saved into the 'Done_Tasks' table, whose contents

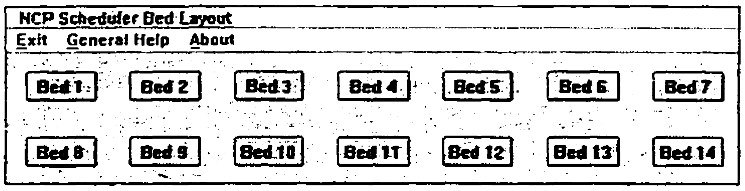

Figure 3.11: Bed Layout Dialog Box

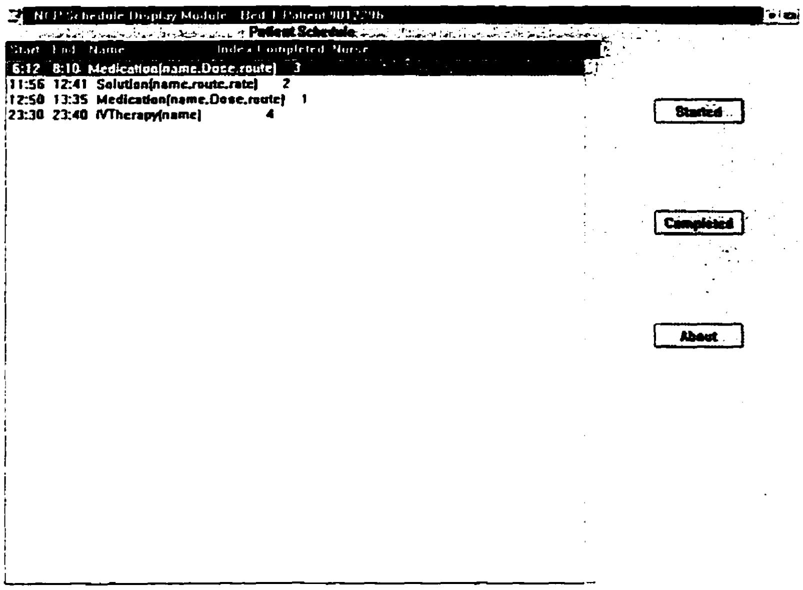

Figure 3.12: The Schedule Display Window of the NTA Module

are described in figure 3.11. The tasks that were completed may be tagged in the Scheduled_Tasks table with a flag indicating that they were done. This flag will be useful when re-scheduling, as tasks that are tagged done should not be taken into consideration. The NTA module is linked to the NWS module. This is achieved by having the scheduled tasks corresponding to a particular patient read from the database table 'Scheduled_Tasks', and having the annotated tasks also saved into the separate 'Done_Tasks' table in the database.

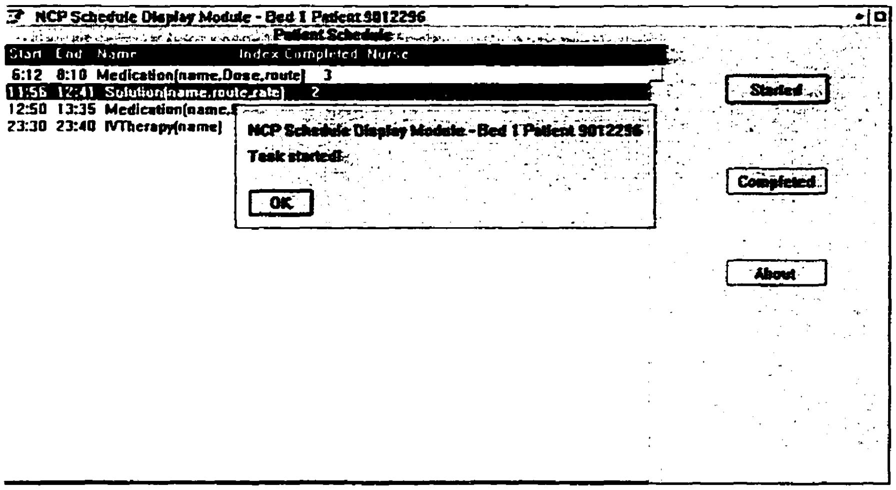

Figure 3.13: Starting to do a Task

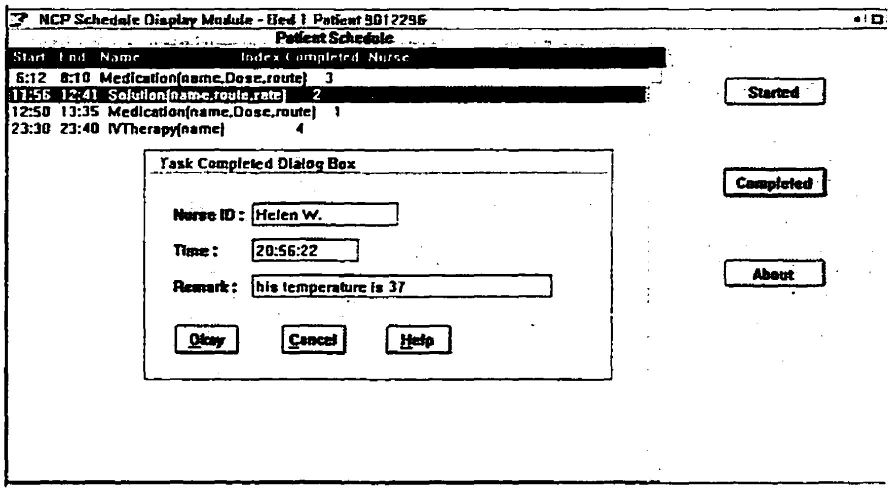

Figure 3.14: Dialog Box for Annotation of a Task Done

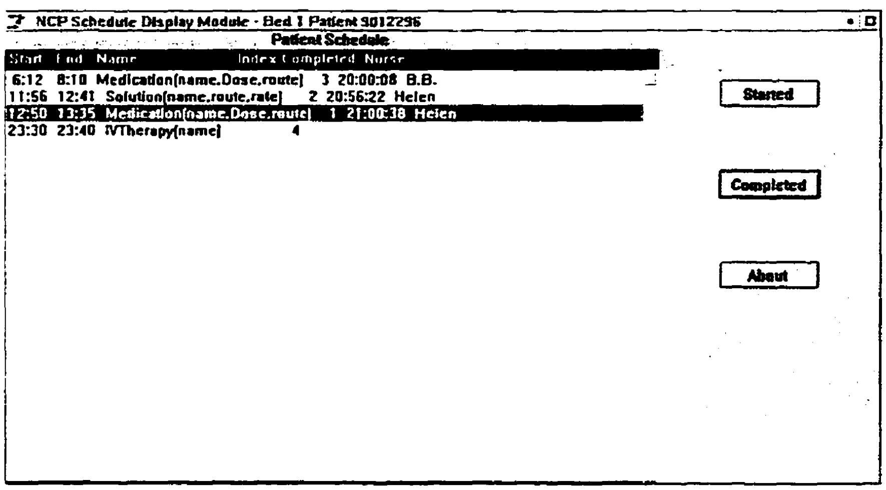

Figure 3.15: Screen Dump of Annotated Tasks in the NTA Window

Chapter 4 Implementation, Results, and Future Work

This chapter describes the implementation of the database, the integration of the modules comprising the NWMS, field testing results of the NWMS, as well as performance results of the NWMS.

4.1 Implementation

4.1.1 Database

The database is implemented using the relational database management services available from OS/2 Extended Edition Database Manager Version 1.3. The application uses SQL statements which are embedded in the C source code of the program to communicate with the Database Services. These embedded SQL statements act as a database programming language statements. These statements are preprocessed by the precompiler which in turn generates the language statements and the function calls that interface with the Database Services at run time to perform the functions specified by the embedded SQL statements.

The C source program is called the host language because it hosts the embedded SQL statements. Host variables are declared using a special area of the host language program that can be parsed by the precompiler and the host language compiler. The host variables can be accessed by the host language and referenced by SQL statements to retrieve data in them from Database Services.

When the nurse has created a nursing plan of care using the NWM module, and elects to save the care plan, whether under the same name or under a different name,

```
INSERT INTO NCP Patient_ID, NCP_ID, Diagnosis, Diagmemo,
Operations, Allergies, Notes, Total_Points
VALUES (?,?,?,?,?,?,?,?)
```

Figure 4.1: SQL Statement for Inserting into a Database Table

```
EXEC SQL
EXECUTE N1 USING :host_patient_id, :host_NCP_ID,
    :host_Diagnosis, :host_DiagMemo,
    :host_Operations, :host_Allergies, :host_Notes,
    :host_Total_Points;
```

Figure 4.2: SQL Statement for Inserting Data from Host Variables to Database Table

the care plan information is automatically saved by appending this information into the appropriate tables in the PDMS Database using SQL embedded C code.

For example, the SQL statement of figure 4.1 will insert into the fields mentioned, which relate to the Nursing Care Plan, in the NCP table.

Another SQL statement, shown in figure 4.2, then inserts the variables specified by the user by the host variables into the database.

When the nurse selects the patients for scheduling from the dialog box in the user interface, the NWS automatically calls the function that contains embedded SQL statements which essentially fetch all the data rows corresponding to a key from the pertinent database tables. The search key is the comprised of the patient ID and the time and date of the nursing care plan, all in one string.

```
SELECT FROM NCP MAX(NCP_ID) WHERE Patient_ID = ?
```

Figure 4.3: SQL statement for retrieving the latest NCP_ID

```
SELECT Task_Description, Start_Time, End_Time
FROM Scheduled_Tasks WHERE Bed_Nbr = ? , Start_Time >= '07:30:00'
ORDER ASC by Start_Time
```

Figure 4.4: SQL Statement for Retrieving Some of the Scheduled Tasks for a Particular Bed

4.1.2 User Interface

The NWM module and NWS module have been implemented under OS/2 version 1.3 operating system. The NTA module has been implemented under OS/2 Warp (version 3.0).

The NWMS can run on any OS/2 operating system of version 1.3 or a later version. In fact the NWMS has run successfully on OS/2 versions 1.3, 2.1 and Warp (3.0).

The NWMS ran in the Montreal Children's Hospital with the presence of a doctor and an expert nurse at the Pediatric Intensive Care Unit. The functionality of the system was demonstrated by selecting some nursing care plan records which had previously been carried out and submitting them to the NWM and NWS modules.

4.1.3 Producing a Hard Copy of the Schedule

A hard copy of the scheduler may be produced by running a simple query in the query manager. The report produced by the query manager may then be saved to text file which may in turn be sent to a postscript printer, or as an alternative the report may be sent directly to a printer. Figure 4.4 shows a SQL query used to produce a report for the scheduled tasks for test case 1, from within the query manager.

A listing of the schedule generated by the NWS for one of the supplied test cases is presented on pp. 63-67.

TASK NAME	START TIME	END TIME
Midazolam 2mcg/Kg/min	07:31:00	07:32:00
Ranitidine 3.5mg IV	07:32:00	07:35:00
Intake and Output	07:35:00	07:37:00
Specimens	07:37:00	07:40:00
Neurological signs	07:40:00	07:41:00
Pulmonary artery catheter	07:41:00	07:45:00
Turn and Position	07:45:00	07:55:00
Chest Dressing Change	07:55:00	08:05:00
Dopamine 4mcg/Kg/min	08:24:00	08:25:00
Neurological signs	08:25:00	08:26:00
Arterial line	08:26:00	08:27:00
Vital Signs observation	08:27:00	08:29:00
Fentanyl 5mcg/Kg/hr	08:29:00	08:30:00
Inocor 4mcg/Kg/hr	08:30:00	08:31:00
Midazolam 2mcg/Kg/min	08:31:00	08:32:00
Intake and Output	08:32:00	08:34:00
Central venous pressure	08:34:00	08:36:00
Pulmonary artery catheter	08:36:00	08:40:00
Dopamine 4mcg/Kg/min	09:24:00	09:25:00
Neurological signs	09:25:00	09:26:00
Arterial line	09:26:00	09:27:00
Vital Signs observation	09:27:00	09:29:00
Fentanyl 5mcg/Kg/hr	09:29:00	09:30:00
Inocor 4mcg/Kg/hr	09:30:00	09:31:00
Midazolam 2mcg/Kg/min	09:31:00	09:32:00
Intake and Output	09:32:00	09:34:00
Central venous pressure	09:34:00	09:36:00
Pulmonary artery catheter	09:36:00	09:40:00
Turn and Position	09:40:00	09:50:00
Dopamine 4mcg/Kg/min	10:24:00	10:25:00
Neurological signs	10:25:00	10:26:00
Arterial line	10:26:00	10:27:00
Vital Signs observation	10:27:00	10:29:00
Fentanyl 5mcg/Kg/hr	10:29:00	10:30:00
Inocor 4mcg/Kg/hr	10:30:00	10:31:00
Midazolam 2mcg/Kg/min	10:31:00	10:32:00
Intake and Output	10:32:00	10:34:00
Central venous pressure	10:34:00	10:36:00
Pulmonary artery catheter	10:36:00	10:40:00

Suctioning	11:21:00	11:24:00
Neurological signs	11:24:00	11:25:00
Arterial line	11:25:00	11:26:00
Vital Signs observation	11:26:00	11:28:00
Eye drops	11:28:00	11:29:00
Fentanyl 5mcg/Kg/hr	11:29:00	11:30:00
Inocor 4mcg/Kg/hr	11:30:00	11:31:00
Midazolam 2mcg/Kg/min	11:31:00	11:32:00
Intake and Output	11:32:00	11:34:00
Dopamine 4mcg/Kg/min	11:34:00	11:35:00
Central venous pressure	11:35:00	11:37:00
Pulmonary artery catheter	11:37:00	11:41:00
Turn and Position	11:41:00	11:51:00
Neurological signs	12:24:00	12:25:00
Arterial line	12:25:00	12:26:00
Dopamine 4mcg/Kg/min	12:26:00	12:27:00

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TASK NAME	START TIME	END TIME
Vital Signs observation	12:27:00	12:29:00
Fentanyl 5mcg/Kg/hr	12:29:00	12:30:00
Inocor 4mcg/Kg/hr	12:30:00	12:31:00
Midazolam 2mcg/Kg/min	12:31:00	12:32:00
Intake and Output	12:32:00	12:34:00
Central venous pressure	12:34:00	12:36:00
Pulmonary artery catheter	12:36:00	12:40:00
Arterial line	13:23:00	13:24:00
Central venous pressure	13:24:00	13:26:00
Dopamine 4mcg/Kg/min	13:26:00	13:27:00
Vital Signs observation	13:27:00	13:29:00
Fentanyl 5mcg/Kg/hr	13:29:00	13:30:00
Inocor 4mcg/Kg/hr	13:30:00	13:31:00
Midazolam 2mcg/Kg/min	13:31:00	13:32:00
Intake and Output	13:32:00	13:34:00
Specimens	13:34:00	13:37:00
Neurological signs	13:37:00	13:38:00
Pulmonary artery catheter	13:38:00	13:42:00
Turn and Position	13:42:00	13:52:00
Neurological signs	14:24:00	14:25:00
Arterial line	14:25:00	14:26:00
Dopamine 4mcg/Kg/min	14:26:00	14:27:00
Vital Signs observation	14:27:00	14:29:00
Fentanyl 5mcg/Kg/hr	14:29:00	14:30:00

Inocor 4mcg/Kg/hr	14:30:00	14:31:00
Midazolam 2mcg/Kg/min	14:31:00	14:32:00
Intake and Output	14:32:00	14:34:00
Central venous pressure	14:34:00	14:36:00
Pulmonary artery catheter	14:36:00	14:40:00
Suctioning	15:18:00	15:21:00
Neurological signs	15:21:00	15:22:00
Arterial line	15:22:00	15:23:00
Vital Signs observation	15:23:00	15:25:00
Ancef 70mg IV	15:25:00	15:28:00
Eye drops	15:28:00	15:29:00
Fentanyl 5mcg/Kg/hr	15:29:00	15:30:00
Inocor 4mcg/Kg/hr	15:30:00	15:31:00
Midazolam 2mcg/Kg/min	15:31:00	15:32:00
Ranitidine 3.5mg IV	15:32:00	15:35:00
Intake and Output	15:35:00	15:37:00
Dopamine 4mcg/Kg/min	15:37:00	15:38:00
Central venous pressure	15:38:00	15:40:00
Pulmonary artery catheter	15:40:00	15:44:00
Turn and Position	15:44:00	15:54:00
Neurological signs	16:24:00	16:25:00
Arterial line	16:25:00	16:26:00
Dopamine 4mcg/Kg/min	16:26:00	16:27:00
Vital Signs observation	16:27:00	16:29:00
Fentanyl 5mcg/Kg/hr	16:29:00	16:30:00
Inocor 4mcg/Kg/hr	16:30:00	16:31:00
Midazolam 2mcg/Kg/min	16:31:00	16:32:00
Intake and Output	16:32:00	16:34:00
Central venous pressure	16:34:00	16:36:00
Pulmonary artery catheter	16:36:00	16:40:00
Neurological signs	17:22:00	17:23:00

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TASK NAME	START TIME	END TIME
Arterial line	17:23:00	17:24:00
Central venous pressure	17:24:00	17:26:00
Dopamine 4mcg/Kg/min	17:26:00	17:27:00
Vital Signs observation	17:27:00	17:29:00
Fentanyl 5mcg/Kg/hr	17:29:00	17:30:00
Inocor 4mcg/Kg/hr	17:30:00	17:31:00
Midazolam 2mcg/Kg/min	17:31:00	17:32:00
Intake and Output	17:32:00	17:34:00
Pulmonary artery catheter	17:34:00	17:38:00

Turn and Position	17:38:00	17:48:00
Neurological signs	18:22:00	18:23:00
Arterial line	18:23:00	18:24:00
Central venous pressure	18:24:00	18:26:00
Dopamine 4mcg/Kg/min	18:26:00	18:27:00
Vital Signs observation	18:27:00	18:29:00
Fentanyl 5mcg/Kg/hr	18:29:00	18:30:00
Inocor 4mcg/Kg/hr	18:30:00	18:31:00
Midazolam 2mcg/Kg/min	18:31:00	18:32:00
Intake and Output	18:32:00	18:34:00
Pulmonary artery catheter	18:34:00	18:38:00
Arterial line	19:21:00	19:22:00
Neurological signs	19:22:00	19:23:00
Specimens	19:23:00	19:26:00
Vital Signs observation	19:26:00	19:28:00
Eye drops	19:28:00	19:29:00
Fentanyl 5mcg/Kg/hr	19:29:00	19:30:00
Inocor 4mcg/Kg/hr	19:30:00	19:31:00
Midazolam 2mcg/Kg/min	19:31:00	19:32:00
Intake and Output	19:32:00	19:34:00
Dopamine 4mcg/Kg/min	19:34:00	19:35:00
Pulmonary artery catheter	19:35:00	19:39:00
Central venous pressure	19:39:00	19:41:00
Suctioning	19:41:00	19:44:00
Turn and Position	19:44:00	19:54:00
Central venous pressure	20:22:00	20:24:00
Arterial line	20:24:00	20:25:00
Neurological signs	20:25:00	20:26:00
Dopamine 4mcg/Kg/min	20:26:00	20:27:00
Vital Signs observation	20:27:00	20:29:00
Fentanyl 5mcg/Kg/hr	20:29:00	20:30:00
Inocor 4mcg/Kg/hr	20:30:00	20:31:00
Midazolam 2mcg/Kg/min	20:31:00	20:32:00
Intake and Output	20:32:00	20:34:00
Pulmonary artery catheter	20:34:00	20:38:00
Central venous pressure	21:22:00	21:24:00
Arterial line	21:24:00	21:25:00
Neurological signs	21:25:00	21:26:00
Dopamine 4mcg/Kg/min	21:26:00	21:27:00
Vital Signs observation	21:27:00	21:29:00
Fentanyl 5mcg/Kg/hr	21:29:00	21:30:00
Inocor 4mcg/Kg/hr	21:30:00	21:31:00
Midazolam 2mcg/Kg/min	21:31:00	21:32:00
Intake and Output	21:32:00	21:34:00
Pulmonary artery catheter	21:34:00	21:38:00
Turn and Position	21:38:00	21:48:00

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TASK NAME	START TIME	END TIME
Central venous pressure	22:22:00	22:24:00
Arterial line	22:24:00	22:25:00
Neurological signs	22:25:00	22:26:00
Dopamine 4mcg/Kg/min	22:26:00	22:27:00
Vital Signs observation	22:27:00	22:29:00
Fentanyl 5mcg/Kg/hr	22:29:00	22:30:00
Inocor 4mcg/Kg/hr	22:30:00	22:31:00
Midazolam 2mcg/Kg/min	22:31:00	22:32:00
Intake and Output	22:32:00	22:34:00
Pulmonary artery catheter	22:34:00	22:38:00
Central venous pressure	23:19:00	23:21:00
Arterial line	23:21:00	23:22:00
Neurological signs	23:22:00	23:23:00
Vital Signs observation	23:23:00	23:25:00
Ancef 70mg IV	23:25:00	23:28:00
Eye drops	23:28:00	23:29:00
Fentanyl 5mcg/Kg/hr	23:29:00	23:30:00
Inocor 4mcg/Kg/hr	23:30:00	23:31:00
Midazolam 2mcg/Kg/min	23:31:00	23:32:00
Ranitidine 3.5mg IV	23:32:00	23:35:00
Intake and Output	23:35:00	23:37:00
Dopamine 4mcg/Kg/min	23:37:00	23:38:00
Pulmonary artery catheter	23:38:00	23:42:00
Suctioning	23:42:00	23:45:00
Turn and Position	23:45:00	23:55:00

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4.2 Evaluation Procedure

Evaluation scheme consisted of running the NWMS for real test cases of patients from the Pediatric Intensive Care Unit of the Montreal Children's Hospital. The Nursing Care Plans were taken from an expert nurse of the ICU and were entered through the NWM module.

Next the schedule for each test case was prepared by using the NWS module using default task priorities as found in table 3.8. The schedule was then shown to the nursing staff to get feedback about both the content and validity of the schedule produced.

Two test cases were provided by the nursing staff of the Montreal Children's Hospital. The nursing care plan tasks described in the paper form of the nursing care plan were entered through the NWM module, by clicking on the appropriate task in dialogs (refer to figure 3.3 for an example of these dialogs), and for the medication and solutions by entering the solution/medication name, its route, dose using the IV therapy and medication dialog boxes respectively (refer to figures 3.5 and 3.4). Then, the care plans were saved in the PDMS Database, after which the scheduler module in the NWS module was run, to produce the schedule for each test case. For test case 1, all the tasks were scheduled to start at 7:30AM, which is the shift starting time at the Montreal Children's Hospital. For test case 2, however, the tasks' starting time was varied such that different tasks would start at different times during the shift.

The priorities of the nursing interventions were selected to be the default values, which are according to table 3.8.

The length of the different tasks was selected to be the default value, as extracted from the PRN System Scoring Sheet.

For the frequency of the different tasks, the default value from the PRN System Scoring Form was also used. For the Vital Sign Monitoring, the frequency was set to the default which is once every hour, since the patient's vital signs are checked every hour.

For medications prescribed, the frequency entered by the user through the user interface was used.

For the purpose of testing the functionality of the NTA module, a set of tasks for a particular patient were created, independently of the NWS module, and were saved into the PDMS Database, in the 'Scheduled_Tasks' table. Later these tasks were retrieved from the database to the NTA module. Then, some of these tasks were annotated as 'done' using the NTA user interface, which resulted in saving the task history in the 'Done_Tasks' database table. This was verified by running an SQL query to check the contents of the PDMS database table 'Done_Tasks'.

4.2.1 Data Validation

Saving the Nursing Care Plan into Database

As was mentioned, the nursing care plans given on the paper form were entered using the NWM module, and saved under a specific file name and saved automatically into the database. To verify that the data of the nursing care plans was saved completely into the PDMS Database, SQL queries were run for each of the NCP, Task, Medication, and Solutions tables of the Nursing Care Plan, to verify that these tables indeed contained the tasks entered through the NWM module user interface windows. This was done for each of the test cases to verify that the tasks of the care plans were completely saved into the database.

Retrieving Nursing Care Plan for Scheduling

Once a patient is selected through the NWS menu, the application finds the Nursing Care Plan Identification Number, NCP_ID, corresponding to that Patient id, which has the recent date and time. This NCP_ID is used to reference the corresponding data in the 'Task', 'Medication', and 'Solutions' tables. The SQL statements used to fetch the NCP data from the corresponding Nursing Care Plan tables may be found in Appendix A. By reviewing the data fetched from the database through the Task Editing Dialog Box, shown in figure 3.10, it was verified that all the tasks found in the Task, Medication, and Solutions tables were correctly retrieved by using the SQL statements described in Appendix A.

4.3 Test Results

This section describes the result of running the given tests by the NWMS. In particular, it includes a description of the output schedules for the test cases, their content, validity, and comments of the nurses on these schedules.

4.3.1 Nursing Care Plan

The nursing care plans' data were all successfully transformed from the paper form of the nursing care plan to the computer by using the NWM module, these care plans were saved into the database to be retrieved by the scheduler program for scheduling the tasks.

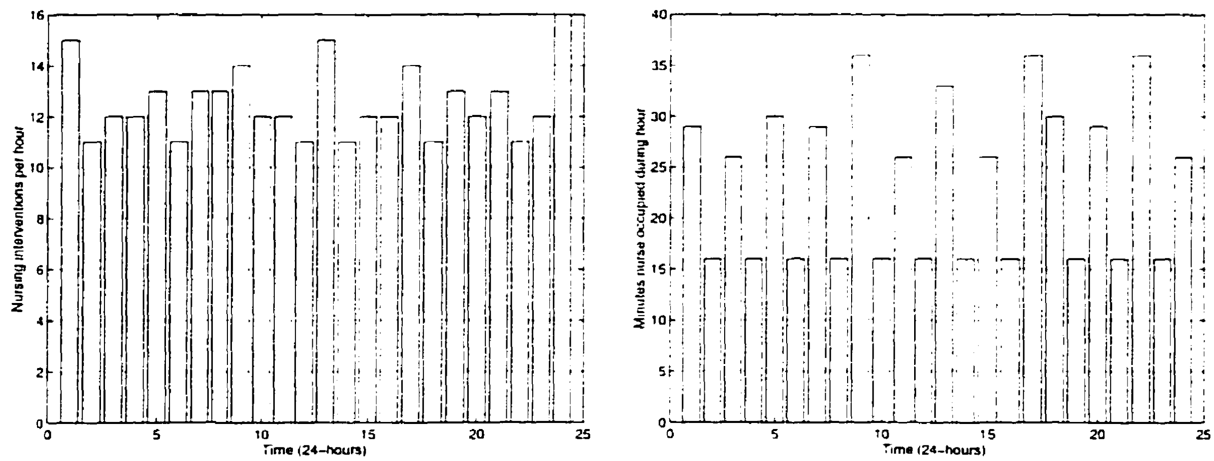
It was found that for all the test cases the correct number and relevant data for each task was saved into the database.

For scheduling, it was found that for all test cases, the nursing care plan activities were correctly and completely retrieved for scheduling using the SQL statements listed in Appendix A.

4.3.2 Scheduled Tasks Category

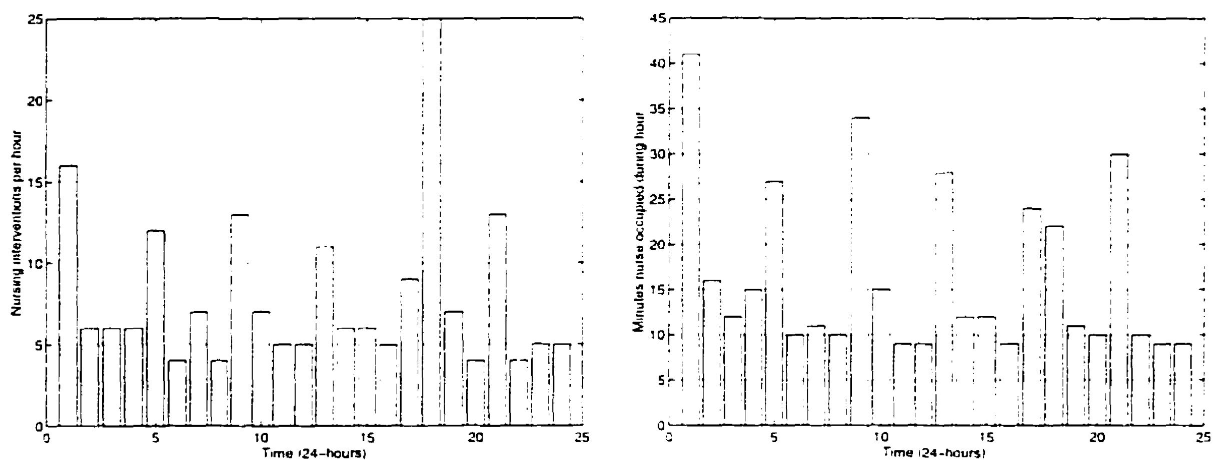
For all test cases that were entered using the NWM module, and run through the NWS module, no tasks were left unscheduled at the end of the scheduling process.

Figure 4.5 (left) shows interventions versus time for test case 1. Figure 4.5



Nursing Interventions During Hour   Minutes Nurse Occupied During Hour

Figure 4.5: Plots of Nursing Interventions and Busy Time for Test Case 1



Nursing Interventions During Hour   Minutes Nurse Occupied During Hour

Figure 4.6: Plots of Nursing Interventions and Busy Time for Test Case 2

(right) shows the number of minutes the nurse is busy during an hour of the shift for test case 1. As can be seen from the figure, the peak of the nursing activities, as generated by the scheduler is at the start, middle, and end of the shift, respectively. Figure 4.6 shows the corresponding figures for test case 2. The output of the NWS for test case 2, which is the scheduled tasks, may be found in Appendix B.

Test Case	Slack Factor
Test Case 1	64.38%
Test Case 2	72.57%

Table 4.1: Slack Factor

4.3.3 Slack Factor

The slack factor is defined to be the percentage of time the nurse is idle. The slack factor is calculated as:

$$\frac{\text{Total Time in Shift} - \text{Total Time Nurse is Busy}}{\text{Total Time in Shift}}$$

Using this relationship, the slack factor for the test cases is calculated, and is summarized in table 4.1. Although the slack factor appears to be very high, in reality the nurse takes a longer time to execute particular tasks. In other words, the nurse will be free as much as is indicated in table 4.1 if the tasks are started and ended exactly as scheduled.

4.3.4 Un-scheduled Tasks Category

Unresolved tasks are the result of not finding a proper time slot for a task. None of the test cases resulted in unresolved or unscheduled category of tasks, which is a favorable result.

4.3.5 Comments of an Expert Nurse

A copy of the schedule of the tasks for test case one, as was produced by the scheduler of the NWS module was given to an expert nurse in the Pediatric Intensive Care Unit of the Montreal Children's Hospital. The nurse concluded that the NWMS functions well as a scheduler. Upon reviewing the prescribed tasks, the nurse concluded that the schedule is clinically appropriate. In order for the schedule to be 'practically' helpful, the next stage of this project should involve a dynamic interface that is sensitive to the work schedules of nurses. For example, as a matter of convenience, it would be best to schedule things 'on the hour', particularly the routine tasks. The nurse also pointed out that the system could also help facilitate the tasks of nurses' 'archiving' of what is actually done, by asking the nurse to confirm when a task is actually done. The nurse pointed out that this would provide the system with the necessary information for creating a permanent record, and it would tell the system of things that are not done, so then the system could provide nurses with reminders, or if necessary, rearrange the schedule as more urgent things become overdue. Falling behind schedule is a reality, and sometimes less significant tasks can be left undone. The system could work more interactively with the nurse in managing these time pressures.

The current functionality of the Nursing Task Annotator module is such that it may serve as the provider of most of the functions mentioned in the previous paragraph, since its current design facilitates the annotation of done tasks, as well as generating a warning or a reminder when a task is left undone. Since this module is linked with the PDMS Database, all history of what got done could be saved into the database. Future work on that module would include introducing it to the nurses in the ICU, and add to it perhaps a 'Task Manager' which would with the, interaction of the nurses, manage the schedule during the course of the day.

4.4 Performance Results

This section describes performance results of the NWMS in terms of computational speed, and explores memory requirements of the system, in terms of projected memory storage requirements.

4.4.1 Computational Performance

The computational speed of the NWMS is found to be directly proportional to the speed of the NWS module. For both test cases, the data from the NWM module was saved into the database in under 1 second. As well, data to be scheduled by the NWS was retrieved from the database in under 1 second as well. Scheduling time varied for all the test cases depending on the time each task was scheduled to start. Scheduling time varied from 12 minutes to a few hours. Long execution times require further investigation. Once a schedule was produced by the NWS module, the resulting schedule was saved into the database in under 2 minutes for all test cases.

4.4.2 Memory Requirements

The maximum hard disk memory requirements per day of the NWM module is estimated as follows:

The total number of slots for the eight categories of nursing care (excluding medication and solution information) amount to 189 slots. These slots are part of the TASK table.

A single row in the Task table requires 79 bytes, while an entry in the Medication and Solution table require 116 bytes and 105 bytes respectively. Thus the total number of bytes for one bed are calculated as :

525 bytes for an entry in the NCP table +
79 bytes for an entry in the Task table $\times$ a maximum of 189 task slots +
116 bytes for a medication $\times$ 10 (assuming 10 medications per patient) +

105 bytes for a solution × 10 (assuming 10 solutions per patient) =
Total 17,999 bytes per bed.

This number is multiplied by 14 beds, which is the number of beds in the ICU, and it results in 0.247 M Bytes memory, per day. Per week that translates into 1.73 M Bytes of disk space per week, assuming full bed occupancy in the ICU.

This translates to 631.45 M Bytes (or 0.63 G Byte) of storage per year, if appending new data into the database for one year, assuming full bed occupancy every day of the year. This amount of memory can be easily obtained in hard disk storage.

4.5 Future Work

For the future, the scheduler may be modified to accept either a frequency at which the task is performed during the day, and calculate the period from that, or accept the period and calculate the frequency from that. The nursing staff think in terms of 'times per day' and thus it would be most suitable to accept a frequency from the user.

In the current implementation of the NWS module, the schedule, once it has been generated, is saved into a text file on the hard disk, and into the PDMS database. Currently, the schedule output by the NWS may be printed by using the printing utility of the OS/2 Query Manager. Providing a printing capability for the scheduler would be a desirable feature to add to the NWS. This would allow the nursing staff to produce a hardcopy of the schedule. As currently implemented, the tasks that do not get performed during a shift do not get re-scheduled for the next shift. To make the system complete, the scheduler must be further developed to be able to re-schedule the remainder of the tasks, or to be able to generate a new schedule after adding a new task to the current schedule.

During the preparation for scheduling phase, the user may alter the fields related to the frequency of a specific task. It is desirable to save these changes back into the Nursing Care Plan information so the next time the care plan is loaded, these changes will have been saved.

The NTA module has formally undergone the first phase of testing; the alpha test; during which testing of this module was performed in the research lab. The next phase of testing for this module will be the on-site test and the beta test, during which the NTA module will be introduced to the nursing staff of the ICU and be asked to use it.

A good addition to the user interface of the NTA module would be the ability to allow the user to enter a task that was not part of the schedule. For instance a nurse may take a temperature at a given moment. The user would then enter this observation at the time it was made. This would result in adding more flexibility to the interface.

Another improvement to the user interface of the NTA module would be to display a 'window' of time at one moment, for example, the window may be chosen to be an hour, in which case only the tasks within that hour would be displayed in the window and be visible to the user, while the rest of the tasks would be hidden. Then, the nurse may scroll backwards or forwards in windows of one hour time, for example.

The NWMS should be further tested in the field (i.e. in the hospital ICU) to determine whether the workload predicted by the system matches that predicted by the nursing staff. This process will provide a way to further refine the system to more reflect nursing needs. Specifically, test cases could be conducted to determine whether the PRN scoring produced by the system matches that calculated by the nurse.

The long execution times of the scheduling part of the NWS need further investigation. A future modification of this part of the NWS would be to re-write the expert part of the scheduler in CLIPS. It is estimated that this will cause the scheduling part to execute 1000 times faster. This gain in execution speed would be a very desirable effect since it will cause the scheduler to terminate and produce a schedule much faster.

As part of the future work on the NWMS, a training course or tutorial has to be designed for the nurses to familiarize them to the software, and to be able to use it correctly and safely. This may involve passing a test after learning the system. This training will also help the software developers to make the necessary updates to the system to ensure its reliability and validity.

Chapter 5 Conclusion

This thesis presented a computerized Nursing Workload Management System (NWMS) for the Patient Data Management System (PDMS) being developed for the Pediatric Intensive Care Unit (PICU) of the Montreal Children's Hospital.

A literature review of benefits of computerization in hospitals was presented. As well, issues of user interface, reliability of software, nursing documentation and quality of care improvement, and care delivery annotation were discussed. This was followed by a description of the hardware and software configuration of the PDMS, as well as a description of each of the its individual modules. The design, implementation and integration of the modules comprising the Nursing Workload Management System was described. The evaluation procedure, description of patient test cases preparation, and evaluation of the test cases was included. The evaluation of the NWMS shows that scheduler performance was acceptable, and useful scheduling results for the test cases were obtained. The user interface was found to be user friendly and functional. Preliminary evaluation of the NWMS by the care giver was positive. Further on site evaluation of the NWMS was recommended. The thesis concluded with some suggestions for future improvements to the system.

Glossary

API	Application Programming Interface
BP	Blood Pressure, an input parameter to the Expert Monitoring System
CASE	Computer-Aided Software Engineering
CliniCom	a bedside system designed to use either a portable hand-held terminal, a wall-mounted touch screen, or both to obtain data
CLIPS	an expert system shell
CPU	Central Processing Unit
CVP	Central venous Pressure, an input parameter of the Expert Monitoring System
CVS	Cardiovascular System
DLC	Data Link Controller, a software module of the Patient Data Management System
EMS	Expert Monitoring System, a real-time monitoring and warning expert system developed at McGill University for the patient data management system of the intensive care unit of the Montreal Children's Hospital
GPI	Graphics Programming Interface
HR	Heart Rate, an input parameter of the Expert Monitoring System
ICU	Intensive Care Unit
IV	Intravenous
NCP	Nursing Care Plan, a plan of care required for a patient

NTA	Nursing Task Annotator, computer software for annotating nursing tasks as they get done, developed at McGill University for the patient data management system of the intensive care unit of the Montreal Children's Hospital
NWM	Nursing Workload Manager, computer software for preparing nursing care plans, developed at McGill University for the patient data management system of the intensive care unit of the Montreal Children's Hospital
NWMS	Nursing Workload Management System, a computerized nursing workload management system, developed at McGill University for the patient data management system of the intensive care unit of the Montreal Children's Hospital
NWS	Nursing Workload Scheduler, computer software for scheduling the activities of nursing care plans, developed at McGill University for the patient data management system of the intensive care unit of the Montreal Children's Hospital
PDMS	Patient Data Management System, a personal computer-based information management system developed at McGill University for handling patient data in the intensive care unit of the Montreal Children's Hospital
PICU	Pediatric Intensive Care Unit
PM	Presentation Manager
PRN	Progressive Research in Nursing
RAM	Random Access Memory
VR	Virtual Reality
WMS	Workload Measurement Systems

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Appendix A SQL Statements for Interacting with PDMS Database

The SQL statements contained in this appendix are embedded in C language program corresponding to the module that they refer to. Through the use of SQL statements, data may be inserted into the database, as well, SQL statements may be used to query and fetch from the database specific data relevant to the module.

The following SQL statements insert the data from the nursing care plan information into the PDMS Database, through the NWM module interface. In particular the data is saved into the NCP, Task, Medication, and Solutions database tables.

Note: In all the following SQL statements, the '?' represents a host variable which holds the value corresponding to the field it represents.

To insert the general information of the nursing care plan:

INSERT INTO NCP Patient_ID, NCP_ID, Diagnosis, Diagmemo,
Operations, Allergies, Notes, Total_Points
VALUES (?,?,?,?,?,?,?,?)

To insert the tasks information of the nursing care plan:

INSERT INTO Task NCP_ID, Task_ID, Frequency, Points, Memo
VALUES (?,?,?,?,?)

To insert the medication information of the nursing care plan:

INSERT INTO Medication NCP_ID, Name, Route, Dosage,
Frequency, PRNTag, Points
VALUES (?,?,?,?,?,?,?)

To insert the solution information of the nursing care plan:

INSERT INTO Solutions NCP_ID, Number, Name, Route, Rate,
TypeTag , Points
VALUES (?,?,?,?,?,?,?)

The following SQL statements query the PDMS Database for the data that is relevant to the NWS module, which is essentially the information pertaining nursing plan of care. In particular the following SQL statements query the database tables NCP, Task, Medication, and Solutions.

Before the nursing care plan tasks pertaining to a patient identified by the Patient_ID may be fetched, the NCP_ID is found and retrieved from the NCP table.

The NCP_ID corresponding to a particular patient given its Patient_ID:

SELECT MAX(NCP_ID) from NCP where Patient_ID = ?

To retrieve the tasks for scheduling :

SELECT DISTINCT Task_Name, Task_priority, Task_Length, Period,
Task_Frequency FROM
Scheduling_Info, Task
WHERE Scheduling_Info.Task_ID = Task.Task_ID
and Task.NCP_ID = ?

To retrieve the medications for scheduling :

SELECT Name, Task_priority, Task_Length, Period,

```
Frequency FROM
Scheduling_Info, Medication
WHERE Scheduling_Info.Task_ID = 107
AND Medication.NCP_ID = ?
```

To retrieve the solutions for scheduling :

```
SELECT Name, Task_priority, Task_Length, Period,
Task_Frequency FROM
Scheduling_Info, Solutions
WHERE Scheduling_Info.Task_ID = 124
AND Solutions.NCP_ID = ?
```

Note: In the last two SQL statements, task id 107 corresponds to a medication task, and task id 124 corresponds to a solution task.

For saving the schedule produced by the NWS module into the PDMS Database, the following SQL statement is used :

```
INSERT INTO Scheduled_Tasks Patient_ID, Schedule_Time, Schedule_Date,
Bed_Nbr, Task_Description, Task_Index, Task_Priority,
Start_Time, End_Time
VALUES (?,?,?,?,?,?,?,?,?)
```

Appendix B Scheduled Tasks (Output of NWS) for Test Case 2

This appendix contains the output of the NWS module for test case number 2.

TASK NAME	START TIME	END TIME
Monitor (intake or output)	07:30:00	07:33:00
Chest physiotherapy	07:33:00	07:37:00
Analysis on Unit	07:37:00	07:40:00
Preventive skin care	07:40:00	07:43:00
Respiratory exercises	07:45:00	07:48:00
D 12.5% Nom.	07:51:00	07:52:00
Midazolam	07:52:00	07:53:00
Fentanyl	07:53:00	07:54:00
Lasix	07:54:00	07:57:00
Cefuroxine mg	07:57:00	08:00:00
artificial tears	08:00:00	08:03:00
Cisopide	08:03:00	08:06:00
Ranitidine	08:06:00	08:09:00
Observation	08:27:00	08:30:00
Monitor (intake or output)	08:30:00	08:33:00
Midazolam	08:59:00	09:00:00
Fentanyl	09:00:00	09:01:00
D 12.5% Nom.	09:01:00	09:02:00
Observation	09:27:00	09:30:00
Monitor (intake or output)	09:30:00	09:33:00
Suctioning	09:39:00	09:42:00
Midazolam	09:59:00	10:00:00
Fentanyl	10:00:00	10:01:00
D 12.5% Nom.	10:01:00	10:02:00
Observation	10:27:00	10:30:00
Monitor (intake or output)	10:30:00	10:33:00
Weight or Measure	10:53:00	10:59:00
Midazolam	10:59:00	11:00:00
Fentanyl	11:00:00	11:01:00
D 12.5% Nom.	11:01:00	11:02:00
Gavage feedings without pump	11:03:00	11:06:00
Burns - c.p.	11:24:00	11:27:00
Observation	11:27:00	11:30:00

Monitor (intake or output)	11:30:00	11:33:00
Chest physiotherapy	11:33:00	11:37:00
Preventive skin care	11:40:00	11:43:00
Respiratory exercises	11:45:00	11:48:00
D 12.5% Nom.	11:57:00	11:58:00
Midazolam	11:58:00	11:59:00
Fentanyl	11:59:00	12:00:00
artificial tears	12:00:00	12:03:00
Observation	12:27:00	12:30:00
Monitor (intake or output)	12:30:00	12:33:00
Midazolam	12:59:00	13:00:00
Fentanyl	13:00:00	13:01:00
D 12.5% Nom.	13:01:00	13:02:00
Observation	13:27:00	13:30:00
Monitor (intake or output)	13:30:00	13:33:00
D 12.5% Nom.	13:57:00	13:58:00
Midazolam	13:58:00	13:59:00
Fentanyl	13:59:00	14:00:00
Cisopide	14:00:00	14:03:00
Observation	14:27:00	14:30:00
Monitor (intake or output)	14:30:00	14:33:00
Midazolam	14:59:00	15:00:00
Fentanyl	15:00:00	15:01:00

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TASK NAME	START TIME	END TIME
D 12.5% Nom.	15:01:00	15:02:00
Gavage feedings without pump	15:03:00	15:06:00
Burns - c.p.	15:24:00	15:27:00
Observation	15:27:00	15:30:00
Monitor (intake or output)	15:30:00	15:33:00
Chest physiotherapy	15:33:00	15:37:00
Suctioning	15:39:00	15:42:00
Preventive skin care	15:42:00	15:45:00
Respiratory exercises	15:45:00	15:48:00
Midazolam	15:53:00	15:54:00
Ranitidine	15:54:00	15:57:00
Cefuroxine mg	15:57:00	16:00:00
artificial tears	16:00:00	16:03:00
Lasix	16:03:00	16:06:00
Fentanyl	16:06:00	16:07:00
D 12.5% Nom.	16:07:00	16:08:00
Observation	16:27:00	16:30:00

Monitor (intake or output)	16:30:00	16:33:00
Midazolam	16:59:00	17:00:00
Fentanyl	17:00:00	17:01:00
D 12.5% Nom.	17:01:00	17:02:00
Observation	17:27:00	17:30:00
Monitor (intake or output)	17:30:00	17:33:00
Midazolam	17:59:00	18:00:00
Fentanyl	18:00:00	18:01:00
D 12.5% Nom.	18:01:00	18:02:00
Observation	18:27:00	18:30:00
Monitor (intake or output)	18:30:00	18:33:00
Midazolam	18:59:00	19:00:00
Fentanyl	19:00:00	19:01:00
D 12.5% Nom.	19:01:00	19:02:00
Gavage feedings without pump	19:03:00	19:06:00
Burns - c.p.	19:24:00	19:27:00
Observation	19:27:00	19:30:00
Monitor (intake or output)	19:30:00	19:33:00
Chest physiotherapy	19:33:00	19:37:00
Preventive skin care	19:40:00	19:43:00
Respiratory exercises	19:45:00	19:48:00
Midazolam	19:56:00	19:57:00
Cisopide	19:57:00	20:00:00
artificial tears	20:00:00	20:03:00
Fentanyl	20:03:00	20:04:00
D 12.5% Nom.	20:04:00	20:05:00
Observation	20:27:00	20:30:00
Monitor (intake or output)	20:30:00	20:33:00
Midazolam	20:59:00	21:00:00
Fentanyl	21:00:00	21:01:00
D 12.5% Nom.	21:01:00	21:02:00
Observation	21:27:00	21:30:00
Monitor (intake or output)	21:30:00	21:33:00
Suctioning	21:39:00	21:42:00
Midazolam	21:59:00	22:00:00
Fentanyl	22:00:00	22:01:00
D 12.5% Nom.	22:01:00	22:02:00
Observation	22:27:00	22:30:00
Monitor (intake or output)	22:30:00	22:33:00

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TASK NAME	START TIME	END TIME
Midazolam	22:59:00	23:00:00

Fentanyl	23:00:00	23:01:00
D 12.5% Nom.	23:01:00	23:02:00
Gavage feedings without pump	23:03:00	23:06:00
Burns - c.p.	23:24:00	23:27:00
Observation	23:27:00	23:30:00
Monitor (intake or output)	23:30:00	23:33:00
Chest physiotherapy	23:33:00	23:37:00
Preventive skin care	23:40:00	23:43:00
Respiratory exercises	23:45:00	23:48:00
artificial tears	00:00:00	00:03:00
Cefuroxine mg	00:03:00	00:06:00
Lasix	00:06:00	00:09:00
Ranitidine	00:09:00	00:12:00
Fentanyl	00:12:00	00:13:00
Midazolam	00:13:00	00:14:00
D 12.5% Nom.	00:14:00	00:15:00
Observation	00:27:00	00:30:00
Monitor (intake or output)	00:30:00	00:33:00
Midazolam	00:59:00	01:00:00
Fentanyl	01:00:00	01:01:00
D 12.5% Nom.	01:01:00	01:02:00
Observation	01:27:00	01:30:00
Monitor (intake or output)	01:30:00	01:33:00
D 12.5% Nom.	01:57:00	01:58:00
Midazolam	01:58:00	01:59:00
Fentanyl	01:59:00	02:00:00
Cisopide	02:00:00	02:03:00
Observation	02:27:00	02:30:00
Monitor (intake or output)	02:30:00	02:33:00
Midazolam	02:59:00	03:00:00
Fentanyl	03:00:00	03:01:00
D 12.5% Nom.	03:01:00	03:02:00
Gavage feedings without pump	03:03:00	03:06:00
Burns - c.p.	03:24:00	03:27:00
Observation	03:27:00	03:30:00
Monitor (intake or output)	03:30:00	03:33:00
Chest physiotherapy	03:33:00	03:37:00
Suctioning	03:39:00	03:42:00
Preventive skin care	03:42:00	03:45:00
Respiratory exercises	03:45:00	03:48:00
D 12.5% Nom.	03:57:00	03:58:00
Midazolam	03:58:00	03:59:00
Fentanyl	03:59:00	04:00:00
artificial tears	04:00:00	04:03:00
Observation	04:27:00	04:30:00
Monitor (intake or output)	04:30:00	04:33:00
Midazolam	04:59:00	05:00:00

Fentanyl	05:00:00	05:01:00
D 12.5% Nom.	05:01:00	05:02:00
Observation	05:27:00	05:30:00
Monitor (intake or output)	05:30:00	05:33:00
Midazolam	05:59:00	06:00:00
Fentanyl	06:00:00	06:01:00
D 12.5% Nom.	06:01:00	06:02:00
Observation	06:27:00	06:30:00

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TASK NAME	START TIME	END TIME
Monitor (intake or output)	06:30:00	06:33:00
Midazolam	06:59:00	07:00:00
Fentanyl	07:00:00	07:01:00
D 12.5% Nom.	07:01:00	07:02:00
Gavage feedings without pump	07:03:00	07:06:00
Intubation	07:19:00	07:24:00
Burns - c.p.	07:24:00	07:27:00
Observation	07:27:00	07:30:00

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IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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