Educational Process Modelling with Workflow and Time Petri Nets

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Abstract

The research presented in this thesis describes how to use workflow management technology to model educational processes with a time axis.

As workflow management technology has been widely used in modelling business processes, it has the potential to model educational processes. Based upon the components of workflow, educational processes and business processes have many common features such that educational processes can be modelled with workflow management technology. In addition, owing to the importance of the time component in processes, time Petri nets have been chosen as the design language for the modelling of the educational processes. The notation of time Petri nets has been illustrated in this thesis for the educational process.

In this thesis, three different educational processes have been presented and modelled with workflow management technology as well as with time Petri nets individually. Furthermore, the architecture of the educational process management system has been constructed by adopting the reference model from the Workflow Management Coalition.

To show the validity of using workflow management technology in the education domain, a sub-process of an educational process has been modelled and developed with certain developing techniques. It provides the potential research direction for further research on the modelling of educational process with workflow technology associated with a time component.

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Chapter 1. Introduction

1.1. Background

Workflow management technology is described as a technology that is able to manage, coordinate, and control the activities of a business process (Meng, Su, Lam, & Helal, 2002). Actually, a business process is defined with business events and rules. When business events are executed, they are enforced under business constraints, policies, strategies, and regulations, specified by rules.

The technology has been utilised to model many specific business processes (Ailamaki, Loannidis, & Livny, 1998; Buford, Hefter, & Matheus, 1998; Iwaihara, Jiang, & Kambayashi, 2004; Vouk, 1998; Xu, Qiu, & Xu, 2003). The flexibility features are required because of the nature of business processes. Therefore, some researchers are focused on establishing successful workflow models which have the capability to model dynamic changes of the business environment as their business is running (Cichoki & Rusinkiewicz, 1999; Meng et al., 2002).

However, an educational process has its own characteristics once it has been modelled and executed. An educational process indicates a pedagogy that includes theory teaching, practice, and educational strategies. A variety of processes relevant to educational areas comprise the educational system, whereas all kinds of educational activities are elements for the process in a defined order. In this thesis, an educational process will be analysed and modelled as the focus of the research.

Currently, there is a variety of research on the modelling of educational processes either with (Mangan & Sadiq, 2002) or without workflow technology (Fung & Ruan, 2004; Huitt, 2003; Martin, 2001; Rokou, Rokou, & Rokos, 2004; Shor & Robson, 2000). But none of them models the educational process integrated with time components. An exception is that Fung and Ruan (2004) integrate time concepts but only into course planning, although time is an important and integral part of all components in the educational process.

As workflow management technology has been widely used for modelling the business process, it provides the potential ability to improve its efficiency. Most business processes are concerned with modelling across different departments, manufacturers, or even different companies (Chiu, Cheung, Karlapalem, Li, & Till, 2004; Vidal, Lama, Bugarfn, & Barro, 2003; Xu et al., 2003). Therefore, in this thesis, the technology leads to a model of educational processes after a comparison of these two processes: business and educational processes. The author argues that the workflow management technology is equally applicable in modelling and analysing educational processes. For instance, Mangan and Sadiq (2002) suggest using workflow technology to model flexible processes in academic programmes.

Therefore, there is a gap between workflow technology and the emphasised time component for modelling educational processes. The purpose of this research is to fill this gap.

1.2. Motivation

Most current educational systems only use computer technology along with network technology to enhance functions of the educational system. In addition, previous research about workflow in the educational field always focused on utilising advanced information technology to map educational systems in the workflow model. Because of the very nature of an educational system, students and teaching staff involved in education can be treated as an individual node in the educational system with each node having been assigned tasks. For students, they must choose several papers for their study programmes and they also participate in the study procedures of papers for the completion of their programmes.

The concept of time is the natural feature which should be integrated into educational activities. For example, a paper has been scheduled with time, such as beginning classes, lecture timetable, assignment due date, and examination time. Furthermore, each participant in the educational system also has other tasks besides study tasks, like the enrolment procedure, or the procedure on borrowing and returning books to the library, which also have time constraints. Therefore, the concept of time-driven workflow management is the basic idea on modelling educational processes in this thesis.

The educational system consists of diverse processes. No matter which event is occurring, single or multiple processes occur and schedule in parallel, sequence, or asynchrony to reach the final point of the event as output. To model all kinds of educational processes is an effective and efficient way to construct the educational system. Concerning the term 'process', it represents the bridge to fill up the gap between the education domain and the model derived from workflow management technology. The educational process has the potential to be organised and managed by the employment of the workflow technology which created efficiency in the business domain. It is the motivation for this research.

1.3. Scope

The research focuses on modelling various educational processes grouped by the characteristics of their features. In addition, owing to the concept of time in educational processes, they will be modelled by appropriate language associated with workflow management technology and time. After modelling these processes, the architecture for the educational management system will be worked out.

However, due to the limitation of research time available, the development of a comprehensive architecture for an educational system is beyond the scope of this project. Nonetheless, an important component of the architecture will be developed to verify the validity of using this technology and time concept to model educational processes and to construct the educational management system.

1.4. Research Questions

In this research, the author is trying to use workflow technology associated with a time component to model educational processes. To achieve such a purpose, several questions should be answered progressively

- What are the conceptual requirements for process-oriented educational activity modelling?
- Why has workflow technology been chosen and utilised in the modelling of educational processes in this research?
- When workflow technology has been used in educational process modelling, what aspects of the system would become more efficient and effective derived from the application of such technology?
- As modelling tools are essential in modelling various processes, why choose Petri nets as the modelling tool in this research after analysing several other modelling tools?
- Why does time have to be emphasised in modelling educational processes? What is the function that time plays in educational processes? What are the advantages of using a

time component in modelling educational processes besides the original time concept in the workflow technology?

- How has the time concept been integrated with classical Petri nets to model the educational processes?
- How would various educational processes be modelled with workflow technology and time component using time Petri nets?
- What are the advantages of using such technology in modelling educational processes? What should be highlighted in this research? In addition, what further developments can be explored in this field from this research?

1.5. Aims and Objectives

The aims of the research are:

- To identify the common features of educational processes and business processes.

  Note: After analysing these processes, this work addresses and distinguishes the common characters of both processes. This is the basic step in setting up an educational process model, with the technology to model business processes.

- To investigate aspects concerned in the development of the underlying reference model of business processes, which will contribute to the development of the model for educational process with workflow management technology.

  Note: From the current study of workflow management technology in business, aspects considered to build a suitable reference model in different business processes need to be investigated for the educational processes.

- To develop models for various educational processes using both workflow technology and timing components.

Note: After stating the characteristics of educational processes and after considering aspects in setting up business process models, this will contribute to the establishment of these models for various educational processes with workflow technology. In addition, as timing is the significant component integrated in various educational activities, the functions of timing in educational processes will be illustrated and expressed. Therefore, timing is emphasised in modelling educational processes besides the workflow technology.

- To improve the efficiency of educational processes, the time component has been expressed and emphasised in the model.

  Note: Although the traditional workflow process has a time notion, it is considered as inadequate in representing the time features in the educational process. For an educational process, time is the axis and mainstream of the process that leads the process to move from one status to another.

- To apply the model in one particular process as a case study.

  Note: To show the applicability of the model, one sub-process model will be developed as a case study. A web-based assignment management system is chosen to be implemented to show how the workflow technology and timing component work for the assignment management process, which is a small part of an educational process.

1.6. Methodology

The research will focus on how to model and manage various educational processes. In addition, the framework of an educational management system will be established based on previous efforts. Thus, the thesis adopts a research methodology from Bourner (1996).

- **Research the field of study**

  It is important to collect information on current educational systems and to analyse them to look for an appropriate technology that is applicable to the construction of the mechanism of the educational arena.

- **Develop a model or frame**

  The framework consists of all kinds of educational processes operating in educational programmes. At this stage, cataloguing different educational processes is the first step. After analysing them, applying workflow management technology is the approach to modelling these processes.

  Furthermore, an attempt will be made to establish a framework for the educational management system with such technology.

- **Test the model**

  Testing the whole model by developing a comprehensive all-round educational system is beyond the scope of the thesis. Therefore, a subprocess of the main educational process is chosen as a subset of an overall generic model. The established system for the subprocess is a reasonable compromise to verify the validity of the framework.

  Specifically, the assignment management process is chosen to demonstrate the whole lifecycle[1] of assignments from beginning to end, which is similar to other educational processes having life duration.

- **Evaluate and reflect**

  The last step of this research is to evaluate and reflect. Time is described as the most important component to be integrated in modelling the educational process. Time Petri [1]Lifecycle: the survival period of an object. utilised to present different educational processes. In addition, the assignment management process has been developed as a case study to test the workflow model. Following the time line of the lifecycle of assignments, time Petri nets present the status of the process under different time constraints.

1.7. Report Structure

The report has the following structure, which is aligned with the Aims and Objectives as set out in section 1.5 and the Methodology in section 1.6.

Chapter 1: Introduction

The background of this research is presented in this chapter to illustrate the reason to carry on this research direction, together with a description of the research problem and lists the main aims of the research.

Chapter 2: Educational Processes

This chapter elaborates the features of various educational processes. Then, from the viewpoint of education, educational processes have been classified into three different types. A number of process modelling tools are described. The reasoning behind the choice of the most effective tool to model the educational process according to the features of the educational process is explained. Moreover, the reason why various educational processes should be modelled with this modelling tool is discussed. In addition, the time component is shown to be an important component that should be considered in modelling such educational processes.

Chapter 3: Workflow Technology in Educational Processes

This chapter concerns the expression of the original concepts of workflow and reference models. The application of workflow management technology to business is investigated to form the educational process model. In addition, workflow concepts can be modelled with the model tool which was chosen in Chapter 2. The time concept which has been emphasised in workflow technology is integrated into workflow technology with the time features of the educational processes.

Chapter 4: Time Reasoning in Educational Processes

In Chapter 4, the issue of 'time' is emphasised in educational processes. A time component will be integrated into the process modelling tool associated with workflow technology to model various educational processes.

Various educational processes are also presented and analysed in this chapter. Petri nets have been chosen as the suitable design tool to model these educational processes owing to the features of educational processes. Hence, the time component has been emphasised and integrated into traditional Petri nets to model educational processes. In addition, from these process models, an attempt is made to construct an architectural model of the educational process system that focuses on every task related to education.

In addition, the time-driven concept has been raised as a significant component in modelling educational processes. Owing to the time concept, a temporal database is elaborated to store time information along with the general data.

Chapter 5: Case Study: A Web-based Assignment Management System

Chapter 5 shows previous research on the assignment management. According to the lifecycle of assignments and the function of the assignment management process, a part of the student learning process, implementation for the process model is an effective way to illustrate the validity of modelling educational processes with both workflow management technology and the time component. In addition, it has been evaluated with the assignment management part of WebCT. The result of this evaluation shows whether a time component and workflow technology deserve to be used in educational processes.

Chapter 6: Conclusions and Future Work

This final chapter provides a summary of the findings of this research and discusses their relevance to the main aims stated in Chapter 1. Furthermore, it discusses the future studies which may be addressed based on this research.

References - Referred articles and papers are listed.

Appendices - The user manual of a developed system and relevant publication from this project will be presented.

Chapter 2. Educational Processes

The previous chapter offered a general introduction that included motivations and objectives of this thesis, as well as the steps of the research methodology.

In this chapter, special features of the educational process will be presented from the perspective of the nature of education. Educational processes will been analysed and described into three different types. Each type of process has certain roles to play from its beginning to the end. Therefore, role management is involved in the running of the process. In addition, the flow of each educational process is described. By examining the characteristics of the educational process, the type of modelling tool required to illustrate the flow of process is determined. After presenting the features of Petri nets – a process modelling tool, the tool will be adopted for modelling educational processes.

2.1. Specific Features of Educational Processes

An educational process organises educational activities in a process-oriented approach. Using a process-oriented approach to organise educational activities allows activities to be grouped and managed effectively. A series of educational activities can be carried out one by one in order, so that the study goals of the students can be efficiently and effectively reached.

Each educational process has its own special features. A process organises and defines various educational tasks to run harmoniously. Each task is assigned a role with responsibility to execute. There are three types of participants involved in the educational process: students, academic staff, and general staff. Students are pursuing study goals with different materials and tools to reach the goals, such as a degree or certificate. Academic staff are the instructors or lecturers who provide teaching. The general staff offer only general support for students and academic staff and include the people who do office jobs for the administration.

The education domain is a special area which is different from other areas. For example, a business process focuses on communications among organisations for business issues.

A business process may involve different industries to reach the final result, such as producer, seller, marketing, and so on. A business process describes one commodity's journey. Once the commodity has been produced from the factory, it travels in different industries and finally it will be sold to a customer. However, the educational process happens around a campus across different offices and departments which offer services to the students so that they can reach their goals. The final goal of each educational process is to reach the student's study programme goal. In order to reach a study goal, a paper is the object which is like the merchandise in the business process travelling in the process. Moreover, to assist a student in his study, one document or material is the object instead of a study paper in the process.

In addition, the educational process emphasises the time concept in the running of procedures. The time component is the key feature for the education community which is different from the situation in the business enterprise. Although time has been concerned in the business process, the business process focuses on smooth transfer among different organisation in the business area. However, all tasks, conditions, and activities of education which take place highly rely on the time dimension. Therefore, time is the first prioritised constraint in the educational processes to be addressed in Chapter 4.

2.2. Role Management

As mentioned in section 2.1, there are three roles involved in the educational process. Once a process starts, these roles participate in and have different functions during the execution of the process until the final purpose is reached. Three roles, student, instructor, and administration staff, mentioned in section 2.1 as student, academic staff, and general staff, play differently in different educational processes. It is difficult to model the functionality of each role in different processes in a generic way. Therefore, role management reflects the management of the process. Roles for a particular process have different tasks to complete and have different priorities for resources. Distinguishing tasks and resources for roles is the approach used to manage the roles involved in the process.

In the traditional role-central management approach, coordination with groups of people and accomplishment of tasks within a schedule are involved for each role (Plaisant & Shneiderman, 1995). In the business process, roles are distributed in different phases of the process. They also take different responsibilities and activities to complete certain task of each phase. The educational process is similar to the business process except that tasks are arranged and completed within the time schedule, as mentioned about the time feature of the educational process. The time component is the significant index for different roles to operate certain information. A pre-defined process has been divided into several stages with time points within which the particular role must be acted out. The trigger mechanism from one stage to another is the time restriction along with the role priority. The time reasoning issue will be discussed in Chapter 4 in detail.

2.3. Processes Description in Education

As described above, there are three different roles involved in the educational processes, student, instructor, and general staff. Obviously, learning and teaching is the main task for students and instructors. It is a very complex process not only for instructor and student taking part in it, but also other staff assisting in it to support the running of the process. For an individual person, no matter which role he[1] takes in the process, he has a certain task to complete. For such a task, he has his own steps and paces to follow. In addition, there are general administration issues for students or even general officers, which require commitment like general office work. After configuring each role's responsibilities in different processes, three different processes have been presented in this thesis. They are the *learning/teaching process*, *administration process*, and *personal process*.

2.3.1. Learning/Teaching Process

Obviously, the learning/teaching is the key process in comparing with others in education. There is only one object to be processed in the process—"paper". In some circumstances, people also call it "course". Participants involved in the process enable the paper to be evolved from one state to another until the paper's lifecycle has ended. Here, the *learning/teaching process* calls for two actors— the student and the instructor— working face to face.

[1]his: as the sole person used as a participant in this research is of the male gender, all references within this thesis will use the terms "he", "his", and "him" as gender specific references.

For learning/teaching processes, students have their own purposes of study. Some of them are keen to gain degrees. However, some are interested in studying for only a few papers. No matter what requirements the students have set, they have to finish certain papers. Each paper has its timetable for internal students, whereas extramural students have their study guides to follow. Students are required to follow them to complete their studies. Otherwise, they could not keep up with the pace of study, which will result in failing the paper and affect their further study. The entire process can be divided into several time-based phases in which the students have to perform their respective duties. Meanwhile, these phases can be described as different states of the paper. From a student's point of view, a lecture timetable or study guideline indicates the status of a paper in the study. An examination section is to verify the consequences of the study of a paper. Besides the fixed timetable, there are lots of flexible time slots. For example, the assignment availability period shows the requirement of self-learning. The self-learning period indicates that activities for study are organised by students themselves and therefore vary between different people. There is no pattern or time restriction for how to take these activities one by one in detail. This self-learning process is described as the *personal process* that will be defined later.

On the other hand, from an instructor's viewpoint, a lecture is a place where the instructor presents his teaching at a reasonable pace. This section requires the performance of the instructor. The activities are designed and organised by the instructor only. He can ask students to be involved, but the overall pace is under his control. Therefore, the performance in a lecture also can be defined as a personal process of the instructor varying according to different teaching methodologies. Similarly, in the assignment and examination period, the instructor acts as a supplier to provide questions and as an examiner, he later appraises the students' performances after examination.

Eventually, every paper has exactly the same time definition pattern. It has a timetable, the time for assignments' completion, the examination time, and so on. Although papers have the same time definition pattern, they perform differently. The actual time setting for the timetable, the assignment, and the examination varies between papers. Therefore, to describe a learning/teaching process, these time settings will be split into several time phases.

However, to construct an educational process management system, the learning/teaching process alone is not enough for all participants to depend on. The following description illustrates the necessities for other processes to be involved in education requirements and activities.

2.3.2. Administration Process

Besides the learning/teaching process, it is necessary to describe the administration process for educational purposes. To become a new student of an institute, there are many processes that the student needs to be completed. The approval process for admission as a student of an institute asks the student to provide relevant materials including his curriculum vitae, the proposal of his study, previous study results, reference letters, and so on. The approval process is the procedure of determining whether a student is accepted or not. The object of this process is the actual application for this institute. The student, as the applicant, takes part in the whole process. He may be asked to provide additional documents in the middle of the admission process. In addition, besides the application for gaining admission to the institute, there are a variety of similar approval processes in the education domain, such as the application for a scholarship or awards. Therefore, all kinds of permission procedures with different administration routines, from one person to another, are classified as the *administration process*. It applies not only for the student, but also the staff. Besides, applying for using the facilities of the institute can be described as an administration process.

Furthermore, a general document processing among offices also has a similar routine to an application. The routine for a document transferring from one department or office to another has been defined once the document is generated. The discussion about document processing is similar to the automatic office system for government and business administration.

The process of dealing with an application or a document consists of many administration steps which are taken by people in different offices. The sequence of administration steps is defined according to the features of the material in the process. So, the administration process is a process with predefined routines.

2.3.3. Personal Process

For the purpose of completing some tasks in the process, participants involved are asked to organise activities by themselves. This is called the *personal process* in this thesis. For example, to complete an assignment, the steps and strategies to finish the assignment vary between different students because they have different ideas about doing this assignment. Activities for completing the assignment should be arranged by the students themselves. Similarly, the procedure for the preparation of documents in the administration process is also different. Therefore, personal processes are described as sub-processes of the learning/teaching process and the administration process. Instead of modelling personal process, offering appropriate component with the alternative way is used for modelling this process in the thesis.

On the other hand, personal processes can be illustrated as the largest process for study programmes. When a student chooses a study programme, the study programme needs to be organised by him. For example, he must make a decision on how many and which papers should be chosen for the programme. In addition, the model of the study programme planning should integrate with the learning/teaching processes of the papers and the administration processes for his study including all kinds of applications to enable him to finish his study. Also, personal processes vary between different participants for different tasks.

Instead of actually modelling the flexible personal process with flexible activities, appropriate components are stressed which contribute to model the process. In this thesis, the model of study programme planning process will be presented in 3.4.4.3.

As argued, there are three different processes mentioned: learning/teaching process, administration process, and personal process. All processes comprise the education operation, which covers study and ordinary work. To model these processes, a suitable modelling tool is necessary.

2.4. Petri Nets—A Process Modelling Tool

Petri nets have been proposed in Dr. Petri's 1962 dissertation, which presented the initial theory of modelling process. They have become a very useful mathematical and graphical tool to model, analyse, and design discrete event systems. They also provide a powerful communication medium among user, customer, and requirements engineer in the business area. Complex requirements specifications can be presented in Petri nets graphically rather than using traditional methods like textual description or mathematical notations.

Petri nets are ideally suited for defining and analysing complex processes. Their most useful property is that they make definitions easy to understand for non-experts, although there are many alternative modelling languages for workflow processes, such as extending Unified Modeling Language (UML) (Bastos & Ruiz, 2002), FWF-Net (Zhang, Gu, Lian, & Li, 2003), among others.

2.4.1. Petri Nets vs. Other Modelling Tools

In this section, several process modelling tools will be introduced including Petri nets, UML, activity nets, statecharts, and flowchart.

- **Petri Nets**

Petri nets were established to model and analyse processes. They are useful mathematical and graphical tools to model, analyse, and design discrete event systems. Graphical representations of Petri nets for complex requirements specifications are better than traditional methods. In addition, they have extended formats with time, data, and hierarchy to model workflows.

- **UML**

UML is an object-oriented analysis and design language from Object Management Group (OMG). Usually, UML is utilised for object-oriented software development. It has gained enough support that it has become a standard language for visualising and constructing software programs. It is a graphical notation for modelling object-oriented systems. An activity diagram is a diagram to specify the dynamics of a system. It has constructs to express sequence, choice, and parallelism. It has the ability to model all the constructs needed in workflow models.

- **Activity Nets**

Activity nets (Bochmann, 2000) are another notation, which is similar to UML activity diagrams. It is complemented with UML class diagrams to describe the workflow architecture, but defined independently of state machines.

- **Statecharts**

Statecharts were introduced by Harel (1987) to model behaviour of activities in the structured analysis notation. This notation was widely adopted by OO practitioners, and is now part of the UML. Statecharts in general model parallelism using a hierarchy of state nodes. Its popularity stems from the efficient representation of parallelism, thereby avoiding the state-explosion problem.

- **Flowchart**

A flowchart illustrates the steps in a process. It uses symbols interconnected with lines to represent the flow of information. A process flow diagram illustrates the successive steps in a process, procedure, system, or model. By visualizing the process, a flowchart can quickly help identifying bottlenecks or inefficiencies where the process can be streamlined or improved.

In the industry, there are several process modelling tools using simulation technology to model the real process. For instance, Simcad Pro (CreateASoft, 2006) is a process simulation and modelling tool to build a virtual copy of business in a top-down manner. It defines process in its behaviour and production process. PSE's gPROMS (PSE, 2006) is a true process modelling tool to establish the physical and chemical relationships.

2.4.2. Advantages of Petri Nets

Petri nets were introduced in 1962 by Carl Adam Petri as an established formalism for modelling and analysing processes. The use of such a formalism has a number of advantages (Aalst & Hee, 2002). One of the strengths of this tool is that it enables processes to be described graphically. It can be used to present workflow processes in an accessible way. Despite the fact that Petri nets are graphical, they have a strong mathematical basis which provides a precise definition. Ambiguities, uncertainties, and contradictions are thus prevented, in contrast to many informal diagramming techniques.

Secondly, it is entirely formalised. It thus becomes possible, for example, to establish certain patterns with properties of the process.

In addition, Petri nets have extended formats with time, data, and hierarchy to model various processes which UML does not have. As described in section 2.1 about educational processes, time component is significant in an educational process. Although time issues will be discussed in detail in Chapter 4, there is the advantage of Petri nets with time extension for modelling educational processes. Petri nets extended with time will be emphasised in modelling educational processes with critical time issues. The time and time intervals define phases of the process. If there is no time component for modelling each educational process in Petri nets, it means that the educational process is modelled with classical Petri nets which is considered as inadequate. Therefore, the phases move forward in the process depending on roles being fulfilled. Each educational event occurs as long as the previous activity is finished. The factor of human being will be the main reason to delay the process. In fact, eliminating human factors from the running of the educational process is the focus in this research. That is the reason why using time constraint is an effective approach because forcing the role playing under time constraints helps to make the process move forward.

2.4.3. Classes of Petri Nets

In this section, Petri nets, including classical and high-level Petri nets, will be introduced. As one of high-level Petri nets, Petri nets with time extension will be briefly presented because of their time features in modelling processes, which also are suitable for the time features of an educational process.

2.4.3.1. Classical Petri Nets

A Petri net consists of places and transitions (Aalst & Hee, 2002; K. Jensen & Rozenberg, 1991)(Figure 2-1). In principle, a circle represents a place. A transition is shown as a bar. Places and transitions in the Petri net can be linked by means of directed arcs. The place represents either an input or output place depending on the direction of the arc. If the arc is from a place to transition, the place is an input place. On the contrary, if the arc is in the reverse direction, the place is an output place. Places may contain tokens represented as black dots, which indicate both physical objects (e.g. resources and humans) and information objects (like an insurance claim). Transitions are the active nodes in a Petri net. When an event is fired in the transition, the distribution of tokens among places indicates the state of the Petri net.

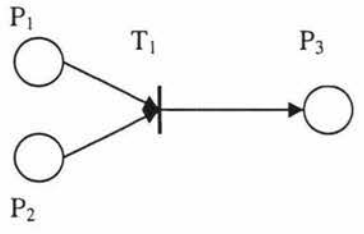


Figure 2-1: The classical Petri nets

Formally, an ordinary Petri net is presented as PN=(P,T,R),
where P= $\{p_1,p_2,\ldots,p_n\}$ is a finite set of places;
T= $\{t_1,t_2,\ldots,t_n\}$ is a finite set of transitions;
$R \subseteq (P\times T) \cup (T\times P)$ is a binary relation corresponding to the set of directed arcs from P to T or from T to P. And $P \cap T=\emptyset$. Places represent possible states of the system and transitions are events or actions that cause the change of state.

Here, a simple example is given to show how Petri nets work for modelling a process (Figure 2-2). The process description is that a passenger gets through the international airport when his aeroplane lands from overseas. Table 2-1 shows the places and transitions of this example process.

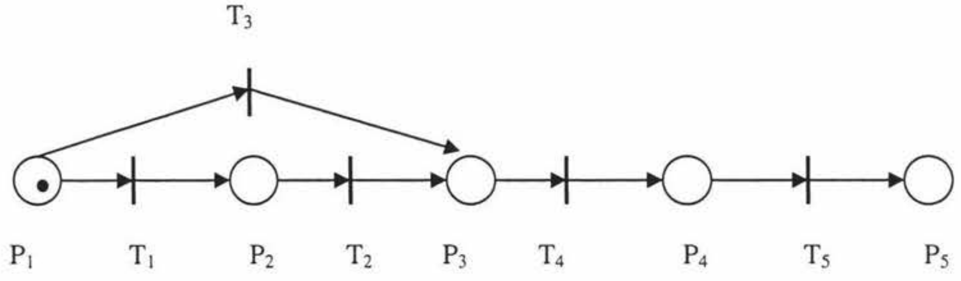


Figure 2-2: An example of a process modelling with Petri nets

P_1	A plane flies from overseas to the city where the passenger lives	T_1	The plane flies and arrives at the airport
P_2	The passenger gets off the plane and waits for the customs service	T_2	The officer is checking travel documents
P_3	The passenger gets through customs and waits for his luggage	T_3	Luggage is delivered to the passenger
P_4	The passenger takes his luggage and waits for a taxi	T_4	The passenger gets his luggage
P_5	The passenger arrives home and his business trip is finished.	T_5	The passenger gets into the taxi and is driven to his home

Table 2-1: Description of places and transitions for the example

The token shown in the Petri net is the passenger. This example is a very simple process with several sequential tasks, which offers an initial idea on modelling a process with Petri nets.

2.4.3.2. High-level Petri Nets

As the graphical representation is the impressive feature of the Petri net, it displays its accessibility and usage. In addition, it also has a strong mathematical basis and is completely formulated. Despite the strengths of the classical Petri nets, they have disadvantages and shortcomings in many practical situations (Aalst & Hee, 2002; K. Jensen & Rozenberg, 1991; Tabak, Vries, & Dijkstra, 2004). For a complex system, the diagram becomes very big, if only the classical Petri net is utilised. This is why the classical Petri nets have been extended in many ways. There are three most important extensions: colour extension, time extension, and hierarchical extension.

In the following, Petri nets with three extensions are described respectively. All of them are useful to analyse and model processes. Especially, Petri nets with the time extension is emphasised in this thesis for modelling educational processes.

2.4.3.2.1. Colour Extension

In the classical Petri nets, a token is a very simple data entity without any attributes. To distinguish tokens with different definitions in the same place, they are assigned with a data value for the modelling process, which is called *the token colour* in the colour extension (Aalst & Hee, 2002; K. Jensen & Rozenberg, 1991; Tabak et al., 2004). Therefore, a token with a value is distinguished from others. In a colour-extended Petri net, conditions for different coloured tokens are set independently to enable the firing of the transition. Then, a transition is enabled only when the token in the input place matches the preconditions.

2.4.3.2.2. Time Extension

Classical Petri nets do not have a time concept. Therefore, it is impossible to model processes if they emphasise time. In fact, in the real system, modelling temporal data is required. Even with the colour extension, it is still difficult to model time in the process. To solve the problem, the solution is to extend the classical Petri net with the time factor. Adding a timestamp to a token is an approach to form a Petri net with a time extension. The timestamp determines the time that a token is available to be consumed by a transition. A transition is enabled only at the moment when each of the tokens with a timestamp equal or prior to current time has been consumed. With this timestamp, it is possible to model delays and durations in the system. In the educational processes, time is always involved. For example, the paper has a starting date and a cut-off date. Each lecture also has a beginning time and an end time in its schedule. Therefore, time is the integral considerable component in modelling educational process owing to the time feature of educational processes.

2.4.3.2.3. Hierarchical Extension

Although Petri nets with the colour and time extensions have been introduced, there are still problems in modelling large processes, therefore we need hierarchical extension (Aalst & Hee, 2002). The hierarchical extension proposes to model complex processes with a number of sub-Petri nets (Aalst & Hee, 2002; Tabak et al., 2004). Each sub-Petri net contains a network of places, transitions, and arcs. Therefore, the overall picture of hierarchical Petri nets is a main Petri net with a set of sub-Petri nets. The advantage of using hierarchical Petri nets is to model process in great detail without losing the big picture.

2.4.4. Ideal Tools to Model Processes

After describing the classical Petri nets and the advantages of using Petri nets in modelling processes, it is worth mentioning that there are benefits to utilising Petri nets in modelling educational processes in this research.

Firstly, Petri nets have a firm mathematical foundation that allows analysis of performance measures and analysis of properties of educational processes. It indicates that all transitions including educational processes and reactions can be enabled; the number of tokens in the process is limited; each role having the same functionality is repeated by one token; it ensures proper termination. When one educational process begins, the procedure will terminate eventually. There is no dead task in the educational process. The outcome of each educational process is to complete the purpose set by a student. In terms of education systems, it ensures that all educational processes could be carried out and while the system executes, there will be no infinite tasks to do. In addition, it is easy to use Petri nets to represent the states of an educational process.

The second benefit of Petri nets in educational processes is that they explicitly represent states, which allows for the modelling of milestones and implicit choices. The third benefit is that time Petri nets can express temporal constraints on the earliest and latest time of a transition which are suitable for the educational process. This detail will be discussed in Chapter 4. Furthermore, the hierarchical structure of Petri nets can control the complexity of the representation of an education system.

2.5. Processes Modelling with Classical Petri Nets

As described in section 2.4, Petri nets are ideal modelling tools for modelling educational processes. In this section, classical Petri nets will be used to model some of the processes. We delay the time extension to later chapters to indicate that even classical Petri nets are still suitable for modelling a wide range of educational processes.

- **Learning/teaching process**

Learning/teaching process is considered as the lifecycle of a paper in this thesis. Learning process applies to the students, whereas the teaching process applies to the instructors. In the following descriptions, 'lecturer' is used instead of using 'instructors'. From the description of learning/teaching process in section 2.3.1, there are several sub-processes comprising the learning/teaching process. To model the learning/teaching process with classical Petri nets, the first thing that should be done is to address roles and activities involved in the process. Similarly, this also should be applied for both the administration process and the personal process.

In this section, a lecture is presented to illustrate how Petri nets work for the flow of one lecture in Figure 2-3. The main role in the lecture is the lecturer. The definition of places and transitions is shown in Table 2-2.

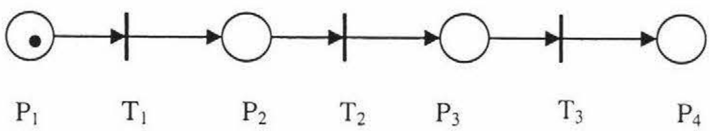


Figure 2-3: Modelling the lecture with classical Petri nets

P_1	Paper is ready to teach	T_1	Time for starting lecture
P_2	The lecturer starts to teach	T_2	Teaching lecture
P_3	The lecturer is teaching	T_3	Time for ending lecture
P_4	Lecture ends		

Table 2-2: Description of having lecture with classical Petri nets

In this flow, place 'The lecturer is teaching' in Table 2-2 presents the state of the flow, which shows that the lecture keeps going on and the status of the process is lecturer in teaching. The process in this stage also can be treated as the personal process for the lecturer. In this place, the lecturer may have his own steps to organise materials to teach and he also has his own opinions and methodologies in teaching this unit of knowledge to students during teaching. In addition, it may include other roles' activities. For example, the lecturer may schedule students to be involved in answering his questions during the lecture. The group discussion may be set as a part of the lecture as well. Elaborating on each place may produce detailed discussions of the personal process.

Moreover, there are other kinds of processes belonging to the learning/teaching process, such as tutorial, self-studying, taking an examination, doing an assignment, and so on. The following Figure 2-4 shows the model of taking assignment with classical Petri nets associated with explanation of the place and transition of the model in Table 2-3.

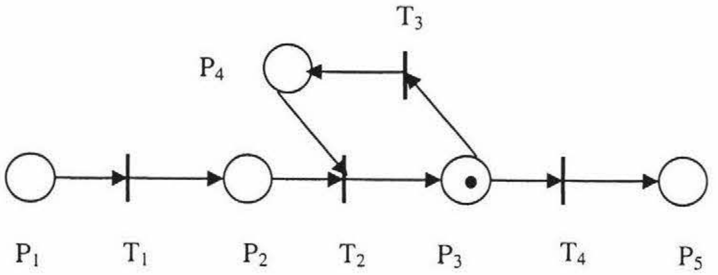


Figure 2-4: Modelling assignment process with classical Petri nets

P_1	Assignment is ready	T_1	Downloading materials and assignment instructions
P_2	Students are ready to do the assignment	T_2	Start doing assignment
P_3	The student is in the process of doing the assignment and not yet finished.	T_3	Asking for extension if not finished
P_4	Get approval about extension	T_4	Submitting the assignment if finished
P_5	Assignments are under assessment		

Table 2-3: Representing assignment process with classical Petri nets

- **Administration process**

The administration process also can be modelled with classical Petri nets. It emphasises the steps of processing the requirement or applications from one office to another or even from one department to another. A typical flow is shown in Figure 2-5 with place and transition explanation in Table 2-4.

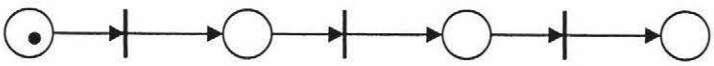


Figure 2-5: Modelling to prepare application with classical Petri nets

P_1	Applicant is eligible to apply	T_1	Gathering related material to apply
P_2	Ready to apply	T_2	Filling forms
P_3	Application package is ready	T_3	Handing in application package
P_4	Application is being processing		

Table 2-4: Description of preparing application with classical Petri nets

- **Personal process**

The personal process has been mentioned in the learning/teaching process. Similarly, it also appears in the administration process. When the application is being processed by an officer of an administrative office, how he deals with this application is the personal process integrated into the administration process. Therefore, when one participant has a particular task to complete, various activities carried out comprise the personal process for this participant. Gathering materials for application is the personal process for the applicant. Teaching in a lecture also is a personal process for the lecturer. Meanwhile, doing the assignment is the personal process for students. The personal process is not the same as other processes. It varies between different people although it has the same target and outcome at the end. Owing to different habits and other factors, to reach the final goal various activities may be arranged differently. Therefore, it is difficult to model various personal processes in one generic model. It varies case by case. In Chapter 4, one personal process is presented and modelled as an example.

2.6. Event-driven Mechanism in Classical Petri nets

Event-driven mechanism in the classical Petri nets is the firing mechanism of the process. As long as the token in the Petri nets has the ability to move under certain conditions, the fire mechanism is invoked. As the event is finished, the token is moved to the next place and the status of the process is changed. For example, when documents are submitted, the person is ready to process these documents starting from the first handed in to the last one submitted at the last minute of the due day. The person has to process them starting from the first submitted document until the last submitted file arrived at the due day. In fact, there must be a time period from the first arrival of the document to the due day. When a new file is coming, he must process it and leave his work behind until this one has been finished.

2.7. Value of Adding Time in Education System Modelling

There is value in adding a time component into the process management because the process will not move forward until all submitted documents have been collected after the due day, for example. Therefore, the user in next stage may arrange his current or other work before the due day of submission. After the due day, he must focus on this task until the due day of this work is due. That means he arranges other work and tries to finish other tasks before the due day of current process status. After the due day of submission, he must deal with these submitted documents only. This approach may improve the quality of the job outputs. During this work period, he will not be disturbed by other things and try his best to complete these documents before his due day on this task is coming.

In fact, there are lots of educational systems for students and instructors to use. One of the most popular education systems is WebCT. It is a highly flexible e-learning system providing tools for course preparation, delivery, and management. It also considers about the time issue in the system. However, it only adds time stamp into role's every activity. For instance, when students submit their assignments, each submitted assignment has its own time stamp which shows the submitted time. It is easier for the marker or instructor to know when students take this submission action. In addition, there are online quizzes and examinations associated with beginning and end time for students in different learning stages. Time is only used as prerequisite for the specific role—student, to carry out his action and complete his task.

The most effective way to make the process move forward is using both time and event driven mechanism. If tasks have been done before the time is due, event driven mechanism is fired for the next phase. But it only applies to the personal process, like the marker marking assignments. Firstly, the marker must finish his marking task before his due day for marking. If he can finish marking before the due day, the marked assignments can be transferred to the next person in the next phase which makes the process move ahead. In this thesis, the function that time plays is not only as prerequisite for role-playing, but also as triggers to move forward the process. To show how it works, three different educational processes have been analysed and designed with time Petri nets and reported in Chapter 4.

2.8. Summary

In this chapter, specific features of education have been presented firstly, which are helpful to illustrate education activities in process-oriented mode. Therefore, three different educational processes have been represented. They are learning/teaching process, administration process, and personal process.

Learning/teaching process is for both students and instructors to describe the education activities during the study and teaching procedure. Administration process involved in the campus or education area is similar to the office work. It deals with applications for students who have requirements during their study, for instance. Personal process focuses on individual participants taking part in learning/teaching and administration processes. When each person or role has to complete one particular task in the process, each has his own steps or methods to finish it from the beginning to the end. The arrangement with activities for this particular task comprises the personal process for this task.

After presenting three educational processes, a certain modelling tool is deemed necessary to visualise the processes. Therefore, Petri nets have been chosen after comparing it with other process modelling tools. Classical Petri net notation has been addressed and high-level Petri nets also have been described according to different process requirements. Moreover, time Petri nets have been mentioned to emphasise time component in modelling processes.

Time component is a vital component in the education area. Various education activities have to be carried out under certain time constraints. Classical Petri nets are utilised to model each educational process. Ignoring time function in modelling will render the model impotent to describe each process with precise format and definition. Therefore, time component has to be recommended and integrated in modelling these educational processes. In Chapter 4, Petri nets with time component will be presented and will be used to model educational processes.

Chapter 3 will investigate how workflow technology (widely used in business process modelling) fits into educational processes modelling.

Chapter 3. Workflow Technology in Educational Processes

Chapter 2 illustrates education activities from a process-oriented perspective and three different educational processes were identified. They are learning/teaching, administration, and personal processes respectively. All of these processes aim to complete tasks for the purposes of achieving educational goals. Once an educational activity has been identified as a process, it is necessary to have a powerful modelling tool to capture its characteristics and behaviour. After comparing Petri nets with other tools, Petri nets have been chosen to model these processes. In addition, these educational processes have been modelled with the classical Petri nets.

While education activities can be modelled from a process-oriented perspective, there are other technologies that can be applied to organise and control these activities and processes. In this chapter, workflow technology will be employed to study educational processes. In fact, workflow technology has widely been applied in modelling business processes. After analysing the features of the educational process and the business process, this chapter will look at how workflow technology can be employed in studying educational processes. In addition, the reference model from WfMC[1] will be adopted as a reference in this project.

3.1. Overview of Workflow

The introduction of workflow concepts is presented firstly to show how business processes are being modelled. A workflow normally comprises a number of logical steps (known as tasks), dependencies among tasks, routing rules, and participants. Meanwhile, relevant components of workflow technology are described for readers to understand the terminology—"workflow". In addition, it is necessary to introduce the history of workflow briefly.

[1] The acronym for Workflow Management Coalition (see Section 3.3 for details)

3.1.1. History of Workflow

Putting workflow into historical perspectives, two pioneers in 1970s, Skip Ellis and Michael Zisman thought that generic methods could be utilised to support business processes.

Firstly, office information systems were the predecessors of workflow systems. As early as the 1970s, computing technology had been introduced into office work. Then, database systems as an integrated office work infrastructure were evolved rapidly and thereby opened new dimensions for office activities (Jablonski & Bussler, 1996). Due to the difference of users' requirements, their interfaces are extracted from the application programs. Eventually, data management and user interfaces are isolated from the overall application as separate solutions, which are more attractive in development programs for the business domain. The routine shifting from office work to isolating data management and users' interfaces as components of program shows the development of the workflow technology in business, based upon the requirement of the business.

A workflow system manages workflows and organises the routing of case data amongst human resources through programs and thus the idea of workflow management system arose in the 1990s. Since workflow management is closely associated with computer networks, the technology allows control of workflows between various resources-people or applications. Because of the revolution of the hardware technology, the corresponding software technology has opportunity to achieve further, which results in deploying computer software in a revolutionary way (Jablonski & Bussler, 1996). Together with the hardware connectivity of computer networks, common database systems can be deployed that supports integrated applications of all software systems. Seven origins of workflow management have been presented by Jablonski and Bussler (1996). They, in addition, describe three evolving stages of management technology (see also (McCarthy and Bluestein, 1991))

3.1.2. Workflow Terminology

The basic definition of 'workflow' appears in dictionaries as the scheduling of independent jobs on a computer. A workflow describes the individual tasks performed in procedures and the interrelationships among these procedures. The reason to extend the definition is to show a set of relationships between all the activities in a program, from start until finish. Furthermore, activities are related to various trigger relations and they may be triggered by external events or other activities.

From WfMC (1995, p.6), it illustrates that "*workflow is concerned with the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal.*" And the definition of workflow is "*the computerised facilitation or automation of a business process, in whole or part.*" However, the workflow described by Cai et al.(1996) and Vidal et al. (2003) presents that it is a business process abstraction in which activities perform with corresponding resource and rules restricting task execution. From these definitions, it is obvious that workflow concepts have initially been applied in the business area.

Practically, a workflow is normally organised with the support of IT for the procedural automation. A workflow is often associated with Business Process Re-engineering (BPR), which is concerned with the assessment, analysis, modelling, definition, and subsequent operational implementation of the core business process of an organisation (or other business entity)(Aalst & Hee, 2002; WfMC, 1995). In fact, workflow is a specific technological area in which information is routed among users and applications in a formalised manner according to established processes (Simon & Marion, 1996). Figure 3-1 is a simple workflow example from the business area.

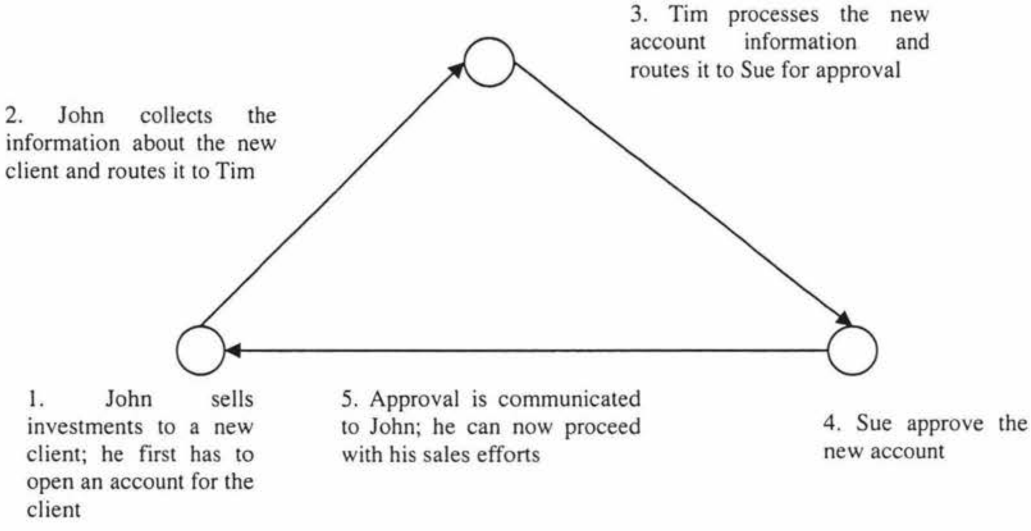


Figure 3-1: A simple workflow example (Simon & Marion, 1996)

In the educational area, knowledge is the information routed among students and instructors. In fact, knowledge is too abstract to be presented to students directly. To present knowledge and ensure the knowledge is being successfully acquired by students, teaching materials, examinations, assignments, and quizzes are the common delivery mechanisms for transferring information between students and instructors. Therefore, an educational process can be described as a workflow with knowledge, students, and instructors.

3.1.3. Components of Workflow

It is necessary to introduce several important workflow components, such as work, activities, roles, activities sequencing, data handling, invoking domain-specific logic, and so on (Cardoso, Bostrom, & Sheth, 2004; Fernandes, Cachopo, & Silva, 2004; WfMC, 1995). These components comprise a process:

- Work: a work itself is organised into activities.
- Activity: each activity is made up of a number of interactions. Each interaction is a role roles that carrying out a task on an artefact.
- Roles: people with certain authorities are involved in work. In this thesis, 'actor' and 'participant' are used for representing roles in the process. Sometimes term 'agent' is used when participants are automated.

- Process definition from WfMC (1995, p.7) states "*the computerised representation of a process that includes the manual definition and workflow definition.*"

The definition for a process is the key concept in this section. To have clear descriptions of what a process is, we need to identify relevant needs. Once a target is established, relevant processes are required to be performed (Aalst & Hee, 2002). In addition, a process is a collection of tasks, conditions, sub-processes, and the relationships among them.

To structure a workflow process, the first step is to identify the tasks of the process. Then, the order of tasks is determined by conditions, which are described by properties of the whole procedure. In essence, a process is constructed from tasks and conditions. There are three types of tasks: manual, automatic and semi-automatic tasks. A manual task is entirely performed by people, whereas an automatic task is performed without any intervention from people. A semi-automatic task is in the middle, which means that people and application software are both involved in semi-automatic tasks. Therefore, the reasonable arrangement of tasks and resources for participants is the main issue to be tackled in constructing a workflow. To support interaction in a workflow, certain services are required, such as one to one correspondence between work and service that support synchronous or asynchronous collaboration (Plaisant & Shneiderman, 1995).

Processes can be described with classical Petri nets (described in Chapter 2) and also with time Petri net to be described in Chapter 4. Conditions are depicted using places and tasks using transitions (Aalst & Hee, 2002). This design language is our tool to design educational processes.

In 1995, WfMC (p.23-24) described the theory of transitions for the process and activity (Figure 3-2 & 3-3).

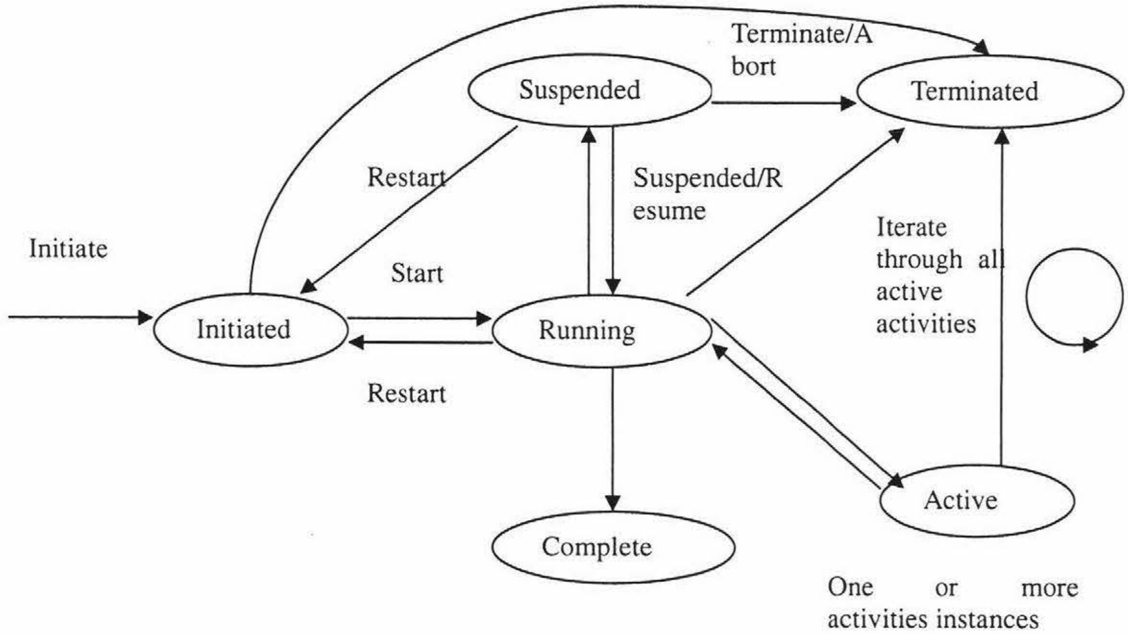


Figure 3-2: Example state transitions for process instances

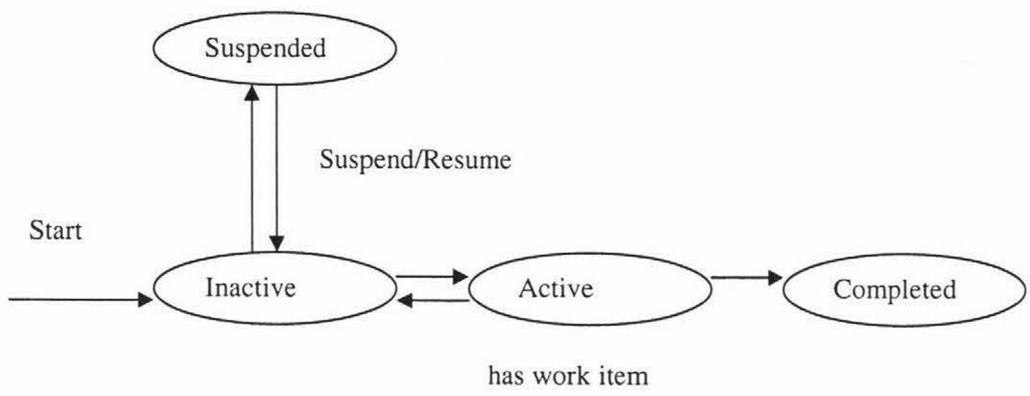


Figure 3-3: Example state transitions for activity instances

- **Executive mechanism**

There are four different mechanisms to represent the execution orders of tasks. Two or more tasks performed in a strict and sequential order is called a *sequence*. At one time, when only one choice is available between two or more tasks, this is called a *selection*. Two or more tasks performed in parallel is called a *synchronization*. *Iteration* represents a process, for the execution of a task, which does not stop until a given condition is achieved. (Aalst & Hee, 2002; Fernandes et al., 2004). These executive mechanisms are represented by Petri nets to show how they work in Chapter 4. Actually, Petri nets have standards to define basic concepts in the workflow. They also have the ability to execute the process, along with certain rules and conditions.

Workflow automation is an event-driven procedure. An event can be any task that a worker executes, such as reviewing purchase orders or approving schedules. When an event has taken place, workflow automation anticipates and leads the worker to complete the assigned work for him, which results in the movement of the flow from this worker to the next participant until the flow reaches the end. Because the movement happens automatically, it is less error-prone than a manual redirection, or a paper-based business procedure. There are two basic mechanisms for work distribution or allocation in a workflow system - *Push* and *Pull* mechanisms.

- Push mechanism: a work item is pushed to a single resource.
- Pull mechanism: a resource pulls work items from a common pool of work items.

The notion of '*Push/Pull*' is an important component in workflow. Push is to get as much potential information as close to the point of need including data that are of interest given alternative predictions of outcomes. Pull is based on a workflow model which filters the pushed information. It facilitates the successful movement of the process with required information.

3.1.4. Characteristics of Workflow

Initially, workflow was introduced to support rules for business processes. Its emphases are arranging appropriate human resources to solve problems on time. The workflow engine is an ideal tool to represent these rules of varying capabilities. There are several characteristics of workflow described by Simon (1996) which discusses the advantages of workflow technology in modelling processes. They are role control, time element, dependency, substitutions, evolution, and privileged information.

As described in the previous section, many people are involved in a process. Based upon the given flow and rules, the specific step and activities should be done by a specific individual. The more people are involved, the more rules are set in the flow, consequently, the more intersections, from one participant to another, occur in the flow. The automatic execution of a process will automatically assign the task to an official substitute or alternative person when this particular person is absent.

It is worth mentioning that workflow also has the dimension of time. The time element should be encoded as a part of the rules that manage the workflow engine. There are typically multiple time elements, such as no earlier than starting time, no later than completion time, and so on. As GHR(2006) mentioned, workflow technology enables and improves process efficiency and quality. However, the GHR system has a number of manual involvements. To reduce processing time, reducing these manual activities or interruptions in the flow and automating them as much as possible are an effective method to achieve the goal efficiently. Automated workflow technology is essential to substantially reduce labour, training, and support costs. In addition, the GHR system has integrated the cycle time for its loan applications. Compared with business processes, the time component has stronger relevance in educational processes. According to the features of an educational process, each activity has certain time constraints. Therefore, the traditional time notions in workflow are not sufficient to monitor educational process. In fact, the movement of an educational process from one stage to another is closely associated with the passage of time. For example, students have to hand in their assignments on or before the due date and they also have to follow a timetable to participate in lectures. The evolvement of an educational process represents the evolvement of the student's learning process and the teacher's teaching processes.

Another characteristic of workflow that should be introduced is privileged information. The workflow should have the capability to support data privacy and security, i.e. information is not routed to anyone who is not allowed to see it.

3.1.5. Non-workflow Technologies

People are benefited by business process automation. All kinds of technologies have been deployed to automate these processes and thereby eliminate time-consuming and error-prone manual interventions. They help processes to achieve more, in less time, with fewer mistakes. There are lots of technologies to model processes in achieving effective and efficient processes. However, for the non-workflow technologies, the process has to be modelled without the workflow reference model and set up with its own procedures that depend on the requirements of these procedures. Therefore, different processes have to be analysed, designed, and developed differently according to their different purposes and fields. For example, queuing network technologies have been available since the mid 1970s. It appears feasible to construct analytic models for workflow maps and to use existing solvers to evaluate those models and calculate performance predictions of the original organizational process. As ISPI(2004) mentioned, HPT model is established with several steps, such as performance analysis, cause analysis, evaluation and so on. This model probably is not suitable for every process modelling. In addition, it also cannot be referred to other processes. Another technology is process simulation(CreateASoft, 2006; IBM, 2001), it focuses on real process behaviour. It starts by defining main process flow. Then, expanding each process cell into its individual processes is compared with the big picture of the main process flow.

Other non-workflow products that are worth mentioning are email, groupware, and image systems. The differences among them are shown below. Email products simply move messages across a network. They do not model sophisticated data activities in finding the appropriate person in the next stage of the flow. It is too weak to model extensive tracking and auditing of processes. Groupware refers to any application that allows users to share information within a group. Its objective is to improve the efficiency and productivity of collaborative participation through shared electronic resources, such as a common database. Groupware lacks the intelligent routing of activities and documents that workflow uses within the business process. However, some image systems can route their images across networks. Typically, an image system is incorporated into workflow.

Non-workflow applications do not add any value to business processes by just performing the work because they are not pro-active in addressing business problems. In contrast, workflow applications are task and event-driven. The ordinary user does not need to learn complex navigation steps. As this project is focusing on education processes that involve different educational activities that are complex, flexible in various conditions and highly confined by time-based constraints, non-workflow technologies are considered inadequate. On the other hand, adopting workflow technology can relieve different actors from training to become familiar with navigating different process steps. The workflow will navigate the roles to join the flow and carry the activities for the running of the process.

3.1.6. Adopting Workflow Technology into the Modelling Process

In businesses, there are tangible benefits derived from adopting workflow technology. It enables organisations to eliminate some unnecessary steps of running business procedures. Therefore, it makes the organisation more efficient based on automatically breaking a process into discrete tasks and sending each task to a participant within the flow for processing. It also automates the flow of information throughout the entire enterprise, while integrating individuals' roles and functions.

Workflow technology has been introduced in many business companies to improve the efficiencies of their processes. The technology is utilised to arrange all steps to make sure both the cost and time required in running business procedure can be reduced. The goal of using workflow technology is to process workflow instances as efficiently as possible. In fact, workflow can be defined as the automation of a business. The materials, information, and tasks are passed from one participant (machine or human) to another for action, according to the sequence of procedural rules. Companies may need to change or modify their workflows in order to adapt them into various requirements. From the opinion of Yamaguchi, Mishima, Ge, & Tanaka (2005), dynamic change is to change workflows having running cases. The most important issue in dynamic change is how the running of cases should be handled. They also give methods to handle these running cases so that dynamic change becomes the most efficient method from the perspective of an evaluation measure called 'change time'. From this point of view, educational processes with various time constraints may be changed. Therefore, the dynamic change of a workflow is another feature to justify the adoption of this technology into the modelling of an educational process. As described in previous research, the time constraints being applied in educational process may be changed, owing to all kinds of situations including both subjective and objective factors. Subjective factors includes scenarios like participants delaying their tasks whereas objective factors can be mechanical problems in the computer environment. Time tolerance allows extending or shortening the time duration of an educational process still goes successfully with the changes of situations. Workflow engine functions to allocate tasks to different roles according to the definition of the process. In addition, when the time changes for each step, the workflow engine should automatically reallocate tasks or hold tasks for specific persons.

Workflow systems are now being used more and more in scientific and engineering sectors. The key benefit derived from process automation is to improve business efficiency and compliance. Workflow systems are helping biotechnology, pharmaceutical, and chemical industries to manage the vast quantities of data.

Workflow technology allows organisations from different departments to quickly respond to a changing requirement. Users from their own areas need to give their inputs into the business environment, be it efficient or inefficient. The workflow system advises which steps must be kept or which can be removed from the process. Most workflow systems adopted in the business sectors are based on the reference model of WfMC(WfMC, 2001) which will be described in section 3.3.

3.2. Workflow Management Technology in the Education System

Information technology has the potential to be utilised in diverse areas of an educational domain. Naturally, a process is a collection of activities constituted for a certain purpose. Educational activities consist of tasks like planning the course schedule, preparing the materials, delivering teaching, and evaluating their efficacies.

From the description of (http://www.nid.edu/aboutus_philosophy.htm), education includes a whole range of activities. Pedagogies can be ranged from direct instruction for readily known facts; group discussions for partly understood domains to discovery learning in a brand new field. Traditionally, the educational process includes the study system, study plans, and the academic programs provided by different educational institutes, such as diploma and bachelor programs. With the introduction of information technology, educational processes become more and more complex. An educational process is a change process, which also influences the changes among students. An educational process occurs when instructions are being delivered to students. In this process, the requirements for a course or a program may be completed with the help from the supporting campus-based staff. However, for distance education students, remote communications, be they one-way or two-way, written or electronic, or in other media forms, should be included and required for the completion of the course. This will enhance the efficiency of the educational process by reducing financial cost and personnel time. This is not only the quest of better administrative efficiency, but in fact a better quality of education.

The educational processes and business processes are in different domains. By comparing the business process with the educational process, it is possible to integrate workflow management technology into educational processes (Table 3-1) associated with the idea of business processes.

	Business Process	**Educational Process**
Aim	Aim for business purpose	Aim for completing an educational purpose
Activity	Activities need to be taken from one stage to another	Activities are required step by step
Order	Arrange activities according to the definition of the process	Based on the definition of the process, certain order for activities are required.
Roles	Participants from different departments or even from different organisation for a process	Student, instructor, staff are involved in process depending on the functionality of the process

Table 3-1: Business process vs. educational process

As workflow management technology has been applied to organise and develop business processes, educational processes also can be modelled and developed with it, in the writer's opinion. Reaching certain aims of an educational process would act like a business process. Each successfully concluded activity with conditions or restrictions leads to the completion of the process and the arrangement of activities is defined from the nature of the process, which can be applied for both the business process and the educational process. In addition, both processes have many participants and they act with certain priorities and responsibilities. For the purpose of business, roles involved in the process are from different departments or even from different organisations. However, there are only three roles being classified that participate in the educational process: instructor, student, and general staff. Owing to the functionality of the educational process, three roles from different offices or even different departments are partly (less than three roles) or fully involved in the process. Thus, the educational process is the same as the business process in the business domain, which can be modelled by the workflow management technology.

3.2.1. Educational Process Modelling

As educational processes are for people to accept knowledge from the outside, how to implement such processes is considered extremely important. There are many methods for people to study and learn knowledge. For example, they may read materials from the public media, or communicate with people who have different personal experience, personalities, and so on. But the most traditional way for people to gain knowledge is to learn from professional instructors and that was happening in the classrooms (Garland & Noyes, 2004). As information technology has been widely used in all areas of society, it has also been used in education. Therefore, the notion of information education has emerged. It influences the traditional relationship between instructor and student (Garland & Noyes, 2004). This idea not only makes up the gaps left from traditional education methodologies, for instance, confining students to study in specific places (classrooms), but also enhances the abilities of education and provides various methods for students to learn knowledge. Based upon the notions of 'education material' and 'pedagogies', research on the modelling of the educational process has started evolving.

For example, Huitt (2003) develops the model of teaching/learning process from the perspective of systems theory that arranges the relations between the parts of the whole. Similarly, Martin (2001) stresses the use of holistic approach to model the educational process, rather than the prescribed approach, which is more flexible for instructors to offer programs. Shor and Robson (2000) have introduced student-centered feedback control to model the educational process instead of program-centered feedback control mechanism, to improve the performance of students.

According to the previous research on the modelling of educational processes and the features of an educational process which has been compared with the business process, the method used to model business process is utilised to also manage and organise educational processes in this thesis.

3.2.2. Workflow Management Technology in Modelling the Educational Process

Three different groups of participants are identified to perform educational processes independently or together: the educational staff who teach, administration staff, and students who study in different programmes. Students enrol in corresponding papers for different programmes. Each paper has its own properties, like the lecture time schedule in a semester, the name of the instructor who teaches the paper, the pre-requirement of the paper, and tasks needed to be completed for the paper, including assignments, midterm examination, final examination, and so on. The staff manage the paper-teaching schedule.

As the basic definitions of a workflow were all designed for business processes, one needs to distinguish the differences and common factors between business processes and educational processes before adopting workflow technology into education. In this thesis, we will look at how workflow technology constructs powerful educational information systems which are capable of organising a variety of processes. The learning/teaching process, for example, being described as the main process in education, is characterised by a variety of learning opportunities. These opportunities are often shaped significantly by student-defined requirements and contexts (Friesen & Anderson, 2004). After analysing the deficiencies of commercial web-based educational products, Lin et al.(2001) introduces a flexible e-learning environment built upon workflow technology to provide a more flexible learning solution. They model the study process to manage the learning and teaching activities for instructors and students. The Flex-eL concept is mentioned as the usage of workflow technology which has flexible abilities on controlling own study pace, especially for students. The Flex-eL focuses on having more flexibility in modelling and organising the study process. It emphasises how to remove the time constraints, so that students may have their own strategies and pathways to study without any constraints. In addition, a degree program in tertiary institutes is chosen by Mangan and Sadiq (2002) to establish a model for these flexible processes. They also illustrate the Flex-eL system for the flexible learning and use workflow modelling concepts to model student's planning and academic advising with the inherent flexibility.

Regardless of the non-time limitation of the Flex-eL concept, it offers flexible capabilities for students to organise their own study activities, which emphasise the flexibility management of these activities in the process. In this thesis, the idea of the flexibility in the process modelling is represented in the modelling of the personal process in education for participants to manage and arrange their own activities (see details in 4.3.3). However, the time constraints are emphasised in the modelling of educational processes for effective management and seamless execution of the processes from beginning to end. It indicates that participants involved in a phase of an educational process with certain priorities should carry out their activities with flexible options, personal pace, and approaches. Each participant has his own time limitation for each phase of the process and the overall process also has an overall time span from beginning to end. For the process, it should be modelled with exactly strict time restrictions and the workflow management technology. In addition, a study programme planning for students will be modelled as a personal process for the study program of the student to show how flexible workflow management technology and time restrictions work in modelling various activities. However, the study program is different for different students.

Although workflow management technology already emphasises the 'right people', 'right resource', and 'right time' to model the process to ensure that it can run successfully, the time concept is described as an additional component being integrated with the original workflow management technology to model various educational processes in this thesis.

3.3. Workflow Management Coalition (WfMC)

The Workflow Management Coalition was founded in August 1993 as a non-profit-making, international organisation by several vendors developing workflow systems (Jablonski & Bussler, 1996; WfMC, 2001).

The missions of WfMC (2001) are:

- Increase the value of customs investment with workflow technology.
- Decrease the risk of using workflow products.
- Expand the workflow market through increasing awareness of workflow.

The objectives of the WfMC are to achieve advancing opportunities for the exploitation of workflow technology through the development of common terminology and standards (Meng et al., 2002; WfMC, 1998). Three major committees consist of the Coalition: the Technical Committee, the External Relations Committee, and the Steering Committee (WfMC, 2001). The purposes of committees are to define workflow terminologies, interoperabilities and connectivity standards, conformance requirements, and for assisting in the communication of this information to the workflow user community.

The WfMC defined a workflow model for business processes. A business process is a set of linked procedures or activities that collectively realise the business objective or policy goal normally within the context of an organisational structure. It is similar to the educational process, which also has to link various procedures or activities to realise the educational objective and goal under certain educational structure. Therefore, the educational process can map into the workflow model developed by WfMC.

- **Mapping the workflow model constructs to educational entities**

Here the workflow model is used as an educational process by mapping

(1) Activities to educational processes;

(2) Roles have tasks to complete respectively;

(3) Organisational units to educational area;

(4) Workflow participants to each task.

3.4. Workflow Management System

As information technology has made huge leaps forward recently, it results in new methods to organise business processes. Workflow has been described to manage and monitor business processes electronically, therefore the flow of work between individuals and departments can be defined and tracked. Workflow management consists of the automation of business procedures, "workflows" operated information, and tasks from one participant to another with governed rules or procedures, it enhances the effectiveness and relieves the workloads of business processes (WfMC, 2001).

A workflow management system provides the procedural automation of a business process by the management of sequence work activities and the invocation of appropriate human and/or IT resources associated with steps in carrying out these activities. It is more suitable to manage the process, involving application and data integration of heterogeneous, autonomous, and distributed systems. It combines techniques of cooperative information systems, computer aided work, groupware, and active databases to provide tools for defining, creating, and managing workflow activities (Cardoso et al., 2004; Vossen, Weske, & Wittkowski, 1996).

3.4.1. Definition of Workflow Management System (WfMS)

There are many definitions for workflow management from different researchers. The definition of Workflow Management System from WfMC, (1995, p.6) is that "*... completely defines, manages and executes 'workflows' through the execution of software whose order of execution is driven by a computer representation of the workflow logic*". Xu et al. (2003) believes that business process management is workflow management. Therefore, the system providing the management for business processes is the workflow management system.

Furthermore, Aalst (2002, p.27) describes "*A workflow management system has a number of functions that can be used to define and graphically track workflows, thus making both the progress of a case through a workflow and the structure of the flow itself easy to revise.*"

Therefore, workflow management systems are a set of applications and tools to manage activities in workflows, including the definition, creation, execution, and monitoring of these workflows. The workflow management technology, however, combines people, organisations, and the process to form a chain for the particular task.

The aim of this research focuses on establishing a workflow management system with the workflow management technology through defining various educational processes. One requirement of a workflow management system is that each workflow needs to be defined with corresponding tools or applications. Moreover, creation, execution and monitoring of workflows are essential parts to make workflows run smoothly and successfully.

- **Workflow Management System Software Development**

Actually, the software development process also can be described as a workflow, which is a coordinated execution of tasks by individual team members (Hawryszkiewycz & Gorton, 1996; Reinwald, 1994).

To develop a workflow management system, one needs to define the processes of the system, arranging the processes, and managing roles involved in these processes. In this thesis, it is argued that modelling and defining processes and strategies for managing roles are critical methods to develop workflow management system architecture.

Recently, workflow management systems support business processes with their information logistics. In other words, they allow the right information to reach the right person at the right time, or the right information being submitted to the right computer application at the right moment (Aalst & Hee, 2002; Reinwald, 1994). It is obvious that data, tools, and the right time are three fundamental requirements and significant components in the workflow management. Therefore, these three components are the main issues concerned with analysing educational processes and are essential parts to develop certain workflow models. From the definition of Hales and Lavery (1991), a specific work is organised as a series of tasks. Moreover, participants are involved in executing these tasks. Additionally, a workflow management system is characterised by its major duties: passing tasks among participants, controlling participants to fulfil their contributions, and providing some kind of exception handling.

Therefore, the development of workflow management system (WfMS) is viewed as a bottom-up approach inside an organisation (Cardoso et al., 2004). The bottom-up approach means to customize WfMS by using business processes from the requirements of an organisation. The logic, control flow, and data flow of existing business processes are identified first. The next step is to organise these processes. After gathering of relevant information, a workflow model is constructed.

A workflow management system typically consists of workflow definition tool, process definition tool, workflow engine, constraint repository, and database. Xu et al. (2003) described a workflow definition tool to create the business process representations, including separating processes as well as business rules and process logics. A workflow engine is a software service that provides a runtime execution environment for a workflow instance, which is capable to initiate utilities to activate appropriate applications for the execution of particular activities. The workflow instance has to also interpret process specifications, control process instances, and navigate among processes within a given and restricted workflow. Furthermore, it maintains workflow data and workflow control data and supervises actions related to control, administration and auditing. Typically, the constraint repository contains the workflow regulations, the workflow ordering list, and the mechanism to keep data consistent with the constraint. The agent-based workflow structure is the dynamic model that shows the functional flows of workflow processes. As the workflow executes, corresponding agents execute tasks either sequentially or asynchronously.

In the business domain, Aalst and Hee (2002) explain that a good reference frame is required in business processes. Therefore, the process can be defined and analysed clearly within this reference frame. WfMC (1995) introduces a reference model that will be presented in the next section. This reference model will eventually be adopted for educational processes.

3.4.2. Reference Model of WfMC

Depending on the complexity and duration of various constituent activities defined in the individual business process, a process has a lifecycle ranging from minutes to days or even months. To realise these activities, systems must use information technology and communication infrastructure which are operated in an environment ranging from small local workgroup to an inter-enterprise system.

Workflow management systems exhibit certain common characteristics, which provide a basis for developing integration and interoperable capability between different products in different objectives. The Reference Model of WfMC (1995) describes a common model for the construction of a workflow system. Taking a broad view of workflow management technology, the reference model of WfMC intends to accommodate a variety of implementation techniques and operational environments which characterise this technology.

3.4.2.1. Functions of Workflow Management System

There are three functional areas described by WfMC (1995) which comprise a workflow management system:

- The Build-time functions: defining and modelling the workflow process and its constituent activities. They translate a process from a particular case from the real world into a formal, computerized definition. In addition, the definition may be expressed in textual or graphical form or in a formal language notation.

- The Run-time control functions: managing the workflow processes in an operational environment, sequencing the various activities, and handling them as parts of each process. They act as the linkage between the process with the modelled definition and the process seen in the real world. The core component is the basic workflow management control software (or "engine"), which is responsible for creation and deletion, the control of activity scheduling within an operational process and interaction with application tools and human resources.

- The Run-time interactions with human users and IT application tools are for processing various activity steps. They transfer the ability to control the process between activities, to ascertain the operational status of processes, to invoke application tools, to pass on the appropriate data, and so on. The benefits of having a standardised framework are that a consistent interface can be used for multiple workflow systems and developing common application tools is possible for different workflow products.

3.4.2.2. Product Implementation Model

WfMC constructs and provides a general implementation model of a workflow management system which can be matched to most products in the marketplace.

The main functional components of the generic workflow system are illustrated in Figure 3-4. The generic model has three types of component:

- Software components which provide support for various functions within the workflow system (definition tool, WFM engines, worklist handler, and user interface);
- Various types of system definition and control data which are used by one or more software components (process definition, organisation/role model data, workflow control data, worklist, and workflow relevant data);
- Applications and application databases which are not the parts of the workflow product, but which may be invoked by it as parts of the total workflow system (applications and workflow application data).

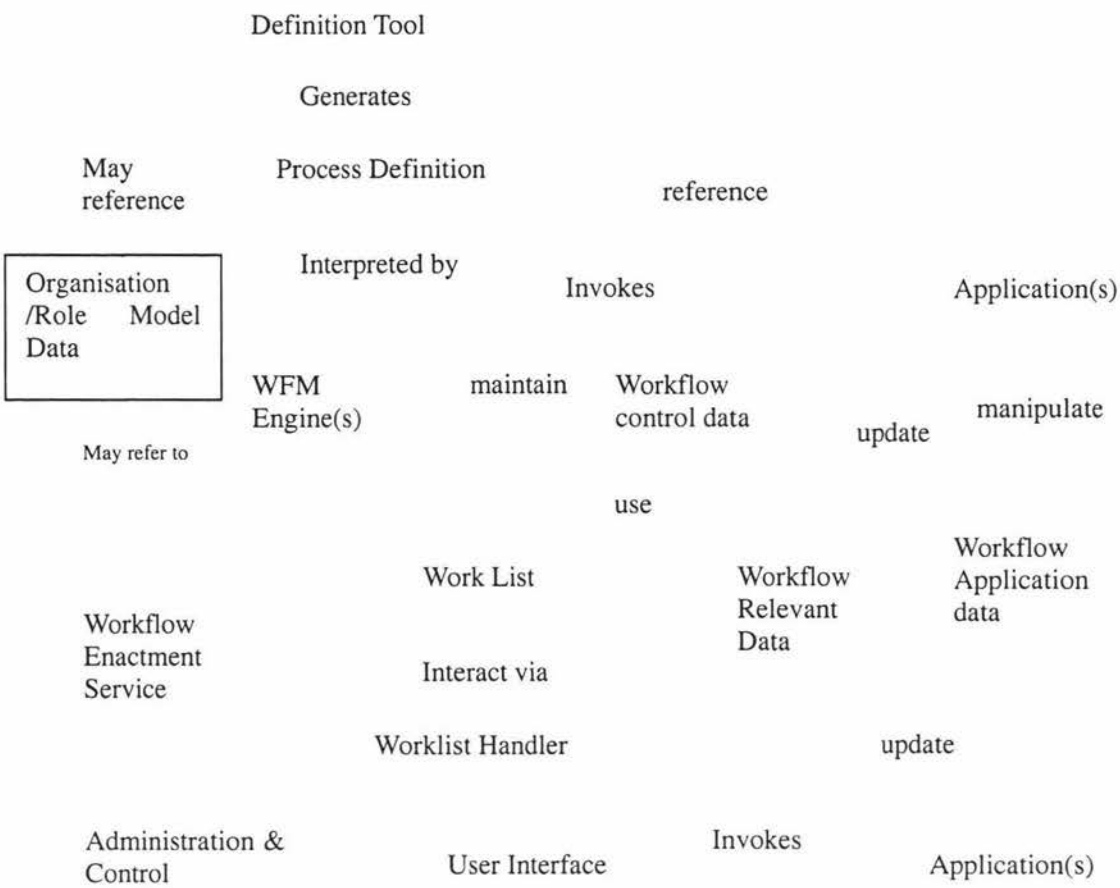


Figure 3-4: Generic workflow product structure (WfMC, 1995, p.13)

Process definition tool: creates the process description in a computer processable form;

Process definition: contains all necessary information about the process to be executed. It includes information about the start and completion conditions of the process, constituent activities and rules for navigating among them, user tasks to be undertaken, references to applications which may need to be invoked, definition of any workflow relevant data which may need to be referenced, and so on;

Workflow enactment service: interprets the process description and controls the instantiation of processes and sequencing of activities, adding work items to the user work lists and invoking application tools as necessary. All of these are done through one or more cooperating workflow management engines, which manage the execution of individual instances of the various processes;

Worklist handler and user interface: worklists handler is a software component, which manages the interactions between workflow participants and the workflow enactment service. User interface is responsible for the look and feel of the user dialogue and control of the local interface with the user.

WfMC (1995) also presents alternative implementation scenarios:

- Centralised or distributed workflow enactment service;
- Worklist handler location and distribution mechanism.

3.4.2.3. Workflow Reference Model (WfMC, 1995)

WfMC develops a reference model to standardise interfaces and data interchange formats when interfaces of a generic workflow application are able to interoperate these products at various levels. The reference model offers a general overview of workflow systems. In addition, a number of generic components are in workflow systems and interact under definition.

Figure 3-5 shows the major components and interfaces within the workflow architecture.

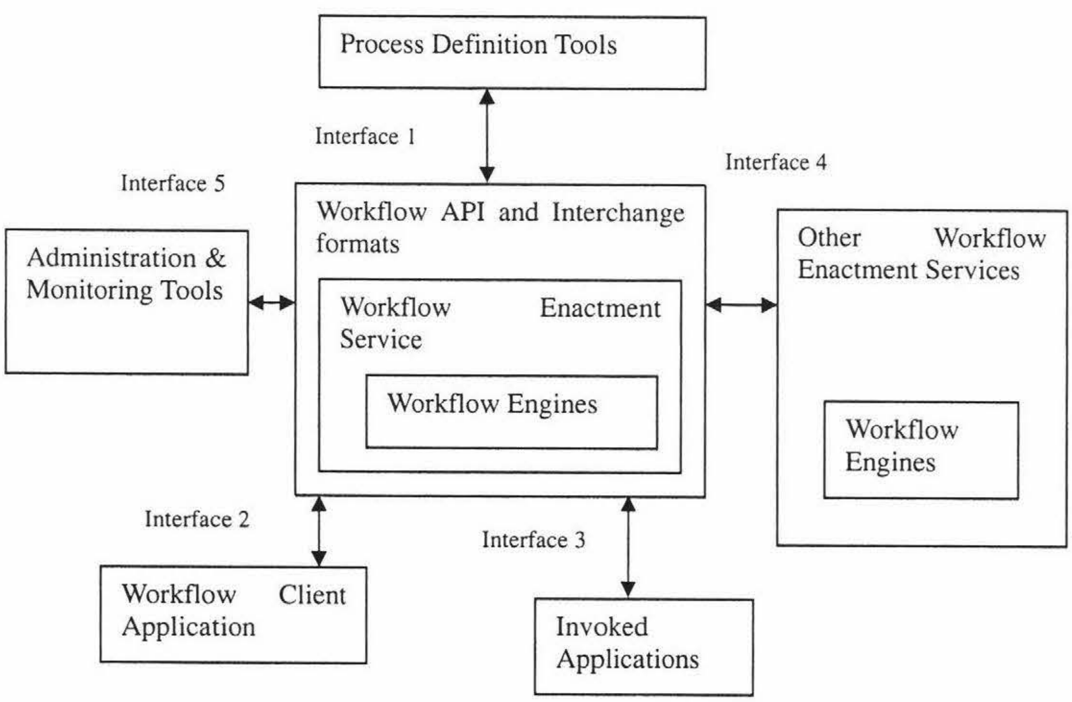


Figure 3-5: Workflow Reference Model—Components & Interfaces (WfMC, 1995, p.20)

The interfaces of Figure 3-5 indicate that appropriate services are provided to support the management functions across these five functional areas rather than five separated and individual interfaces.

The central part of this architecture is Workflow Enactment Service. It is defined as "*a software service that may consist of one or more workflow engines in order to create, manage and execute workflow instances. Applications may interface to this service via the workflow application programming interface (WAPI).*" (WfMC, 1995, p.21) It comprises a logical separation between the process and activity control logic. The application tools and end user tasks constitute the processing associated with each activity. Furthermore, the workflow engine shown in Figure 3-5 represents "*a software service or 'engine' that provides the run time execution environment for a workflow instance.*" (WfMC, 1995, p.22)

3.4.3. The Applicability of Workflow Approach in Business

Owing to the increasing development of the economy, it is necessary for an enterprise to adopt new models and infrastructures to reorganise business processes to survive the intense competition with flexible and reliable approaches (Cardoso et al., 2004). Actually, a directed and essential business process can be described by the workflow (Vidal et al., 2003). On the other hand, the workflow is defined as the computerised facilitation or automation of a business process (WfMC, 1995). It is also described as a business process abstraction, which indicates that activities, resources, and rules combine together to form the whole business process execution mechanism (Cai et al., 1996). According to the dynamic features of business services, the workflow technology is an enabling technology for managing, coordinating and controlling the activities of a business process (Meng et al., 2002). The following section aims to present areas to which workflow technology have been applied.

3.4.3.1. Employing Workflow Technology in Business

In fact, fundamental aspects of business organisation are business processes. Therefore, improving business processes is a vital step to reach success among business competitions. A business process is a set of one or more interdependent procedures or activities, which collectively realise a business object or policy goal. Applying workflow technology is the solution to improve business processes, because it demonstrates the automation of business processes, data transfer, and information sharing across organisations.

Workflows are designed from the actual business processes of the organisation. The management of workflows offers an opportunity to improve the execution of continuous business processes. In addition, a workflow system consists of a set of applications and tools, which are able to manage various activities associated with workflows (business processes) while the business process is coordinated and managed by participants. It reads, automates, processes, and manages workflows by coordinating, sharing, and routing information. When tasks, information, and documents are transferring from one participant to another under certain conditions and rules, the automation of work items makes for process efficiency. Therefore, a workflow model is needed for Workflow Management System (WfMS) to customise the specific business process structures (Cardoso et al., 2004). Most business processes adopt the reference model of WfMC to set up their own system (Cardoso et al., 2004; Cheung, W., & Till, 2002; Chiu, Cheung et al., 2004; Chiu, Cheung, & Till, 2003; Vidal et al., 2003).

3.4.3.2. Applicability Areas for Business

Process-based business transactions between enterprises can be supported by workflows with standards (Iwaihara et al., 2004). Workflow management system (WfMS), however, is used not only as a tool of a business process automation in a single organisation, but can also be used as one of the solutions supporting inter-organisational processes (Cheung et al., 2002; Iwaihara et al., 2004; Jun & Han, 2003; Meng et al., 2002). On the Internet, organisations and individuals can collaborate to carry out various activities, providing valuable services, and to communicate with each other. More recent researches on workflow technology attempt to model business activities with cross-organisational workflows and build web-enabled advanced WfMS. It has been installed and deployed successfully in a wide spectrum of organisations. It works as a bridge between two or more organisations. In a distribution system, the flow of the work involves the transfer of tasks among different departments' workflow products to enable different parts of the business process to be enacted on different platforms or sub-networks by using particular products that are required in the process.

For example, Xu et al.(2003) took advantages of workflow automation and software agent technologies to establish coordination mechanisms for Supply Chain Management to have real-time cooperative operations between the business and the dynamic and sometimes unpredictable market. The most useful contribution is that they concentrate on constructing flexible mechanisms to deal with cross-organisation business activities with workflow. It has the potential to develop e-commerce business systems. Workflow-Contract-Solution model (WCS model) was developed by Iwaihara (2004) to handle and implement solutions for the unexpected e-contract exceptions. Because of the globalisation of the economy, Cheung (2002) composites e-services across organisations as the workflow extension. To satisfy the nature of a business process, Meng (2002) presents a dynamic workflow model for inter-organisational business processes. Similarly, Carlsen et al. (1997) derive flexibility features of workflow products from their quality evaluation framework. Meanwhile, Cichoki and Rusinkiewicz (1999) represent a migrating workflow model to handle the two limitations of the workflow management system: workflow's flexibility in business, and transactional guarantees for workflow applications.

Previous research on workflow technology presented effective models for dynamic business processes that can handle unexpected changes in the business environment during their running. The infrastructure of the workflow management can be used for various domains besides the business domain, such as bio-informatics applications (Vouk, 1998), healthcare (Chiu, Kwok, Wong, Cheung, & Kafeza, 2004), the telecommunication industry (Buford et al., 1998), and scientific research (Ailamaki et al., 1998). However, an educational process for students to learn a paper, for example, can be described as a dynamic process. Like a dynamic business process, the activities of an educational process should have partial orders varying from different people's purposes or habits.

3.4.3.3. Weakness of Workflow Technology in Modelling Educational Process

Even though workflow definition has a time dimension in the workflow process, it is not enough to model educational processes owing to the tight combination of the educational process with time component. In fact, almost every activity of the educational process has certain time constraints for the purpose to be achievable. In the WfMC reference model, workflow engine is the heart of the model. It invokes processes and associate applications for the workflow process to work properly. Because of the importance of timing in education, the general reference model is insufficient for the education area. The workflow engine has to integrate time trigger mechanisms into the original one to make the educational workflow process work smoothly. Time dimension as a part of workflow technology should be emphasised in educational process modelling.

In addition, there are bottlenecks of the workflow because many resources are involved and lots of aspects are considered in modelling processes. Here, we list three main possible problems from Aalst and Hee (2002) and Alonson, Agrawal, Abbadi and Mohan (1997).

- A large number of cases cause major fluctuations in the supply of cases or by a lack of flexibility in the resources. In addition, too many steps in the process need to be passed through sequentially. The 'case' mentioned here means the task that needs to be carried.

- The actual process time is much shorter than completion time. Therefore, reducing the possible completion time over the whole range of processes is needed.

- The workflow's level of service is determined by the completion time. If the completion time fluctuates widely, it is a low level of service.

To eliminate the disadvantages of the workflow listed above, the time component is introduced into the educational process. It cannot guarantee a specific completion time, but it can be set with a reasonable time span. Because the features of educational processes are not identical with business processes, there are not many unpredictable aspects affecting the educational process. The certain time periods may be predefined for the particular educational process. For example, the discussion part of the lecture is difficult to decide because it indicates the performance on both the instructor and students. However, the period for the lecture time is determined into a fixed time period, 50 minutes for example.

3.5. Modelling with Classical Petri nets

Ignoring the time issues in the educational process, the educational process has been modelled with classical Petri nets in Chapter 2, which have been done by many researchers. The following chapter will emphasise the time concept in educational processes in detail.

Mapping Workflow Concepts into Petri Nets

Workflow model can present nesting and ordering of processes, the structural components that participate in the processes, and the roles that play in the process. It also maps to Petri nets, which allow verification of formal properties and qualitative simulation. The workflow can be described with the Petri net techniques. In fact, all workflow concepts— such as process and routing—can be mapped into a Petri net.

- **Process**

The Petri net can present a process. A process in workflow management is an instance such as an application for admission to an institute. The process defines how many tasks need to be performed and in which order. The order of execution of tasks is defined to indicate the steps for the process. In addition, corresponding information about tasks and conditions is required.

Thus, the process may also consist of more than one sub-process, as well as tasks and conditions. A case is represented by one or more tokens in Petri nets. Conditions are presented as places and tasks as transitions (Aalst & Hee, 2002), because transitions are the active components and places are passive components.

- **Routing**

Along with a number of tasks, the routing of a case indicates the order of execution of tasks throughout the defined process. The order in which tasks are performed may also vary from case to case. Four basic constructions for routing are recognised. Four forms of routing can be represented by Petri nets: sequential routing, parallel routing, selective routing, and iterative routing (Figure 3-6) (Aalst & Hee, 2002).

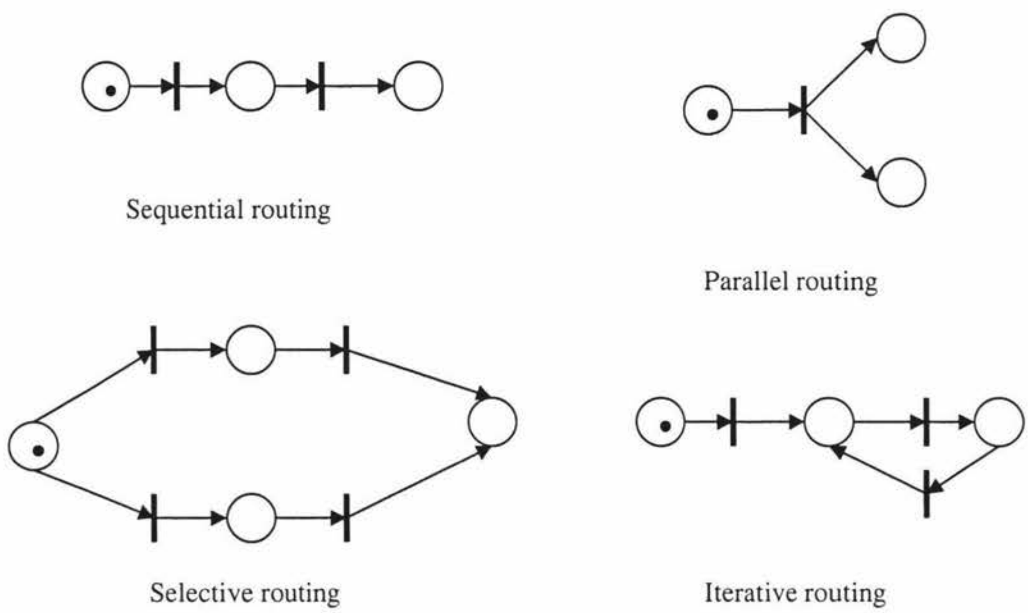


Figure 3-6: Four forms of routing in Petri nets

From Figure 3-6, it is easy to understand what the *sequential routing* is. However, the token in the first place of the *parallel routing* will be moved into two places in parallel, if the transition is fired. In contrast, the token will be shifted to either the upper place or the bottom place if one of the transitions is fired in the *selective routing*. To understand the *iterative routing* presented by Petri nets, it is similar to the sequential routing, but the token will travel back to a previous place.

3.6. Summary

In this chapter, workflow technology has been stated to be an ideal technology to be utilised in automating business process. After comparing the business process and the educational process, the workflow technology has the potential to be applied in educational processes as well.

General workflow terminology has been discussed at the beginning of this chapter including features and components of workflow. In addition, the research presents the requirements in adopting workflow technology into modelling various processes, which may automate the process to eliminate time-consuming tasks and manual interventions as much as possible. After analysing the difference and common features of the business process and the educational process, workflow technology can be used in modelling the educational process. Then, Workflow Management Coalition (WfMC) is introduced to show the common terminology and standards of the workflow user community. In addition, the reference model of WfMC is presented to establish workflow management system in the business area. How the workflow reference model can be fitted into the business area has been investigated. Moreover, as Petri nets have been discussed and chosen to model educational processes in Chapter 2, they should be used to model workflow process components. Therefore, workflow management technology has the ability to make the process run more efficiently and effectively. Petri nets as the modelling tools have the ability to model the educational processes associated with the workflow technology.

As mentioned before, the time concept is very important in the educational process. To emphasise how important time is, the research ignores this dimension in the previous two chapters. In the following chapter, time will be illustrated in detail. Although workflow technology originally has the time dimension to model processes, time stamp and time duration will be described and illustrated in the educational process in the next chapter. In addition, classical Petri nets do not have the ability to show the significance of time in the educational area. Therefore, Petri nets with time extension will be discussed and the educational process will be modelled with this extended notation.

Chapter 4. Time Reasoning in Educational Processes

Educational processes have been described in Chapter 2 and the issue of time in the context of process was discussed in Chapter 3. Furthermore, basic workflow technology is presented in the previous chapter. After discussing the characters of educational process, workflow technology has been adopted to model the educational process as well as the business process.

In this chapter, it is worth to have further discussion about the time issues involved in the educational processes. In Chapter 2, Petri nets with time extension was described briefly to model the educational process. It was shown that this formalism has the ability to show the real educational process with time dimension.

Owing to the importance of this time concept in educational processes, data storage with the information about time is considered in this research. A temporal database is the one that has the capability to store the time information. This technology will be briefly discussed and the advantages of the temporal database will be illustrated.

4.1. Time Reasoning in Educational Process

The notion of 'time' in a process is required to be represented explicitly. Time can be represented discretely or continuously. The differences between discrete and continuous representation result in different models (Stefik, 1995). In a discrete model, the interval of time presents the state of the process, whereas a continuous model shows the gradual changes of the process with real values. Of course, the continuous model is more reasonable than the discrete one because it reflects and is close to the changes happening in the real world. However, for the learning process, there is no actual numerical value that is able to be assigned to the state of the process when it gradually changes, although time scales are involved in the process. There are many facts about 'time' in the education domain, for example, the beginning and the end time comprising the duration of each lecture for a paper study. Normally, several examinations are set for one paper, such as middle term and final examinations. Each examination has duration varying from one hour to three hours for students to finish all questions offered by the instructor of this paper. In addition, the actual time for the beginning of the semester indicates the ready state for papers to be taught. For each phase of the paper, only three values are able to represent status: ready, in the middle status, completion. When the previous phase is completed, it indicates the ready status for the current phase. If the current phase is finished, it not only illustrates the completion of the current phase, but also shows the ready status for the next phase. It is obvious that the middle status is situated between the ready and the completion. However, there is no actual numerical value to demonstrate what has been gradually changed in the middle. For instance, when a paper is being taught, there is no numerical value to show this teaching process with the time elapsing. Therefore, using discrete status is adequate to represent the process. The model designed for educational processes in this thesis is therefore based on the discrete model.

4.1.1. Time-driven Mechanism for an Educational Process

As time is indicated as a key component in educational processes, an educational process can be defined with several time points to divide it into several segments. Following the sequence of time is to organise each task of the process to be executed from the beginning of the process to its end. When one of the defined times arrives, the scheduled task should be executed under certain conditions. Then, the process is shifted into the next stage by conducting the task associated with the time span defined for this task. Similarly, after completing the necessary and required activities of the task in this phase, the arriving time point is the prerequisite for the process to move forward to the next phase till the end. The advantage of using a time-driven mechanism is to reduce human factors because the time triggers the process running. For diverse educational processes, a phase of a process is determined by two time points, which indicate the duration of the phase. All activities that the phase required must be completed during this time. Therefore, reasonable time setting for each phase is necessary and significant for the running of the process. When the end point of time arrives, the status of the process will not stay at the phase defined by this end-point, but will automatically move to the next phase as time goes by. Then, the process moves to a new phase. Similarly, the corresponding activities and roles will take over the process and make the process move forward.

However, if participants cannot complete tasks on time, then extra time permission is required for that phase. Thus, the extra time permission leads to rescheduling the time of the defined process. The rescheduling can be represented as the flexible feature for redefining the process. To emphasise the flexibility of the process, the time constraints can be rearranged when some unexpected situation emerges. It highlights that the process does not have to be redefined only after adjusting several time constraints to make the process move forward again. On the contrary, it also can be described to be in a disadvantage position if reasonable time points are not defined for the process initially. Although the rescheduled time points also follow a time-driven mechanism to carry forward activities in phases, it is not necessary to change time constraints many times. Actually, each phase has sat in the time line. When one phase duration is changed, the remaining phases should be changed simultaneously. In addition, roles playing in different phases have to be noticed with different durations for them to carry out activities. Therefore, sensible setting of the time points of the process is significant for the movement of the process and it also is the effective method to minimize the adjustment for the time points of the process.

4.1.2. Event-driven Mechanism vs. Time-driven Mechanism

Compared with time-driven mechanism when time is the trigger, an event is the trigger for an action in an event-driven mechanism. When an event happens, the actions are activated. For instance, when a person gets the id number from the administration office, his social account becomes active. The event for triggering and reacting his social account is to get the id number from the particular department.

To illustrate the differences between time-driven and event-driven mechanisms clearly, an example is presented. When a student submits his assignment, the assignment will be sent to the marker's mailbox immediately and is ready for marking. This case is under the event-driven mechanism. In contrast, for the time-driven mechanism, the submitted assignment is not available for the marker, even though the student has submitted it. The lifecycle of the assignment has been divided into two phases in this example: one for students only and another for the marker. Each phase has two time points to define its duration. For the time-driven mechanism, the time point separating the two phases is the trigger for the process shifting from one phase to another. Therefore, when current time is still in the first phase for the student, the assignment will not be available for the marker even if the assignment has been submitted. The phase of the assignment is changed from students to the marker only if the time point for the beginning of the marking period arrives.

However, the event-driven mechanism has advantages in some situations. It always obeys first-in-first-out to deal with cases running in the process. In an ideal situation, for the first case running in the process, the first result should be given and leave the process. For instance, when the first application form is submitted, the first approval will be granted without any delay. On the other hand, in the event-driven mechanism, only the order of tasks for the process is defined. If one phase of the process is delayed, the whole process is delayed. It indicates that the efficiency of the process is highly based on the human factors. Thus, time-driven is introduced to eliminate the human factors in the running of process. It sounds unfair for the student who submits the assignment early not to get the result earlier with such a mechanism. However, it is reasonable and fair for all students to get results at the same time no matter when they submit their assignments excluding the overdue submissions. This is the motivation for using a time-driven mechanism in modelling educational processes. The movement of the process is related with the time only. However, the advantages of the first-in-first-out from event-driven mechanism will be adopted in this chapter to model a sub-process.

On the other hand, the event-driven mechanism also can be transformed into time-driven. When the event as the trigger has happened, the actual time of the happening event is recorded as the time trigger for the time-driven mechanism. Therefore, the time-driven mechanism is chosen for modelling processes relevant to the education.

In fact, all educational activities are happening based on the time axis. Indexing activities with date and time is to trace the educational process. To store the time information associated with general information is the motivation of using temporal database where time can be assigned and retrieved with any change of the process in database. More details on temporal database will be introduced in section 4.5.

As described above, time is a vital component in the educational process. In addition, Petri nets are the modelling tool for process modelling. The following section introduces time Petri net to show how it works in modelling educational processes.

4.2. Time Petri nets

There are two formats of time extension - Timed Petri nets (Gu, Bahri, & Cai, 2003; Ramamoorthy, 1980) and Time Petri nets (Merlin & Farber, 1976). Ramamoorthy introduced firing time to the transition in Timed Petri net. In Merlin's Time Petri net, an interval is annotated with each transition and transitions only can fire between corresponding intervals after the enable instant of such a transition. Time Petri nets have more power than Timed Petri nets. For evaluating dynamic systems, time constants have been included into Petri nets by associating them either with transitions or with places. It is derived from Petri nets by associating a firing finite duration with a transition or place of the net. However, time Petri nets are more general than timed Petri nets with two times specified. For Time Petri nets, a transition can fire within a time interval whereas for Timed Petri nets, it fires as soon as possible. In general, these two time values elaborate the minimal and maximal execution times of the transition (Figure 4-1). This kind of Petri nets is convenient to express all processes with temporal relations.

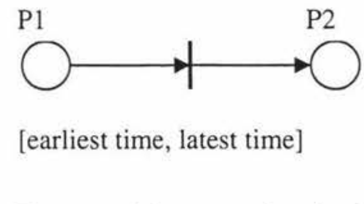


Figure 4-1: The transition notation for Time Petri nets

Time Petri nets emphasise time constraints in transitions. For example, if a task is in place P_1, it must be done and completed during the range from the earliest time to the latest time. In addition, the state of the Petri net is changed after the latest time because the case moves to P_2.

When students receive an assignment from the instructor via the Internet, they are allowed to do it and submit it before the due date. There are the earliest and the latest times for students to complete and submit their assignments, allowing for their paces of doing this assignment. After the latest time, students are not allowed to do any further activities on the assignment. The time interval presented in time Petri nets provides time constraints for the nature of this particular educational process. Therefore, we argue that educational processes should be modelled with the time Petri nets in this thesis.

On the other hand, if time is not considered such as in classical Petri nets, the trigger between two events depends on roles playing in the process. For example, if there is no time constraint for students to finish their assignments, how can the second phase for markers to mark their assignments be invoked? Students may submit their assignments at any time once they have finished. Adopting the event-driven mechanism in this case, the marker can mark the assignment when the student submits it. It means that the marker's activities rely on the submission of students. When the first assignment is submitted, the marker's time has been occupied for marking this assignment. It follows first-in-first-out theory to process the submitted assignments. This is the situation without any time constraint in the process. In fact, the participants involved in the process are not independent and highly intertwined with each other, which may have more potential to delay the process.

Now, we consider the time concept in the process. After students have completed their activities and submitted their assignments, assignments are presented as tokens moving to the marker and are ready to be processed. The marker may stay at his marking stage and hold every assignment until the last assignment has arrived before the deadline of the assignment. After the latest one has been handed in, the real marking process for the marker begins. There is a possibility in making a delay of the process, if there are several students asking for extension of their assignments. The marker has two options to deal with such delay cases, either to hold the status of the process for these delayed assignments, or let the majority of the assignments go to the next stage and extend his own working duration for these particular assignments. On the one hand, the process keeps working smoothly. On the other hand, the marker processes these delayed assignments as soon as possible. Obviously, the second option is a better choice to let the process run more efficiently than the first one. That is the reason for integrating time component into Petri nets to eliminate the human factors from the process execution.

4.3. Modelling Educational Processes with Time Petri nets and Workflow Technology

As described in 2.1, processes happen among student, instructor, and general staff in education. The definition of the educational process is determined by the case, like a paper, running in it. Each type of the process has its own generic model to flow from beginning to end. In this section, generic process architectures are introduced individually.

Incorporating the elements of workflows and the features of educational processes, the definition of educational processes can be easily presented in the design tool: Petri nets. The task is identified by a circle, flows by lines with arrows, and the bar presents an event which fires in generic Petri nets notation.

4.3.1. Learning/Teaching Process

The learning/teaching process, in fact, is two facets of the same process. Actually, the process discussed here concerns about the lifecycle of a paper that the student chooses or the instructor teaches. So, the object being processed in the learning/teaching process is the paper. There are three different actual grouped roles involved in the process: the academic group (instructor group), general support group, and the student. The academic group comprises instructors and associated staff who teach and support teaching. The members of the general support group are people who provide services to forward the process. The student or learner is the role in which to accept knowledge from both instructors and papers.

The features of an educational process warrant the time-driven mechanism discussed in section 4.1.1 to be applied into the modelling of the educational process with its workflow. According to the configurations of a paper, such as lecture timetable, tutorial timetable, examination time, the lifecycle of the paper has been divided into several phases when time goes by. These time points have to be settled when the routine of the paper's lifecycle is designed. It is obvious that the beginning and the end time for the lecture are compulsory time constraints for the process when the process goes into the lecture duration, as well as for the tutorial and the examination duration. Thus, the periods of time for lecture, tutorial, and examination are fixed and cannot be changed. In addition, owing to the arrangement of paper materials that is determined by the pace of the instructor teaching, the instructor gives several assignments and quizzes within the duration. The instructor defines these additional time points for these assignments and quizzes only. Therefore, there are several extra time points besides the fixed timetable of the process. All time points contribute to the configuration of the paper.

However, during the lecture time, for example in one or two hours, the lecturer (using *lecturer* here instead of using *instructor* for better understanding) arranges lecture materials by himself including how many chapters should be covered in this lecture, how many important concepts should be explained to students, and what kind of format should be used for each piece of information to be presented in the lecture, like using .ppt file, transparency, student presentation, or discussion. Efficiently arranging teaching activities in a lecture with the time consumption is an effective way to organise and present materials. The lecturer may give a rough time constraint for each phase of teaching to arrange and to model the process for the lecture. On the other hand, the arrangement of each phase varies from different lecturers with different methodology in teaching under time restrictions. Generally speaking, different lecturers have different methodologies for teaching and also have different understanding of knowledge. Therefore, they may present materials to students in different ways to emphasise which part should be highlighted. The various orders of phases with time and the material organisation for teaching are reasons for introducing the personal process into education. It is an integral part of the learning/teaching process to describe the detailed tasks, which will be illustrated and analysed in the next section.

- **Describing the Flow of the Learning/Teaching Process**

Because the material—course or paper—is processed in the learning/teaching process, it is necessary to describe the process for the paper rather than the process of either the student or the instructor.

The lifecycle of a paper from the beginning to the end can be divided into several phases. Each phase is controlled by a certain role. When a paper is selected by students for their study purposes: degree or diploma, and so on, the lifecycle of the paper is generated, (see Figure 4-2). Each paper has its own timetable which indicates the time for the lecturer to offer lectures or tutorials shown in the dash-line box of Figure 4-2. Besides the time arrangement for lectures, there are a few time slots for students to arrange their own study as self-study. Therefore, the fixed timetable of the paper is controlled by the instructor or lecturer, whereas other time slots are under the control of students themselves. Moreover, a paper has a variety of time points in addition to the fixed lecture timetable, such as the lifecycle of an assignment, mid-term examination, and final examination (Figure 4-2). All of these time points are integrated into the lifecycle of the paper. So, its lifecycle can be divided into several subprocesses. To maintain the big picture of the learning/teaching process, each subprocess is treated as one phase in this thesis.

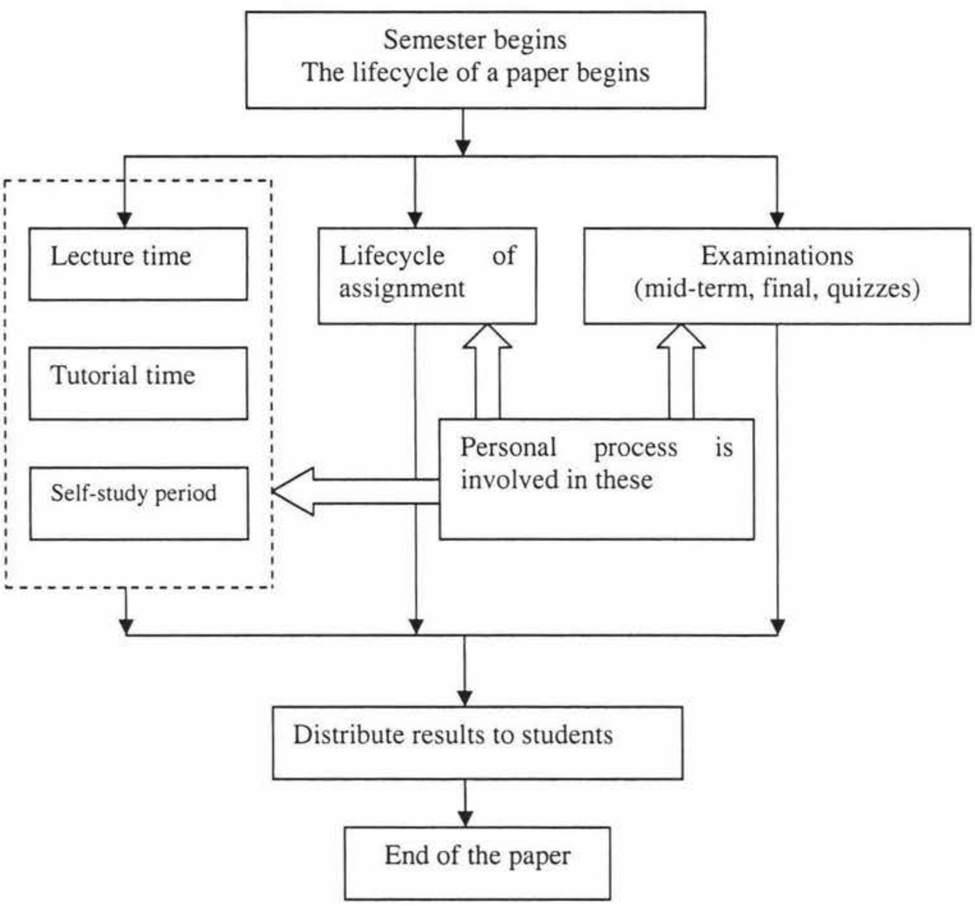


Figure 4-2: The lifecycle of a paper

Each phase of the paper's lifecycle includes diverse personal processes as shown in Figure 4-2. For a lecture, the content, the pace, and the time interval for each step of teaching varies from different lecturers in different representations. Similarly, the tutor acts differently and students participate differently to complete tasks in the tutorial, for instance. Moreover, students may have different methods to arrange their own study.

The performances of students in an examination also are diverse. Therefore, the personal process can be described as integral to the educational process, which represents a serial of educational activities of different roles. It is difficult to describe in detail varying from individuals because it is complex and there are many unpredictable situations existing in its subprocesses. In Chapter 5, the lifecycle of an assignment will be elaborated, and the personal process in an assignment's lifecycle will be introduced.

In fact, there are more than one assignment available for a paper and more than one examination to test students' performance in study in the real world. The parts of a paper shown in Figure 4-2 are integrated into one time axis (see Figure 4-3). The lifecycle of an assignment may span a few weeks across lecture time, tutorial time, and self-study time. The mid-term examination and quizzes times are chosen by the lecturer, except the final examination that is determined at the beginning as the timetable for both lectures and tutorials. Therefore, the time period is the only figure to indicate tasks and authorities of roles for the process. After distributing the results of the paper to students who have enrolled, the paper reaches the end point of its life.

The following diagram (Figure 4-3) shows the time constraints among events presented with a number of fragments of a paper's lifecycle. The lifecycle of a paper is laid out in one semester, for example, notation of the time range from 28th February to 25th June.

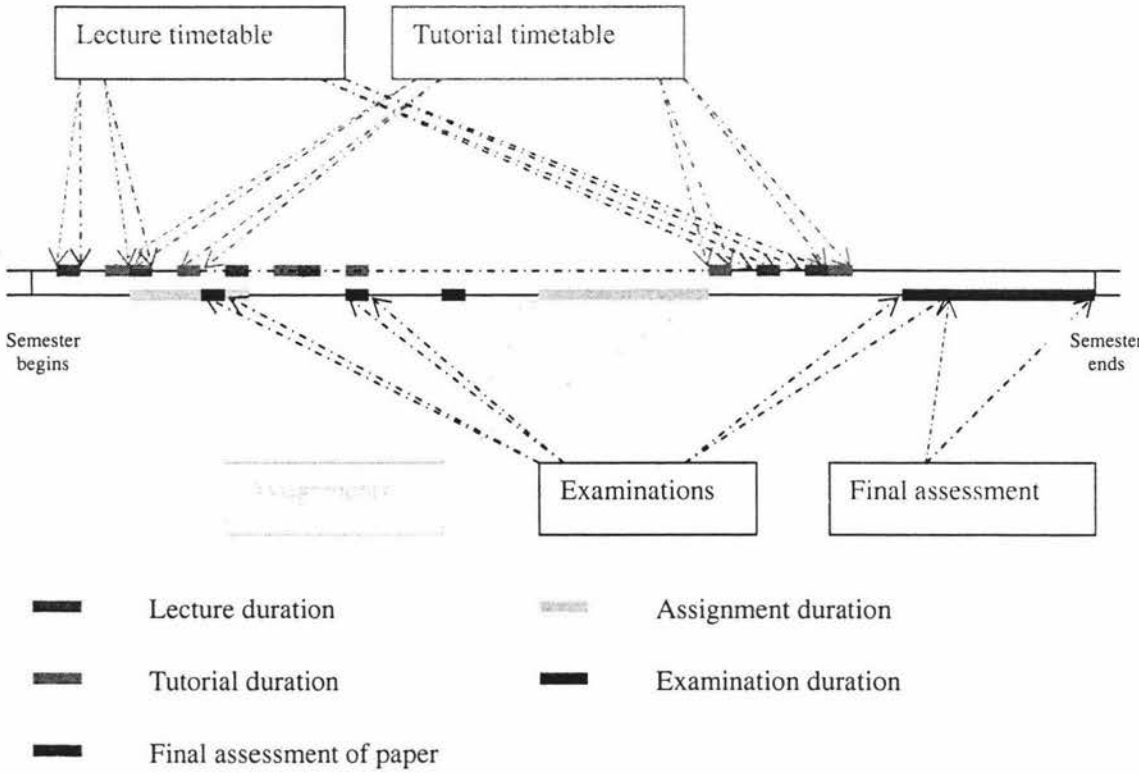


Figure 4-3: Fragment of a paper lifecycle

The diagram (Figure 4-3) shows the arrangement of lecture, tutorial, assignments, and examination in the lifecycle of a paper on the time line. The duration of a lecture has two components: the beginning and the end, which are the same for the tutorial, the assignment, and examination duration. The duration can be calculated with the formula and be precise to the actual time representation, for example every Tuesday from 10 a.m. to 11 a.m. There are many lectures and tutorials every week from the beginning of the semester to the end. The diagram illustrates only a few lectures and tutorials rather than showing them all. The assignment duration indicates the lifecycle of an assignment from the generation date to the cut-off date. It can be refined to many subprocesses that will be discussed in Chapter 5. In this diagram, only two assignments are set for this paper. The examination duration indicates the beginning and the end time of quizzes, mid-term examination, and final examination. The final assessment phase is to deliver the final results to the students. The time slots between the lecture and tutorial time before final examination are self-study periods, which comprise the personal process for students to study.

From this diagram, subprocesses can be executed simultaneously. The assignment duration period parallels with the lecture and tutorial duration as well as the quiz duration, for example. It indicates that the time for students to complete their assignment is overwritten with other educational tasks, such as lecture, tutorial, and quiz time.

- **Modelling Learning/Teaching Process with Time Petri Nets**

The learning/teaching process is much more complicated than any other process because there are three groups of roles involving in the process. The lifecycle of a paper has been described in the previous section that gives the initial frame within which to model the process with time Petri nets.

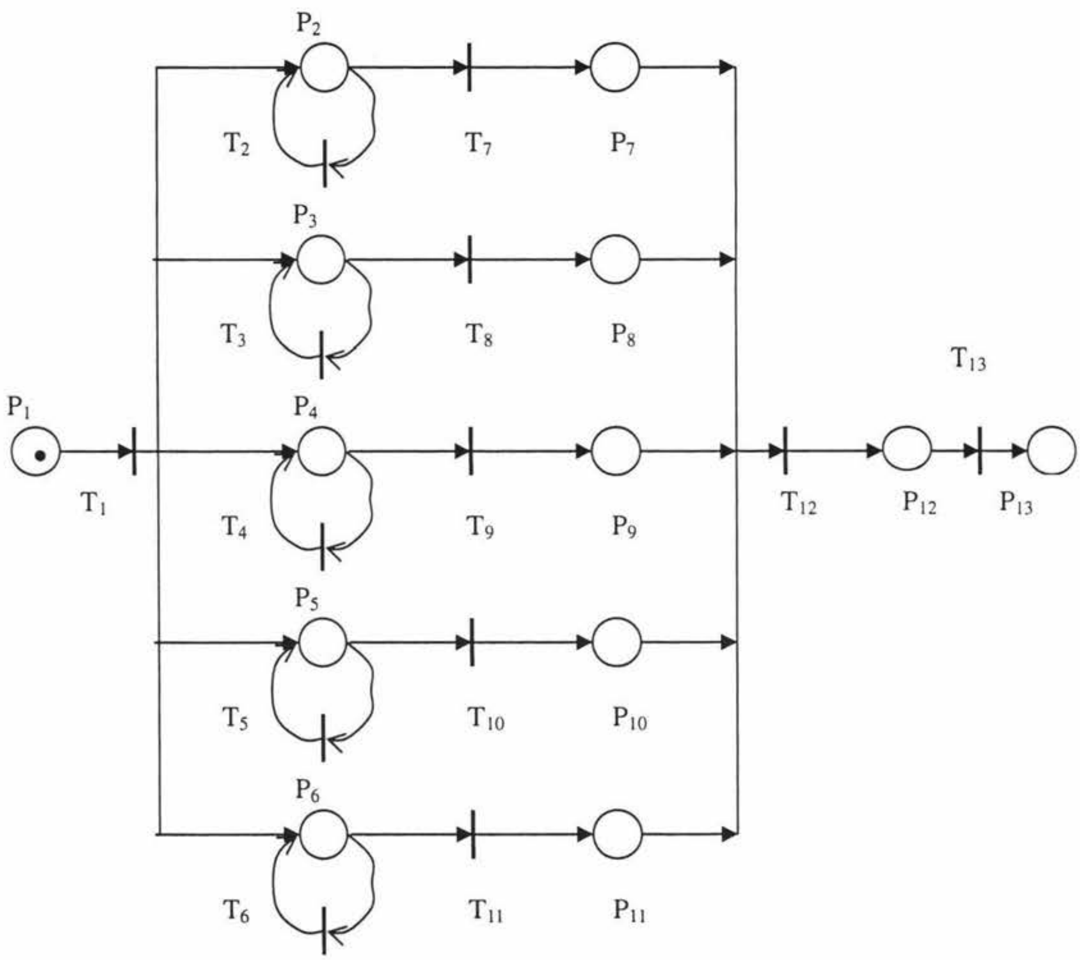


Figure 4-4: Modelling learning/teaching process with time Petri nets

Transitions	Format (examples)	Description
T_1	[28th Feb, 2005 9:00 a.m., 28th Feb, 2005 9:00 a.m.]	The begin date and time for the paper
T_2	[every Tuesday 10:00 a.m., every Tuesday 11:00 a.m.] [every Thursday 1:00 p.m., every Thursday 3:00 p.m.]	Weekly timetable for lectures
T_3	[every Monday 9:00 a.m., every Monday 10:00 a.m.] [every Wednesday 10:00 a.m., every Wednesday 11:00 a.m.]	Weekly timetable for tutorials
T_4	The format is similar to T2 and T3. But time duration for self-study is set flexibly besides the fixed time slots for lectures, tutorials, and examinations. Actually, it is the personal process integrated into the overall learning/teaching process.	
T_5	[15th March, 2005 10:00 a.m., 30th March, 2005 12:00 p.m.] [4th April, 2005 2:00 p.m., 16th May, 2005, 5:00 p.m.]	Two assignments' duration
T_6	[7th March, 2005 10:00 a.m., 7th March, 2005 11:00 a.m.] [3rd April, 2005 9:00 a.m., 3rd April, 2005 10:00 a.m.] [6th June, 2005 9:00 a.m., 6th June, 2005 12:00 p.m.]	The timetable for the quiz, mid-term examination, and final examination.
T_7	[30th May, 2005 5:00 p.m., 30th May, 2005 5:00 p.m.]	The final date and time for lectures
T_8	[30th May, 2005 5:00 p.m., 30th May, 2005 5:00 p.m.]	The final date and time for tutorials
T_9	[6th June, 2005 9:00 a.m., 6th June, 2005 9:00 a.m.]	The final date and time for the self-study
T_{10}	[30th May, 2005 5:00 p.m., 30th May, 2005 5:00 p.m.]	The final date and time for all assignments

T_{11}	[17th June, 2005 5:00 p.m., 17th June, 2005 5:00 p.m.]	The final date and time for all examinations
T_{12}	[17th June, 2005 5:00 p.m., 19th June, 2005 5:00 p.m.]	The duration for the assessment of the paper
T_{13}	[20th June, 2005 12:00 a.m., 20th June, 2005 12:00 a.m.]	The end date and time for the paper

Table 4-1: Transition descriptions for the learning/teaching model

Based upon the description of the learning/teaching process in Figures 4-2 and 4-3, there are five routes for a paper as a token travelling from the beginning to the end (Figure 4-4), having lectures, having tutorials, studying by self, having assignments, and taking examinations. In addition, Table 4-1 provides notation and description of each transition in Time Petri nets.

P_1 indicates the validation of the paper. T_1 has the condition for firing, which is the beginning time of the paper. P_1 and T_1 demonstrate the initial state and condition for the paper.

P_2 presents the ready state for lectures. However, T_2 is a pair of time data [the beginning time, the end time] for the lecture. In fact, the lecture time is scheduled three or two times every week as described in the timetable, for example. In Table 4-1, a formula is applied to describe the time duration for each time pair. The exact date and time pair presents for the available time and the end time, for example in presenting the duration of the assignments and examinations. In contrast, the timetable of lectures and tutorials is described with weekly representation. For instance, the paper has two lectures every week so that T_2 can be presented like [every Tuesday 10:00am, every Tuesday 11:00am] and [every Thursday 1:00pm, every Thursday 3:00pm]. The rule is mapped into tutorial (P_3,T_3), self-study (P_4,T_4), assignment (P_5,T_5), and examination (P_6,T_6). It is worth mentioning that self-study consists of many self-defined and arranged activities for personal purposes, which is defined as the personal process in this thesis. A detailed description of personal process will be presented in 4.3.3. But T_4 describes the time duration for self-study activities. The arrangement of activities differs for different people's habits and personalities.

T_7, T_8, T_9, T_{10}, and T_{11} indicate the end time of the final lecture, tutorial, self-study, assignment, and examination. If the time has arrived, the state of the paper reaches P_7, P_8, P_9, P_{10}, and P_{11}. Then, the performance for the individual student requires to be assessed. T_{12} shows the time constraint and duration to process the assessments to students. P_{12} presents that students get results when the latest time of T_{12} is reached. Then, the paper reaches the end point P_{13} if the end time of the paper, T_{13}, has arrived.

After modelling the learning/teaching process with time Petri nets, it is necessary to notice that there are lots of tasks in every route which have not been elaborated in detail. For example, when T_2 is fired, the lecture will begin at the earliest time and end at the latest time in the notation of time Petri nets. To describe it, the lecturer should organise contents and present items with certain tools or approaches. In addition, different lecturers may have different teaching styles to present these materials. Furthermore, owing to the features of content, the lecturer also needs to utilise different assistant tools to present it. Therefore, the presentation during lecture time varies from different formats, orders, and styles. The detailed activities for the subset of the learning/teaching process can be treated as a flexible subprocess and defined as the personal process in the thesis. To model the flexible process, Lin et al. (2001) present the method in an e-learning environment. However, in this thesis this process will not be modelled, because it is diverse and complex to follow its workflow. But a study programme planning process as an example of the personal process will be presented and modelled in 4.3.3. to illustrate the components and considerations involved in modelling these flexible processes.

4.3.2. Administration Process

The *administration process* is defined as the process that deals with an individual participant's case in an education institute. It describes the administration operations. The object that runs in the process is an application, such as a scholarship application, an application for using facility service, and so on, whereas a paper is the object running in the learning/teaching process. Time constraints are set for each participant to make sure that the case can be transferred smoothly without delay by human beings' effects.

- **Describing the Flow of Administration Process**

Administration process in this thesis is the processing of administration procedures on campus. Students may make many applications during their study. However, academic and even general staff also have administration procedures which need to be approved. Therefore, the applicant in the administration process may be the student, academic staff, and even general staff depending on the requirements. Figure 4-5 is the workflow of the administration process. The administration group mentioned in the fourth step (Figure 4-5) may include academic and general staff working in different departments. The member of an administration group is called *manager* or *administrator* in this section.

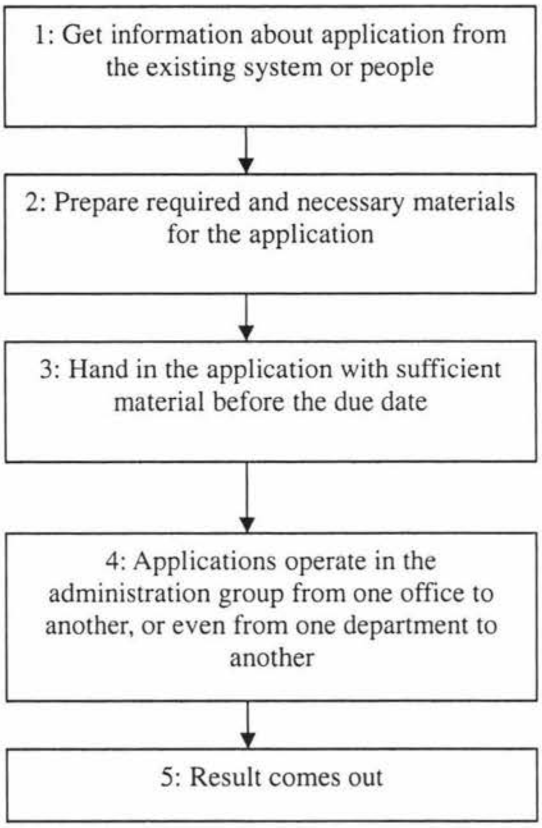


Figure 4-5: Flow for a typical administration process

Applicants are involved in the whole process. They firstly get information from somewhere or someone. Then, they should prepare the required materials for the application in the second step. The third step is that they have to hand in their applications with associated materials before the due date. It is necessary to mention that the personal process is involved in the second step while participants prepare materials. It is flexible and varies among different applicants. When the administration group accepts the application, the administration process is in its fourth step and applicants may be asked to provide additional documents in some cases. Similarly to the second step, the personal process is involved, when an administrator manages a part of the administration process. Administrators have different methods or strategies to deal with these applications. In the fourth step, the routine for applications varies with types of applications. For example, the admission to a degree programme for international students should start from the international student office for an agreement which concerns language entrance requirements. Then, the administration office of the college and institute or department should provide an approval or a rejection of the applicant's application. The exact procedures on how to process the application need not be elaborated in detail. Finally, the result will be sent back to the international student office for the applicant. After the result has been achieved under certain time constraints, it goes to the applicant directly.

Another role involved in the process is that of member in an administration group. The application goes from one member to another for approval. Actually, the route for the particular application procedure is predefined depending on procedure. The actual steps for the administration from one person to another are based on thresholds of the administration. Specifically, for an application, different officers may have different experience and have their own ways to process it. Therefore, when the role is on charge of one phase of a process, the role performs own personal process during this phase. The way to process an application at a certain phase varies from different people, which is similar to different students completing their assignments with different ideas. The application passes through different administrators in different offices or departments, which is similar to the transfer of documents from one department to another or among different offices. To deal with these applications, automatic workflow technologies can relieve staff from the complex paper collection and have a real electronic office environment.

Initially, an administration process obeys the first-in-first-out (FIFO) mechanism to avoid unfair processing orders in dealing with applications. FIFO indicates that the first person who hands in the application is the first one to get the result. This is the reasonable order to process applications and approval cases. That is why FIFO mechanism is adopted for time-driven mechanisms with the advantages in processing applications in this part. A time-driven mechanism has been introduced in section 4.1 to all educational processes according to the time component playing a significant role in processes. Time-driven mechanism illustrates the application processing with time constraints. Although FIFO forms a reasonable order for processing, there are factors that influence the procedures of the process. For example, a member of the administration group may delay the case for his own personal reasons. The participant in the process is authorised with certain priority to do some operations during the certain time period. After the maximum time constraint, all cases held by this member should be sent to another member for further approvals. This forces each member in the process to do the required operations without any delay. Of course, there is an access tool to reroute and reorganise the path of the administration process from one member to another if someone cannot complete operations in time. The reroute and reorganisation is to reconfigure the time extension for participants or set a replacement member to complete tasks that the current participant cannot finish. In addition, adopting the advantage of FIFO, in a certain time period, the authorised member could deal with cases following FIFO. For instance, when applications are delivered to an administrator after the due date, the administrator should deal with these applications in the FIFO order because each application has a timestamp when it is submitted. But after the latest time for this administrator to process, all applications are sent to the next administrator with the comments that the administrator made.

For different types of applications, the transferring route varies among offices and departments because each application has its own required approvals. Therefore, it is impossible to determine the actual steps for every administration process covering all kinds of applications. But it is possible to model the administration process in an overall structure without specifying actual steps for every threshold of applications. Figure 4-6 presents how the time component works in the modelling of the administration process.

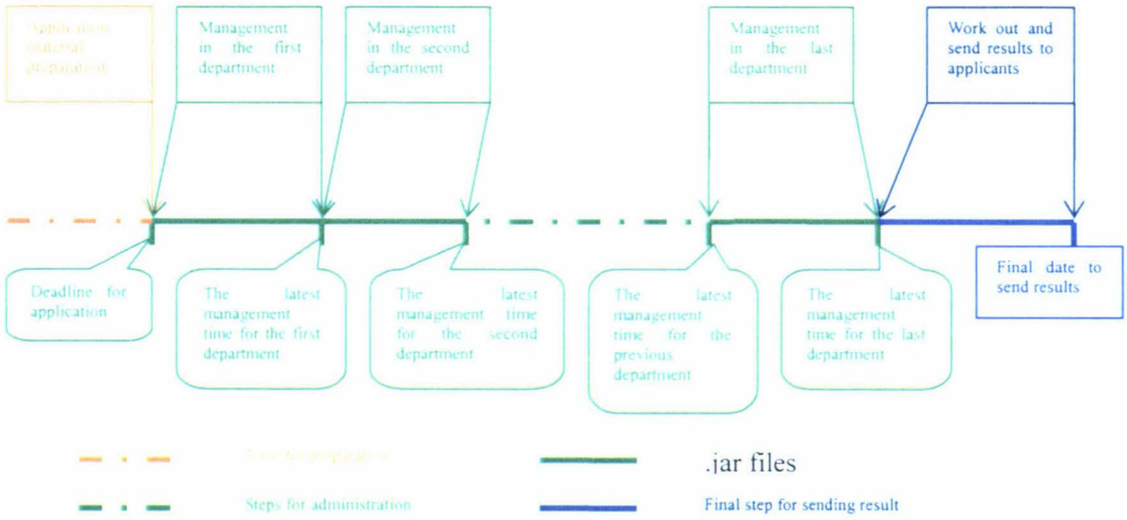


Figure 4-6: Fragments of an application lifecycle

As shown in Figure 4-6, each step has its duration. Applicants need time to prepare required documents before the deadline. The manager in an administration section has a certain duration to process applications. Actually, the method for applicants to prepare these documents varies from different people and different application requirements, which has been mentioned as a personal process. Similarly, managers in different administration sections also have their own methods to cope with an individual application. To get a fair result, the normal practice should be to deal with these applications in FIFO order. Any rejection at an administration step will result in refusal of the application.

After analysing the workflow of the administration process, we now model the process with time Petri nets notation.

- **Modelling Administration Process with Time Petri Nets**

The administration process consists of administration operations among applicants and the administration group.

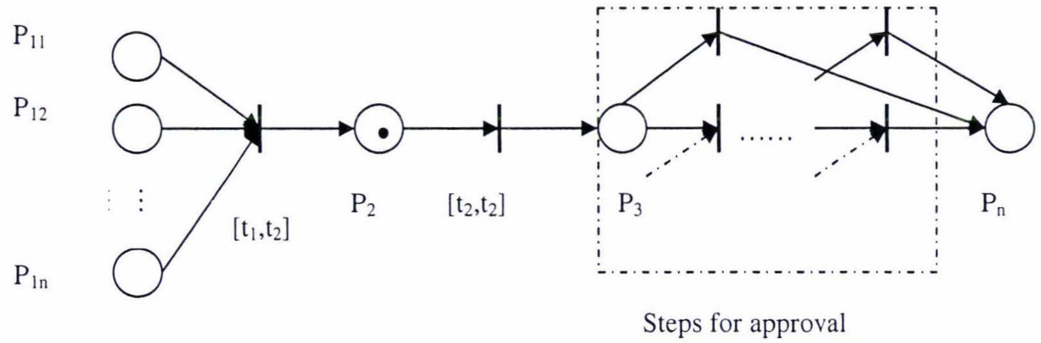


Figure 4-7: Modelling the administration process with time Petri nets

P_{11}, P_{12}, till P_{1n} present preparation of materials which are required for the application. When all of the materials are ready, the application can be submitted after the application becomes available (after t_1), and before the due date (t_2). The transition $[t_1,t_2]$ expresses that applicants may submit their applications during this time period. When the due date t_2 is reached, all applications are transferred to the administration group for processing. In Figure 4-7, $[t_2,t_2]$ indicates that at time t_2 all applications will be sent to P_3 and how the time-driven mechanism works in the process when t_2 is arrived. When applications are held by a manager, the manager needs a time period to process them. In addition, applications will be managed under certain conditions before it transfers to the next stage. In these steps, additional documents may be requested from the applicant. General regulation is required to assist the manager to approve or reject these applications. The additional documents and regulation required are shown as the dash line arrows in Figure 4-7. The manager should process these applications in the FIFO because it is fair for applicants who submit their applications earlier, although all of the final results will be distributed to applicants at the same time under a time-driven mechanism. To cross over steps of the process, time-driven mechanism works, as $[t_2,t_2]$ does. Therefore, time-driven mechanism is the main driving rule to indicate the distribution of cases and the status of the process.

4.3.3. Personal Process

Personal processes have been mentioned several times as they are subprocesses of both the learning/teaching and administration processes. Actually, they are different from other processes because only one main participant is involved. To reach the targets in both the learning/teaching and administration processes, activities are conducted at a certain pace by the participant. The order of activities varies from personal to person. For example, when students arrange activities to complete an assignment, activities like collecting information, reading materials, and writing parts of an essay are organised variously by different students because they have different methodologies to study. The process for completing an assignment is a personal process.

There is only one restriction for the pace of the personal process, the overall duration, which has been set as part duration in the learning/teaching or administration processes. The pace of the personal process defined with time ensures that activities can be carried out and tasks can be completed under the defined time in the learning/teaching and administration process.

In fact, personal process, as a part of process, is integrated into the educational process. For the personal process, although the beginning and end time is fixed, different roles carrying activities in order for the completing of tasks in the personal process do not have any time constraint for each activity. It means that roles involved in the personal process may carry out their actions with flexible time constraint as long as all activities have been finished before the end time. For example, there is only one role involved in the personal process, such as a lecturer performing teaching in the classroom. According to different teaching methods, he may organise materials flexibly. To explain personal process more clearly, the process of teaching in the lecture can be divided into several subprocesses owing to the segments of materials that the lecturer arranged initially. However, the subprocess may be modified and adjusted varying from instant reflection and performance of students, like the responses from students to questions. So, the pace of the personal process is influenced by outside aspects, like students' responses to a discussion topic, although the overall duration for the lecture is defined. As Lin et al. (2001) introduce a flexible e-learning environment based on workflow management technology, they remove the time constraints of the study process so that students can have their own strategies to carry on their study without any limitation. The personal process described in this thesis has flexible time constraints for steps defined with own pathways, which is similar to the flexible study process described by Lin et al. (2001).

Regardless of the flexibility in setting time constraints for the personal process, it is possible to model the personal process under the overall time constraint after analysing the relationship among activities for the task. In this thesis, the performance of the lecturer will not be modelled, whereas the example of a study programme planning process is introduced and modelled as a personal process.

- **Describing the Study Programme Planning Process**

Students have different aims in their studying, such as degree programmes, specific papers, and so on. To achieve the aims of students, the study programme is the object that needs to be modelled in the personal process. It is not the subprocess of either the learning/teaching or the administration process as discussed earlier. The duration of the process covers the whole period of study. Thus, the learning/teaching process and administration process are integral processes associated with personal processes to form this study programme process.

The study programme planning process is presented as an example in this section. The process only presents the course planning, not for the real study programmes process. The student is the unique actor being modelled in this process. To establish the generic model of the study programme planning process for students, it is necessary to analyse the hierarchical relationship (Mangan & Sadiq, 2002) among papers and the time constraints (Fung & Ruan, 2004) of papers offered in different semesters.

For instance, to obtain a degree from an institute, the requirement of the degree comprise several papers including core papers, major papers, and elective papers. The core paper is the compulsory paper for the degree, whereas the major paper presents knowledge related to the major that students choose. Most major papers are available for senior students only. An elective paper is chosen to make up the remainder of credit points of the degree. There also exists a hierarchical relationship among papers. In particular, some papers have their own structures, for example, one paper is a prerequisite of another paper. Therefore, the degree programme is composed of a number of papers based upon the valid duration of the study programme, the relationship among papers, and the overall credit points of the programme. The time restriction should be considered in the modelling of the study programme planning process because some papers are offered in any semester, but not all papers are taught in any semester. Consequently, the time aspect influences the final result of the study programme planning process.

- **Modelling the Study Programme Planning Process**

As described above, a student has specific requirements and situations in his study programme. Therefore, the study programme has its requirements for credit points, core papers, and major papers.

To model the planning process of the study programme for a student, listing potential papers with their properties—like the semester duration, points, and drawing the relationships between papers—is the first step to take.

For example, to achieve a Bachelor of Business Studies (BBS) degree (Table 4-3), there are several requirements. The total points for the degree must be at least 300; fewer than 150 points from 100 level papers (Table 4-2); and at least 200 points, including at least 50 points from a 300 level paper from the BBS schedule of papers; and at least 25 points from papers outside the college of business, in addition to any listed in the core compulsory paper with a maximum of 100 points.

Core Paper (Points)
110.100 (12.5)
125.100 (12.5)
152.100 (12.5)
155.100 (12.5)
156.100 (12.5)
157.100 (12.5)
161.110 (12.5)
178.100 (12.5)
219.100 (12.5)

Table 4-2: Core papers for BBS

Year 1	Year 2	Year 3
Core papers	Core papers	Major paper 300 level
Core papers	Major paper 200 level	Major paper 300 level
Core papers	Major paper 200 level	Major paper 300 level
Core papers	Major paper 200 level	Business elective paper 300 level
Core papers	Elective paper 200 or 300 level	Elective paper 200 or 300 level
Core papers	Elective paper 200 or 300 level	Elective paper 200 or 300 level
Core papers	Elective paper 200 or 300 level	Elective paper 200 or 300 level

Core papers	Non-BBS elective paper 100,200 or 300 level	Non-BBS elective paper 100,200 or 300 level

Table 4-3: Course structure of BBS

Only eight core papers can be taken in year one. The rest of the core papers can be carried on in year two.

The flexibility of modelling a study programme planning process reflects the choice of students. First of all, although core papers are compulsory papers required for students who study BBS, the pace of study for each core paper depends on students themselves. Students may need to re-enrol in the failed paper or resit the examination of the failed paper, which will result in extending the whole study. Then, options on major papers and elective papers vary from different students' choices. Certainly, there are more than three 200 level major papers for students to choose, for example. Similarly, students can choose from more than six elective papers at 200 or 300 level for second and third year study. Therefore, the option is flexible owing to students' alternatives. In addition, non-BBS elective papers can be chosen from other departments. The scope of choosing non-BBS elective papers from 100 to 300 level can be drawn from a very big net whose scope cannot be confined in one department.

Furthermore, the course structure of the BBS can be extended into other study programmes. Because some study programmes have similar core papers to those of the BBS, extending from these core papers with requirement of the study programme along with major papers and elective papers, other study programmes can be reached besides BBS. It expands the net of the study programme planning process.

Figure 4-8 illustrates the model of the study programme planning process for BBS.

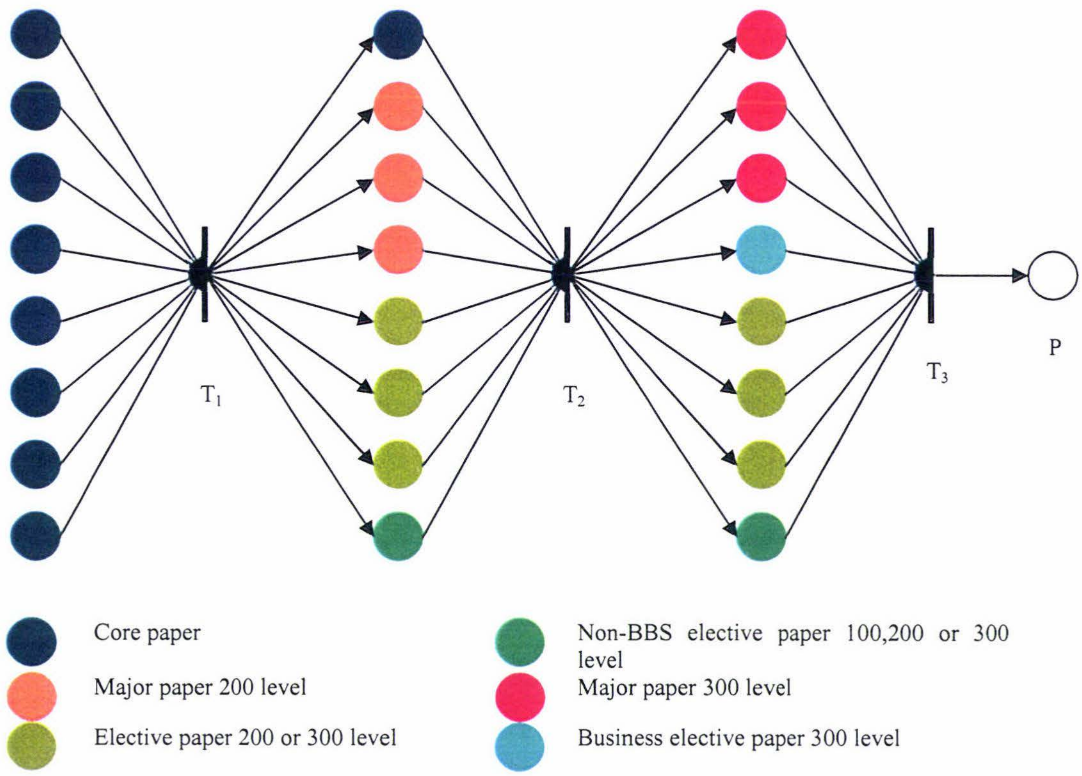


Figure 4-8: Modelling the study programme planning process of BBS with time Petri nets

In Figure 4-8, coloured circles present different papers but do not specify the name of the paper. T_1, T_2, T_3 indicate the time duration for the each paper. For example, T_1 includes time duration for eight core papers in blue. P indicates the completion state of a study programme. Expanding this process with other study programmes, the net integrating every study programme will be very large with a variety of papers and the time duration.

It is worth mentioning about the hierarchical structure of papers. For example, 178.101 is the prerequisite for 178.201 and 178.240. Therefore, if a student wants to study either 178.201 or 178.240, he must study 178.101 first. In addition out of two papers at the same level only one of them can be chosen to contribute credit points. For instance, the student must choose only either 157.324 or 157.369. Figure 4-8 does not show any restrictions or hierarchical relationships among papers.

4.4. Design Consideration (Overall Architecture Modelling)

Based on previous analysis and modelling on the educational processes, it is now possible to design an overall architecture for the educational process management system with time service.

The proposed architecture of the system consists of three education entities. They are student, academic, and general staff. Academic staff indicates instructors or lecturers and general staff is the group of administration staff who provides support for teaching. The overall model for the system has three components: learning/teaching, administration, and personal processes, which have been described before. Each entity has its own functionality over these categorised processes. To manage one particular process, sometimes every entity has been involved but distributed into different time periods.

The architecture for the educational process management system based on the workflow management technology is developed after adopting the generic workflow frame (Figure 4-9) (WfMC, 1995).

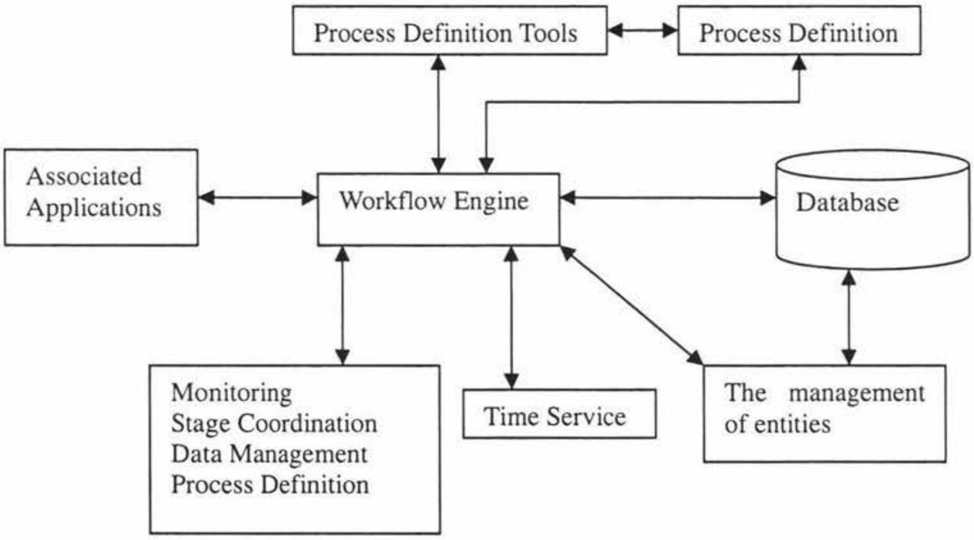


Figure 4-9: Architecture of the educational process management system

In Figure 4-9, process definition tools and process definition are for the workflow engine to define various educational processes. Associated applications are providing services for the engine when applications from the outside are required for the completion of a certain task. For instance, applications are required for the lecturer when he wants to do some demonstration in the lecture. Similarly, markers need tools to assist them to mark assignments. Moreover, the database is the place of storing information. Time service provides the time management for various processes, which have been initially defined with time configurations by process definition tools. In addition, the management of entities is to manage participants involved in the process. There are several interfaces for users to view and retrieve information from the database via the workflow engine. They include process coordination, monitoring process, information management, process definition, and so on.

When a process is defined and generated with process definition tools, it is created as an instance of the process modelling. Process definition tools define the actual route and the time points of the workflow process. Entities management manages potential users with certain role priorities and ensures the process involves the correct participants. Participants in departments involved in different time phases are assigned with corresponding authorizations. As long as the process begins, associated application tools, for example monitoring tools, start and run along with the process. Time service works as a tool for the workflow engine to explore time phases. It advances the process, while the time of the phase is defined as arrival.

In addition, sufficient space for storing information is required for data operations, such as retrieving, creating, or modifying. For participants taking part in the process, they have opportunities to view the status of the process. Moreover, a platform should be offered for participants with authorities to carry out activities that make the process move forward.

4.5. Temporal Database

According to the significance of time information in the educational process, a temporal database has the potential opportunity to store such time information. In this section, temporal database is discussed as the storage for an education system in the future research. The motivation for using temporal database is that time components play a crucial role in various educational processes. However, in the implementation part of this research, a temporal database has not been used due to the scope of the system. The time component of the educational process is implemented as a simple time stamp added into the database in the implementation of the web-based assignment management system in Chapter 5. It only provides the idea that using a temporal database potentially has powerful functionality to manipulate time information in the educational area.

This section gives general information of a temporal database. In addition, it presents the advantages of using such a database for time information, which also will be of benefit for the educational processes in the future research.

4.5.1. An Overview

When an application is developed, the first thing to be considered is to build a database which models and captures the data that the application needs. Most applications with database technology are temporal in nature. For example, the financial, insurance, reservation systems, and so on, are based on the temporal aspects (C. S. Jensen, 2000b). Therefore, the temporal concept should be integrated into the database. The temporal database is the database that supports the aspect of time. Its feature matches the requirements of many applications. Currently, the conventional Database Management System (DBMS) and Structured Query Language make it difficult to manage temporal data for applications(C. S. Jensen, 2000a; Snodgrass, 2000). Therefore, research on developing the temporal data model and the temporal query language has been argued and discussed for decades (C. S. Jensen, 2000a; Tansel et al., 1993). However, this is not the aim for the research of this thesis.

According to the time feature of educational processes, time as the most important information must be stored along with other general data. For instance, students have to consider temporal aspects when they take lectures or examinations in the educational domain. The educational processes are time-dependant. So, the temporal database with time-processing capabilities matches the requirement of the educational process which relies on the time axis. In this section, a literature search has been done to elaborate the reason to use the temporal database as the repository for educational processes, even for the education system.

4.5.2. Research on Temporal Databases

A great amount of research has been conducted on temporal data models and query languages.

Firstly, there are three temporal aspects that need to be understood for the database.

- **Valid time**: the time period during which a fact is true with respect to the real world.
- **Transaction time**: the time period during which a fact is stored in the database.
- **Bitemporal time**: the combination of both valid time and transaction time.

Then, to develop a temporal data model, extending the data models supported by the conventional DBMS is the general approach to capture the temporal aspects (C. S. Jensen, 2000b; Steiner, 1998). In addition, based on the developed data models, extending SQL by adding time components is the method to design the temporal query language (C. S. Jensen, 2000a, 2000b; Steiner, 1998; Tansel et al., 1993). The query language is strongly influenced by the underlying data model so that the language design must consider the impact of the time-varying nature of data on all aspects of the language. Therefore, research on the temporal database includes generating a temporal data model with its own query language.

The following sections introduce the characteristics of temporal databases. Moreover, research on setting up the temporal data model has also been investigated.

4.5.3. Handling Temporal Data

Database requirements lead to the specification of the database schema, associations, and integrity constraints. Functional requirements define user-defined transactions that retrieve and modify data in the database. To build a database application, time-varying data is necessary in some application domains. Therefore, time attributes should be attached to data types in order to record the validity time period. This is the challenge to have effective means to retrieve and modify temporal data from various database statuses.

4.5.4. How are data models affected when time is added?

In fact, a DBMS based on a data model defines constructs and formalisms where all of data can be described, modified, and accessed in a uniform way. The normal data model (M=(DS,OP,C)) consists of three components: the data structures, operations, and integrity constraints. In contrast, a temporal data model (MT=(DST,OPT,CT)) has the same components as the normal data model except being associated with time individually (Steiner, 1998). "*Data structures should be adapted such that they can store time-varying data, leaving it up to the user to choose the level of what data units shall be time-stamped*" (Steiner, 1998). Algebraic and modification operations should be redefined by utilising temporal semantics; for example, the notion of snapshot reducibility which defines the temporal semantics of an operation, with the semantics of its non-temporal counterpart applied at each time point.

4.5.5. How can support for temporal database be implemented?

To support time-varying data, a data model should be modified or extended as well as the DBMS. But the corresponding changes in DBMS should be performed by the DBMS supplier. Other approaches to achieve supports to handle time-varying data are building the temporal functionality into the database applications or using the extensibility inherent to some DBMS for supporting special temporal data structures and behaviour (Steiner, 1998). Four different ways to implement temporal database applications can be identified:

- Use the date type supplied in a non-temporal DBMS and build temporal support into applications;
- Implement an abstract data type (ADT) for time;
- Extend a non-temporal data model to a temporal data model;
- Generalise a non-temporal data model to a temporal data model.

The last two approaches can only be achieved by the change of the DBMS itself. Generalising a non-temporal data model into a temporal one does not means extending the data structures but rather using the notion of temporal object identifiers to timestamp data. Compared with the extended one, it is more effective because it utilises all generalisation means of the non-temporal data model including data structures, the operations, and the constraints to support time-varying data. The first two approaches do not involve any changes to the DBMS. All implementations need to be done by the database designers and/or application programmers.

The difference between these four approaches is how to handle time-varying data. At present, only the first two approaches can be used in practice because there does not exist any temporal DBMS (Steiner, 1998). Although many temporal data models have been proposed, currently none of them have actually been implemented. Existing DBMSs can provide only limited temporal functionalities.

As mentioned before, the time component has been integrated into the process for scheduling. A role involved in the process has a pair of time stamps that define the phase of the process and the process has been predefined with the time duration that is the property of the process. The time component is considered along with every activity for the modelling of various educational processes in Chapter 3 and 4. Therefore, the temporal database is investigated as a repository for the workflow-based educational process management system owing to the nature of educational processes associated with the time concept.

In this thesis, the assignment management process is chosen for the case study in the following chapter. It is defined with time duration. In addition, the process is divided into several phases with the time points such that every role can manage a certain phase individually. Time is pointed as the key information on the data storage. The whole process for an assignment from being assigned by the instructor to being distributed to students with final results is related with time instants in each phase and even every activity. Therefore, the role participating in the process strictly follows the time constraints defined in the process. Consequently, time should be recorded or stamped with the general data in the database when activities have been completed.

However, this process for the case study only emphasises the schedule time when it is defined. The traditional database is able to implement all information that the process required. Therefore, the temporal data model and query language have not been developed and implemented in this case study.

4.6. Summary

In this chapter, the time component of the educational process has been emphasised. The nature of the education activities is associated with time. Every education activity or a student's goal links to a time interval or time period. The time reasoning of the educational processes has been described to show how important and necessary the timing issue is in such processes.

Then, the modelling tool, Petri nets with time extension has been introduced in detail in this chapter to demonstrate how time constraints have been added into the classical Petri nets. In addition, how the transition fires under time condition is also presented. Therefore, educational processes have been modelled by the Petri nets with time extension. It is worth to mention the notation of time Petri net used in this chapter. It does not define time with specific dates and times, due to the nature of the educational process. Because of the timetable for the educational purpose, especially for the learning/teaching process, it is defined as an iterative week. For example, the lecture will take place twice a week on Wednesday and Friday with specific times. Therefore, the time constraints defined for the lecture is defined in generic notation instead of listing every particular day and time.

Moreover, due to the importance of time information in the educational process, temporal database has been considered to store such information for the education system. This research only provides such an idea for deeper research in this area. Temporal database has potential functionality to store time information and its powerful operations may make it easy for further researchers to operate time-based data in the database. In addition, the temporal concept has been adopted to be implemented in the next chapter.

In the next chapter, the assignment management process has been chosen as the case study to show how workflow technology, time Petri nets, and temporal data concepts work for the modelling and implementation of this process.

Chapter 5. Case Study: A Web-based Assignment Management System

In the previous chapter, three classified educational processes have been described. In addition, time Petri net was introduced as the design tool to model these processes with the workflow management technology. After that, the architecture of the educational process management system was presented as an attempt.

This chapter evaluates the validity of the model for educational processes via developing an actual process. As an assignment management process is a subprocess of the learning/teaching process, it has been modelled and developed for the lifecycle of the assignment with web technology. From the perspective of Petri nets, the assignment is a token in the workflow.

5.1. Previous Related Research

Assignments are described by the University of Waterloo in Canada (http://www.adm.uwaterloo.ca/infotrac/ad-checklisttips.html) as tasks provided for students to be implemented. The procedures of working out assignments are experiences for students to enjoy and to acquire knowledge. In addition, the outcome of assignments should be produced as instructors expected.

- **The role of an assignment**

From an instructor's perspective, an assignment provides opportunities for students to reorganise and apply knowledge that they have mastered previously to produce what instructors expect. After completing the assignment, the knowledge related to this assignment is fully mastered and understood by students. Therefore, completing the assignment is significant in the learning process. In addition, an assignment management process is an important part, which is integrated into the learning/teaching process, as shown in Figures 3-6 and 3-7.

There is another important function of the assignment in the learning process. It is a part of the assessment of the paper. The assignment is focused on procedures that integrate the related items and content from one particular research field, which is the guiding principle for generating the assignment. The students' performance on the assignment is assessed. The assessment contributes to the final grade of the paper.

- **Traditional vs. modern way of assignment submission**

The assignment is the critical part in learning, especially for assessment. As information technology has been used in many areas, the approach to submitting assignments has changed. In this section, traditional and modern methods of assignment submission are compared.

For students, submitting hard copies are still the usual method for handing in assignments. Therefore, students are asked to put their assignments into the submission box where secretaries can collect them after the due date of the assignments. This is obviously inconvenient for all participants involved. For example, students have to go to school to hand in their assignments in person before the due date or on the due date and instructors must carry all these heavy printed papers to their offices for marking. In addition, secretaries must classify students' submitted assignments into different groups for different papers. These are the disadvantages of traditional paper-based submission approach. Having said that, paper submission method is the only choice in non-Internet or non-networked environments. Moreover, markers or instructors can offer comments at any place on a paper without any special software support, like a tool supporting the marking or highlighting on the originals. They can write their comments in the margin of the originals. For some markers, it will not hurt their eyesight because they don't have to look at a computer screen for an extended period.

However, with widely developing web technology over the network or even the Internet, people recognise the advantages of its features. Electronic submission is a convenient way that can replace the hard copy method because the network or the Internet offers a direct and novel method for users to communicate easily with each other. Diverse information can be accessed conveniently and equally. This shows that it obviates the disadvantages of paper submission. For instance, students may hand in assignments at home or anywhere over the Internet; secretaries do not have to do frustrating jobs to classify different papers' assignments and record the submission situations of students;

and instructors only view students' assignments from the screen instead of carrying hard copies into their offices. Then, the web-based management system is much more justified and fair for students if standards are applied for the assessment. Personal emotion is not considered in assessing assignments, such as how to process delayed assignments and the extension issues. Furthermore, under a stable network, assignments will be sent and kept safely in the database. Therefore, there is no excuse for students complaining about missing assignments. The most important feature of using web technology in the assignment system is that all participants involved in the assignment management process have opportunities to reduce time consumption. Relying on the web or network reduces human factors, like transferring assignments to the marker automatically without waiting for the marker to pick them up in the traditional way. How this factor works will be introduced in the following section in detail.

- **Related research on assignment management**

Research on the assignments management began a few years ago (Ault, Yong, & Alexander, 2002; Jones & Jamieson, 1997; Pittman, 2001; Thompson & Castro, 1988). In Australia, a research project on the assignment turn-around time was conducted in 1987, which was supported by the Standing Committee on External Studies of the Commonwealth Tertiary Education Commission (CTEC) (Thompson & Castro, 1988). This project presents many facts that contribute to the delay in feedback. It also mentions how important prompt feedback is in influencing students' attitudes and even affecting their pace of study. It also provides effective methods to reduce the turn-around time based on these facts, establishing and recording the accurate date for every activity the participant carried out. In fact, the date and time recording contribute to defining time phases for a process in this research.

Jones and Jamieson (1997) reported on three years' experience at Central Queensland University with three different online assignment management systems. The motivation driving preference for an online assignment management system is to solve the problems of traditional methods. They implemented and evaluated three kinds of online assignment management systems: manual email, automated email, and automated web. The first two management systems relied on the email system for the submission. Manual email sends an assignment to an email address manually, whereas automatic email submission is entirely automatic. However, automated web management reduces the marking turn-around time and provides positive feedback to distance students from the system. In addition, an automated web management system offers prompt feedback to students. From their research, although a process has been divided into several phases with time like the author described in the previous chapter, the automated process management on the web is the more effective option from one phase to another. Therefore, web technology is utilised to develop the process management system owing to the reduction in the turn-around time and adopting the advantages of web technology.

In order to employ the convenient characteristics of the Internet, emailing assignments to instructors—as expected—is an easy approach for students. In addition, McGill University (http://www.cim.mcgill.ca/~dudek/rules.html) expresses the view that for the existing assignment submission system, commands designed for handing in assignments are insufficient, although it can be applied to send assignments to a particular place. They require additional environment to support these commands. Therefore, WebCT (http://www.webct.com) and Blackboard (http://www.blackboard.com), very famous and popular online course management systems, were introduced. Now they are combined together. Both of them cover a small part of the assignments management function. They provide basic practices such as allowing students to submit their assignments online, showing students' information about submitted assignments, and offering the marker and instructors the facility to download assignments for marking. However, the function in managing assignments in both systems is very weak. For instance, from the educational point of view, support for reducing turn-around time for prompt feedback to students from markers or instructors should be included. In addition, there is no time concept included in the process when the roles change, simply giving—for example—the valid time span for each role involved in the whole submission and marking phases.

At present, the web-based assignment management system cannot be limited by the requirement of a computer environment, which is acceptable for students and paper support staff. The following sections present several issues of the web-based assignment management system from the educational point of view and process modelling. In addition, the critical support techniques of a web-based system and some related areas will be discussed.

5.2. Requirement Analysis

From the view of educators, the requirement of the assignment management system is how to get final results efficiently back to the students after they have handed in assignments. The target is to model the assignment management process effectively. The time concept is introduced to define the lifecycle of the assignment and prompt the process to avoid additional time consumption. Of course, there are many other associated issues that need to be concerned. For example, the applications or tools for instructors to format the assignment with sufficient materials before it is issued to students; adequate aids for students to complete assignments effectively, and so on (Salend, Elhoweris, & Van Garderen, 2003). However, these associated issues are not considered in this research.

The main issue discussed in this chapter is how to model and develop the assignment management process that is a subprocess of the learning/teaching process. In this section, aspects considered focus on how to apply the workflow technology to the web-based assignments management. The time component is added to model the assignment management process with workflow management technology as it was discussed when modelling the educational process in previous chapters. The delivery mechanism of the object—an assignment—is illustrated.

5.2.1. Time Dimension Consideration

Time-driven methodology has been discussed in section 4.1. It is this mechanism that drives the lifecycle of assignment management. Each assignment has several time points that need to be accommodated.

- Date and time for the assignment issued by the instructor
- Date and time for the assignment to begin
- Date and time for the assignment to be submitted by students
- Date and time the assignment is due
- The beginning date and time for the marker to mark
- Date and time the assignment is due from the marker
- The beginning date and time for the secretary to publish the results
- Date and time the assignment is due to be returned to the secretary

- Date and time the assignment is due to be returned to students
- Date and time for the assignment cut-off

To simplify the representation of 'date and time' of the assignment management process, 'date' represents the accurate date and time.

Accurate dates divide the lifecycle of an assignment into several phases to form certain time spans. For example, the beginning and due dates of the assignment indicate the time span for students to complete the assignment. Thus, the period for the student to submit the assignment must be set between the beginning and the due date. The beginning date and the cut-off date of the assignment depict the entire life of the assignment in the process.

The reason to model the assignment process under a time axis is to minimise human factors. Feedback, a means to support the performance of students, influences the pace of the educational process in the traditional management way. In the traditional assignment management, the assignment has to stay in one stage until it gets feedback from the participant. For instance, the marker holds the assignment until he gives the mark and comments for this assignment. Otherwise, it will stay with the marker for the feedback. Then, the marked assignment will be sent back to the secretary. Therefore, activities of the participant will affect the pace of an assignment from beginning to end.

It is necessary to schedule activities with time because this ensures that each step of the process is under control. The more roles which play in a process, the more time is consumed. Therefore, addressing the contributing factors of the delay may result in prompt feedback (Thompson & Castro, 1988). This justifies the existence of an effective method to manage the process. Setting up a powerful guideline with time restrictions for each role to follow is also desirable. For the assignment process, providing a clear guideline for the marker to mark assignments is to reduce turn-around time in the marking phase. The guideline also should cover a special situation, which is an extension period that may delay the whole management process. Although time scheduling makes the lifecycle of an assignment less flexible, it reduces the influence from outside of the process. This is the reason why a model for an educational process should be modelled around time.

Concerning the factor of the turn-around time, time-driven methodology is a fair way to deal with the submitted assignments in a certain period of time under the guideline of the process, if every student can get their result at the same time.

5.2.2. Extension Requirement

An extension requirement is a challenge to the time scheduling if the defined time span needs to be extended. It requires rescheduling time restrictions on the process.

For instance, when a student cannot finish his assignment on time with an acceptable reason, he may ask for an extension to have extra time to complete his assignment. The extension requirement influences the whole time schedule of the assignment lifecycle. If one time span is extended, the whole time schedule is changed accordingly.

Of course, this may open a window of plagiarism if extra time is allowed for a particular student. The student may copy other students' assignments. To prevent this situation, Clarke, Butler, Schmidt-Hansen and Somerville (2004) state that the student who cannot submit the assignment on time should undertake a different assignment. However, if the strategy mentioned by Clarke et al. (2004) is taken, it is unfair for the student who has an acceptable reason for postponing the submission time. He has already spent lots of time and put plenty of effort into this assignment. If he has to do another assignment again, his earlier effort is in vain.

In this research, the time component is considered as an extra dimension to model the educational process with the workflow management technology. Therefore, the extension situation is a challenge to rearrange time constraints for the process. In addition, an adaptable system is expected to allow flexible time organisation in the real world.

5.2.3. Assignment Delivery

In the assignment management process, naturally an assignment is the only object that is delivered from one participant to another. Within a certain time period, the assignment is held by a person to be managed and worked on. Role management is applied to handle authorities for roles to access and retrieve suitable information. This indicates that the assignment can be available only to a certain person to work on within a certain time period.

Feedback is a means to support the study of students via interaction among participants in the process. Feedback makes the connections of the process with time constraints. The requirement of feedback determines the time consumption from one defined time point to another. Therefore, this is a significant factor in determining the lifecycle of an assignment.

In this section, feedback has been discussed as additional information along with the procedure of assignment delivery, which affects the pace of the process. When an assignment transfers to a new phase, certain feedback should be given along with it to state the situation of the assignment. For example, comments from the marker or instructor may be presented in diverse ways to assist the student to achieve high performance in the coming assignments as they have been returned to the student.

The content of feedback is not discussed, however, in this project but we focus on when and how to present feedback. When talking about 'when' to present feedback, the exact time to present feedback for the particular person is considered. Furthermore, a time-driven mechanism is applied to reduce turn-around time and reduce time consumption. It eliminates the effects from human being. The arrangement of tasks determines the length of delay which is acceptable before feedback should be given. For example, one day reaction feedback is acceptable for a weekly assignment. Once the time point in the assignment management process is settled, the 'when' is decided. When that time has arrived, assignments are sent to the next stage and become accessible to other authorised people.

However, 'how' to present feedback along with the marked assignment is discussed in the method of transferring feedback to the participant instead of talking about the content of feedback, the emphasis of which is to help students in their performance and to offer suggestions and/or criticisms. Email is described as an effective method to be used for sending feedback during the assignment delivery. Several outstanding features of email are presented by Clarke et al. (2004) to indicate why email is the acceptable approach for communication among participants. In this research, email was employed to perform feedback and assignment delivery in the assignment management process. For example, email is sent to remind students as a notification three days in advance of the assignment due date. In addition, it is supposed to be used as a receipt after receiving an assignment from a student.

5.2.4. Process Monitoring

Monitoring the assignment management process should be addressed to ensure successful operations of the process. Roles in the process have certain tasks to carry out under time constraints. When tasks are completed successfully, the state of the process goes forward. Therefore, probing activities that roles carry guarantees the smooth running of the process. Once activities are monitored and traced along with the process running, this offers opportunities to remove unexpected troubles from the process. In addition, monitoring offers information for participants to coordinate the phases of the process. Therefore, technical support is required for developing monitoring functions for the assignment management process.

5.3. Application Development Technical Support Discussion

To establish a successful workflow process management system, roles involved in processes and the time constraints of processes must be incorporated into the development.

As the Internet allows people to access the Internet without time and place limitation, developing the system as a web application is the natural choice. By combining the features of the Internet and the requirements of the assignment management system, there are certain points that need to be considered.

From the programmer's point of view, a few decisions should be made. The first thing is to choose the programming environment including the programming language and the platform. Then, a suitable database should be developed to manage the data required in the system.

5.3.1. Programming Environment

To establish a web-based system, programmers need a powerful and suitable web-based programming environment. There are many options for developing a web application. For example, in the early days the Common Gateway Interface (CGI) was enormously popular as a means of generating web pages. It is a standard protocol for communication between the client browser and the web server. Meanwhile, almost every programming language has been used to implement CGI-based solutions at some level, but Perl is perhaps the most popular language for CGI development. The alternative solution to CGI is the open-source Apache web server, which has modular API. For example, the package of MySQL database and PHP is a good choice to develop a web-based system.

In addition, several environment tools have been provided for visual programming, such as Delphi and .NET. Delphi's supports for the database application and web application as the key features of the programming environment (Cantu, 2001). Some useful components integrated in the IDE of Delphi can be easily utilised to programme for database and the Internet. So, developers do not have to focus on writing codes for accessing and controlling a database and the advent of Delphi provides Internet programmers with a tool to generate dynamic pages. On the other hand, the .NET Framework environment developed by Microsoft provides an outstanding platform to develop internet-based applications (Oberg, Thorsteinson, & Wyatt, 2002). A great thing about the .NET Framework is that it provides a simple but robust framework to encapsulate a database that allows the rest of the programmes to work with data in a very generic way without worrying about where it came from.

Although the paragraphs above listed a variety of advantages of these programming languages and environments, Java is chosen as the programming language for this research and JBuilder 7.0 is the programming IDE. The following illustrates the reason why Java and Jbuilder 7.0 are chosen in this research. Firstly, Java is the most portable platform-independent language in use currently (Matthews, Cole, & Gradecki, 2002). Secondly, it can be running on different operating systems rather than being bound to one particular platform. It also can be executed within the web browser (Galbraith et al., 2003). In addition, Java Server Pages (JSPs) is introduced to make creative dynamic web content even easier without requiring extensive Java knowledge. Based on the environment in the Massey campus, Jbuilder 7.0 is the IDE widely used in teaching computer science courses.

- **JSPs**

Java Server Page (JSP) is a key J2EE API developed for the server-side application to have manageability during the maintenance phase of the development.

At a glance, JSP looks like plain HTML documents with a few odd tags filled with Java code. The tags are script tags in Java. Therefore, all of the benefits and strengths of Java are shown in JSP. It is important to understand how JSP works at runtime. Figures 5-1 and 5-2 (Jorelid, 2002; Nilsson & Mauget, 2003) show the working theory of JSP. All content within JSP is compiled to a servlet at deployment time or first requested at runtime, and then JSP is translated, compiled and run to produce the HTML for the response. In addition, JSP offers dynamic web content.

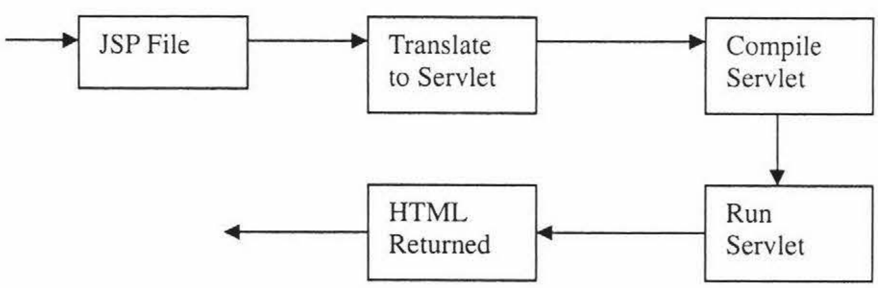


Figure 5-1: JSP first invocation

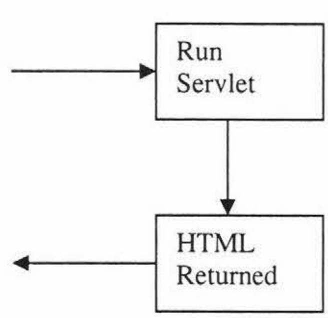


Figure 5-2: JSP subsequent invocation

JSP is the Java code that runs on the server. So, results are consistent when they are called by different browsers. And it provides a convenient way to pass data back to the HTML form. JSP also has the view part of model-view-controller (MVC) architecture (Figure 5-3), which divides an interactive application into three components. The model contains the core functionality and data. Views display information to the user. Controllers handle user input. Views and controllers together comprise the user interface.

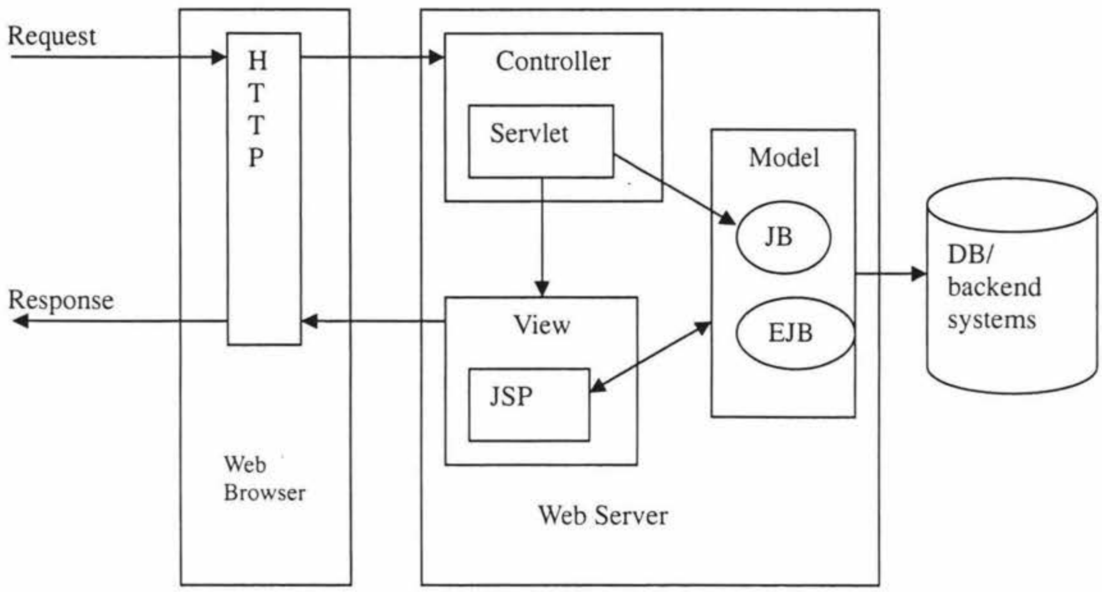


Figure 5-3: MVC pattern overview (Spielman, 2003)

An HTTP request from the client browser creates an event. The web container will eventually respond with an HTTP response. JSP generates the presentation layer, whereas Servlet performs process-intensive tasks. The Servlet acts as the controller and is in charge of the request processing and the creation of any beans or objects used by the JSP, as well as deciding, depending on the user's actions, which JSP page to forward the request to. Particularly, there is no processing logic within the JSP page itself. It is simply responsible for retrieving any objects or beans that may have been previously created by the Servlet, and extracting the dynamic content from that Servlet for insertion within static templates. This approach typically results in the cleanest separation of presentation from content, leading to a clear delineation of the roles and responsibilities of the developers and page designers on the programming team. In fact, the more complex the application is, the greater the benefits from this MVC pattern architecture should be.

5.3.2. Database

A database is a collection of data. For the purpose of the application, the user interacts with a database through the software application that is one of the most fundamental tasks that a programmer is required to perform (Matthews et al., 2002). The theory of a web application working between users and database is that the database is on the web server side and another machine is on the client side for users to use. When a user submits a query through a form of a web page to the server, the server runs a programme to extract the data from that form and generates dynamic pages or results by using data from database if necessary for users (Reese, Yarger, & King, 2002).

In this research, an educational process is modelled with a time component. Therefore, a temporal database is necessary to store sufficient time information. In this chapter, a small assignment management process will be developed. Because the time information of this process is not so complicated, the general database that can store records with timestamp on each tuple is adequate.

In addition, the SQL query language (Structured Query Language), is used for manipulating data in the database. SQL is a declarative language in that the user declares what data is required, not the procedure for how to get it. SQL is also an acceptable and widely used standard (Matthews et al., 2002).

Here Oracle and MySQL are discussed for the database requirement of this project.

- **Oracle**

Oracle was founded in 1978 as a relational DBMS vender. Although the DBMS is Oracle's core product, the product line has diversified into related GUI and multimedia tools, CASE tools, OLAP tools, Object-oriented development tools, World Wide Web application tools, and off-the-shelf application packages are also suitable for implementation in the programming requirement (Rodgers, 1999).

- **MySQL**

MySQL is one of the most fashionable open source database systems and is used as the back-end data storage device for many web sites (Matthews et al., 2002). In fact, it is not a database but computer software that enables users to create, maintain, and manage electronic databases acting as a broker between the physical database and the users of that database (Reese et al., 2002). Therefore, MySQL is chosen to store the information for the assignment management process.

However, Java has been chosen as the programming language in this research. Although one of most popular web development platforms packages is PHP, MySQL, and the Apache web server, Java is one of the simplest languages in writing MySQL applications with its database access API, Java Database Connectivity (JDBC). It is also one of the more mature database-independent APIs for database access in common use, which can be applied to all kinds of database engines, such as Oracle, Sybase, and so on (Reese et al., 2002).

- **JDBC**

Most applications rely on persistent structured data. JDBC is an effective method to access data using Java.

The J2EE SDK is supplied in the package java.sql. JDBC resembles a Java rendition of Object Database Connectivity (ODBC), first promoted by Microsoft in the 1990s (Nilsson & Mauget, 2003). JDBC is a thin Java wrapper for SQL.

The following illustrates the basics of JDBC. A JDBC client follows these general steps to access a database:

- Load a JDBC driver class for the target RDBMS (Relational Database Management System);
- Obtain an active connection object to the database;
- Create one or more statement objects or PreStatement objects from connection. Optionally set parameter values in a PreStatement;
- Issue executeUpdate() or executeQuery() on a statement object or prepared statement;
- Close all statements and the connection object when finished.

5.4. Design and Modelling

This section will present how the system is designed and modelled. It presents the architecture of the assignment management process system. Then, the time Petri nets tool is used to model the assignment management process. In addition, database design is presented. MySQL is an open source database. The assignment management process is a small process. To store the information of each action the individual takes with time, MySQL is sufficient to operate. The functionality of temporal database is not necessary to be used for such a small process.

5.4.1. An Overview of the System

To construct the assignment management system, the assignment management process has been defined with the certain route from instructor, student, marker, to the secretary as general staff who records the final result and finally returns it to student. Therefore, adopting the architecture from Figure 4-9, the structure of the assignment management system is shown in Figure 5-4 without the process definition.

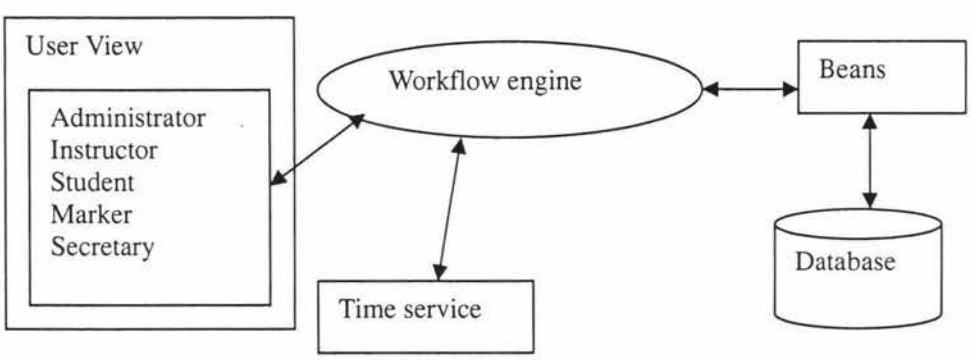


Figure 5-4: Architecture of the assignment management system

There are five participants involved in the process including system administrator. Previously, only four roles are discussed for the educational process. However, for the system, system administrator is a role to manage the process in the system. Each of them has their own responsibility to complete during the certain time period defined in time service and process definition. User view is the place for users to operate their activities. Beans are the interfaces for retrieving data from database to users. Time service provides services to remind the workflow engine to invoke a certain application or users to complete their own tasks. Workflow engine is the heart of the architecture. It indicates the different parts to be involved in the process at the right time with the right person.

5.4.2. Petri Nets Modelling

Petri nets are tools to model the lifecycle of an assignment from first time generated to the final cut-off date Figure 5-5 and Table 5-1.

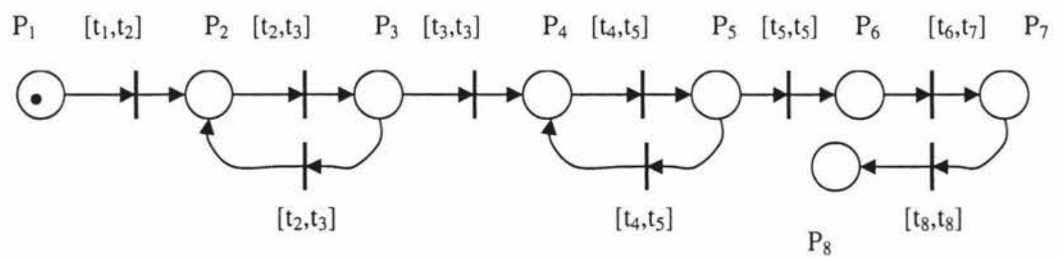


Figure 5-5: Modelling the lifecycle of an assignment with time Petri nets

Place	Description
P_1	Instructor generates a new assignment
P_2	Assignment is available for students
P_3	Assignment has been submitted
P_4	Marker gets submitted assignments
P_5	Assignments have been marked
P_6	Secretary gets results
P_7	Result are ready for students to retrieve
P_8	Lifecycle of the assignment ends

Transition	Description
$[t_1,t_2]$	Instructor uploads assignment specification
$[t_2,t_3]$	Students are doing the assignment Submitting assignment when they finish or retrieving them if they need updating
$[t_3,t_3]$	Assignments are due and sent to the marker

$[t_4,t_5]$	Marking submitted assignments or retrieving them
$[t_5,t_5]$	Marking period is due and assignments are sent to the secretary
$[t_6,t_7]$	Secretary publishes results
$[t_8,t_8]$	Assignment reaches its end

Table 5-1: Description on places and transitions of the model

In the process of managing the assignment, different roles control different phases of the process except that the instructor can access the process at any time because he has the highest priority in the whole process. $[t_2,t_3]$ is under the control of the student, whereas $[t_4,t_5]$ is controlled by the marker, and the secretary controls $[t_6,t_7]$. The participant can retrieve his assignment if the status of the assignment has not been changed. For example, students may retrieve back their assignments even if assignments have been submitted but are not due yet, and can then resubmit the updated assignments. Similarly, the marker is able to deal with assignments before the due date for the marking.

The workflow of the assignment is described below. When an assignment is ready, the instructor has to upload the assignment before t_2. Meanwhile, the configuration of the assignment should be defined associated with the preparation of the assignment. $[t_2,t_3]$ is set for students to complete the assignment. Therefore, the assignment is available only after t_2 and before t_3 for students. During this period, students may submit their completed assignments and retrieve if assignments need modifications, even though they have been submitted. Although assignments have been submitted during time t_2 and t_3, assignments will not be sent to the marker until t_3 arrives. Similarly, the marker has been assigned a time period $[t_4,t_5]$ for marking. Assignments cannot be transferred to the secretary until t_5 arrives. During $[t_6,t_7]$, the secretary is allowed to publish results of assignments. Until t_7 arrives, results are available for students to view. The cut-off time of the assignment is t_8. When t_8 arrives, the assignment reaches its end. Therefore, the life duration of the assignment is $[t_8,t_8]$.

From the description, the time-driven mechanism has been defined very clearly. The state of the assignment will be changed if the specific time arrives. For example, when time t_3 arrives, all submitted assignments would disappear from students and be available for the marker only. If t_3 is equal to t_4 in the model, the due date of the assignment for students is also the begin date for the marking phase. Therefore, the marker can mark assignments with the sorted submitted time order. If a time-driven mechanism has not been applied in the process, the marker has to check the submitted assignments all the time for the newly submitted assignments. From this example, using time as a trigger component to change the state of the process is more reasonable, acceptable, and effective than the ordinary mechanism.

5.4.3. Database Architecture

In this section, the database architecture of the assignment management system is given. The high-level database architecture is presented firstly. The detailed relationships among tables will be provided later.

- High Level Database Architecture

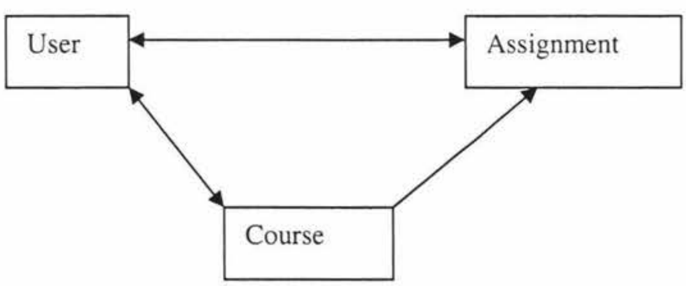


Figure 5-6: The relationship among user, assignment, and course

Figure 5-6 illustrates that the relationships between user and assignment are many—many, like the relationship between user and course, whereas one—many relation is shown for course and assignment.

Database design consists of three major phases which include the conceptual database design, logical database design and physical database design (Connolly & Begg, 2004). In this research, relational database tables depict the relationships among tables. Tables have been created to record the information of assignments, users, and courses. In addition, the relationships between user and course and between course and assignment also have been illustrated. Each table has primary key (pk) and foreign key (fk) to show the relationship with other tables.

The next step is to implement the relations into MySQL. A collection of information in a relational database of MySQL is organised into a set of tables. Converting the relations into a real database schema to produce a relational database in MySQL is the next process. The database schema of the system was created in a data file named database.sql, which can be found in the Appendix A. For example, the relation of assignments was implemented in SQL statements and it is described in Figure 5-7.

```
create table if not exists assignments
(
    assignmentid        bigint unsigned        not null AUTO_INCREMENT,
    lecturerid          bigint unsigned        not null,
    courseid            bigint unsigned        not null,
    title               varchar(128),
    'file'              varchar(128),
    note                text,
    createdtime         datetime,
    lastmodifiedtime    datetime,
    primary key (assignmentid)
);
```

Figure 5-7: SQL for creating the table assignments

The following graph (Figure 5-8) depicts the relationships among tables. In addition, a detailed description of these tables will be provided in Appendix.

- **Diagram of Database**

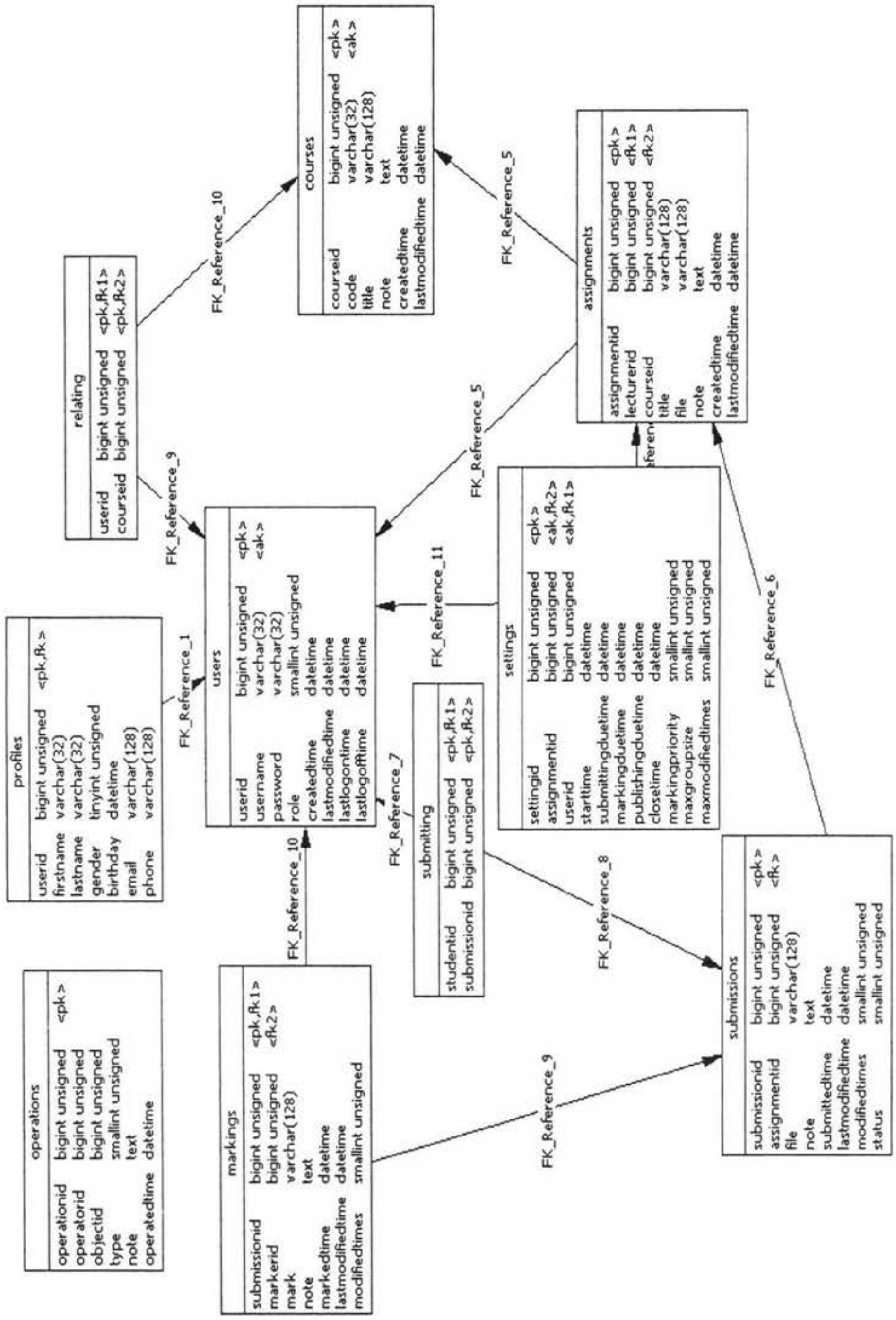


Figure 5-8: The relations of tables

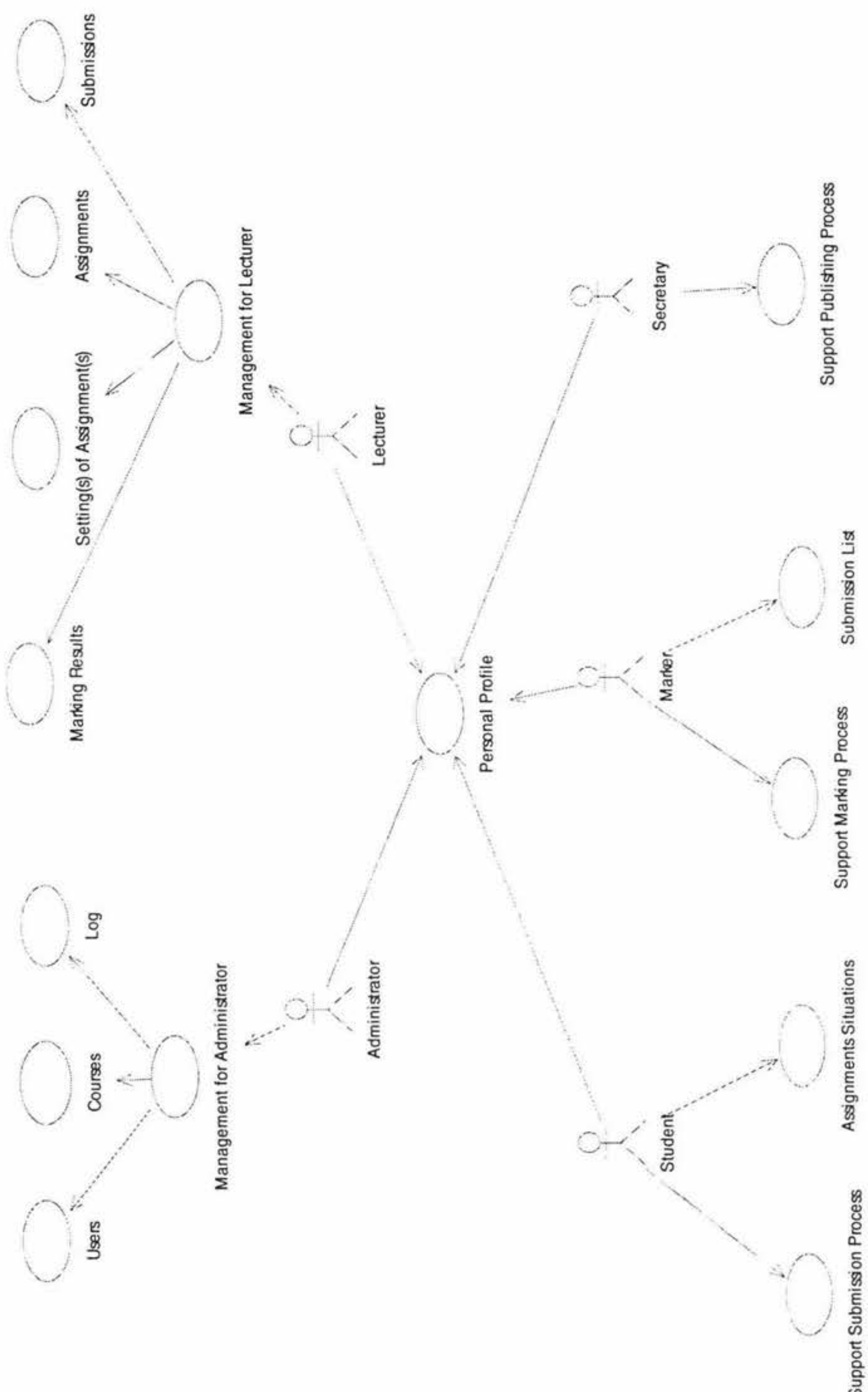
5.4.4. Interface Design

In this section, interface design is discussed. Firstly, every participant has been put into the process as one 'big picture'. User case diagram has been utilised to show the relationship among roles. In addition, it is possible to show the individual function of each participant. Based on this big picture, the layout of the interface is designed with certain technology, which has the ability to format the system in one style. Then, it is necessary to introduce how the system realises the functionalities of each role involved in the assignment management process.

5.4.4.1. Big Picture for System Design

After describing the relationship among tables and establishing the database into MySQL, it is worth mentioning that different roles may have different functionalities to access the system according to their tasks and responsibilities in the assignment management process. Five different roles are involved in the process, each role has a different task and responsibility to complete during a certain time constraint. For instance, the lecturer has the task to set the time span for the assignment, which should define the due day of submission, the due day of marking, and the day to publish the result. When the assignment has been handed out, students take over the assignment management process. Before the due day is arrives, students have their own pace to complete their assignment individually. Therefore, the following graph (Figure 5-9) shows the duties each role has in the process. The administrator has the ability to manage user, course, and the log, which is defined as the system administrator who does not actually play in the timeline of the process. The lecturer has the responsibility to manage the time setting of the assignment, result of the assignment marking, creating the context of the assignment, and submission status of the assignment. However, students have to complete the tasks in the assignment which will result in changing the status of the assignment after they submit the assignment. Then, they alone have the right to view the submitted assignment.

Similarly, the marker should mark and manage the submitted assignments before the marking due day. In addition, the secretary has the access to manage the marked assignments when the marker completes marking tasks.


Users
Courses
Log
Management for Administrator
Administrator
Marking Results
Setting(s) of Assignment(s)
Assignments
Submissions
Management for Lecturer
Lecturer
Personal Profile
Student
Marker
Secretary
Support Submission Process
Assignments Situations
Support Marking Process
Submission List
Support Publishing Process

- User

Case Diagram

Figure 5-9: User case diagram in UML for the web-based Assignment Management System

5.4.4.2. Interface Functionality

Interfaces are significant integrations for the system. Not only should they arrange all operations in a proper place for users to operate, but also vivid and attractive pages should be provided. The interface for the team and individual has been implemented in a convenient way, which is easy for users to handle and utilise. In addition, the operation functions covered in the page also have been arranged in the proper place.

The interfaces of this programme have been presented in a web page. Here, .jsp files are used instead of using .html files. Therefore, the interfaces of roles are constructed by the JSP technology.

- **Generic Page Structure**

To make all pages in the system have the same style and format, the frame of the page has been set up with Struts technology that is Java-based and developed by the Apache group. The Struts-template tag library (Table 5-2) offers dynamic JSPs with a common format.

Tag	Purpose
<template:get>	Gets content from the request scope and either includes the content or prints it
<template:insert>	Includes a template into the JSP
<template:put>	Puts content into request scope

Table 5-2: Template tag reference (Spielman, 2003, p.100)

In the implementation, a page has been divided into five parts: title, header one, header two, desk, and footer. Each part has been defined in the same style with an external .css file where the layout and style of the page are defined. In addition, each part having a template can be included dynamically into the page and the layout of the page is managed separately from the content. Page.jsp is the template file for the generic page. The following box shows how these five parts are defined in the page.jsp.

```
<%@ taglib uri="/WEB-INF/struts-template.tld" prefix="template" %>
<title><template:get name="title"/></title>
<td height="1" bgcolor="#FFFFFF" class="headnote"><template:get name="header"/></td>
<td height="1" align="right" class="headnote"><template:get name="header2"/></td>
<td colspan="2" style="padding: 1px"><template:get name="desk"/></td>
<td height="1" class="footnote"><template:get name="footer"/></td>
```

When constructing each .jsp page for users to view, the overall page structure template is inserted first.

```
<template:insert template="/template/page.jsp">
```

Then, the five parts can be integrated into the page with the prefix word one by one associated with the elaborated content of each part.

```
<template:put name="title">Student: Welcome</template:put>
<template:put name="header">...</template:put>
<template:put name="header2">...</template:put>
<template:put name="desk">...</template:put>
<template:put name="footer">...</template:put>
```

To construct the content of the page, the general HTML pages associated with JSP are required in the implementation. In this programme, besides the Struts technology being implemented to structure pages, the content required in the page is firstly obtain by Java programming from java class and then variables integrated with jsp tag into the HTML to show the entire content of each page.

- **Interface Layout**

Figure 5-10 shows the generic page structure. It consists of five parts including the title, header one and two, desk, and footer. In the title, it shows the title of this interface. The header one and two show the information of user and the operation access for the users. The desk part is the main content area to show the information that the user wants or the operation area for the user to manipulate. The footer is located at the bottom of the page and it is the area to show the copyright information for example.

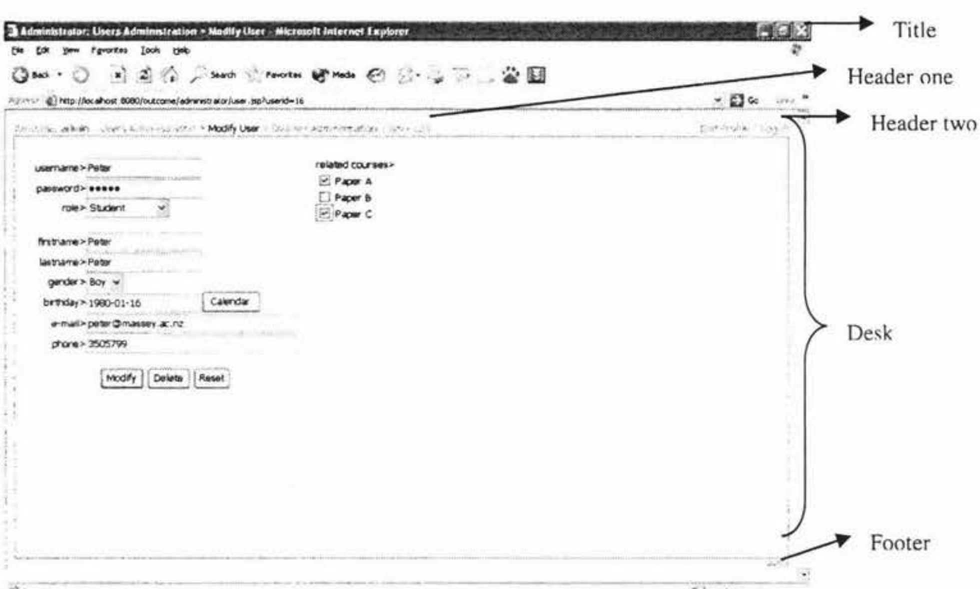


Figure 5-10: Layout of an interface

After introducing the structure and generating content of each page for roles, the following section is to introduce the interfaces for each role.

5.4.4.3. Interfaces for Individual Role

- **Administrator**

In fact, administrator does not belong to the assignment management process. He is the role to manage the system and set the initial configurations for courses. He does not work under certain time constraints. All information sent to the system for the administrator should be completed before the semester begins. As described before, the administrator has several functionalities to be accessed.

1) Managing users

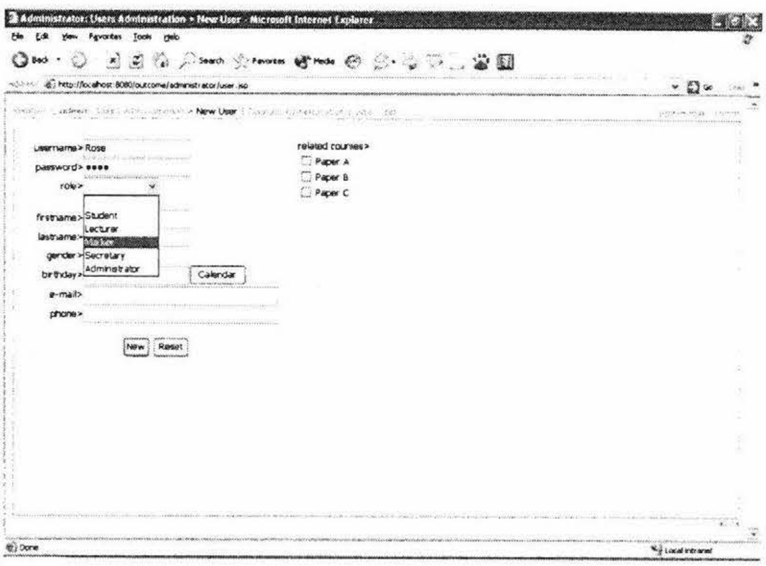


Figure 5-11: Interface to create new user for the system

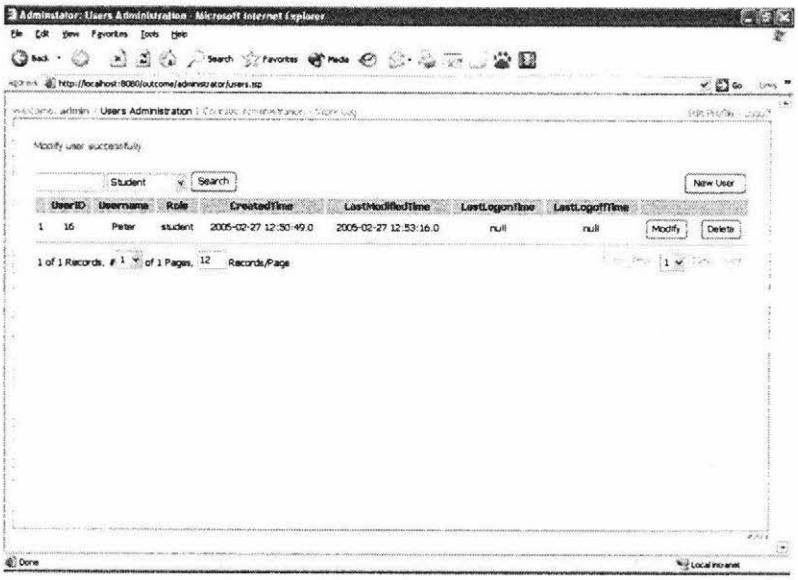


Figure 5-12: Interface to manage users

The interface shown in Figure 5-11 is to create new user for the system. It includes creating new lecturer, student, marker, and secretary for the assignment management process and modifying the existing users' configurations. The information includes username, password, real name, and related course information. Figure 5-12 is to manage the existing users. It provides the accesses to operate create, modify, and delete activities in the process.

2) Managing courses

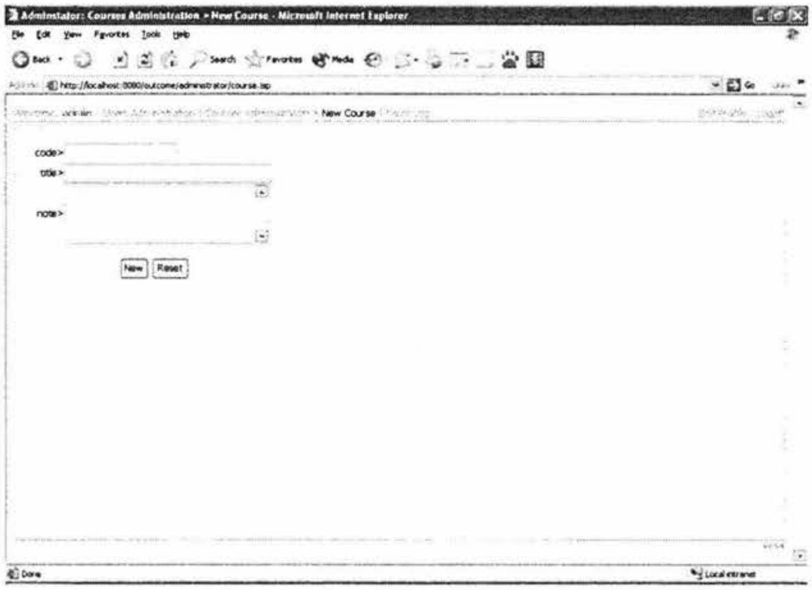


Figure 5-13: Interface to create a new course

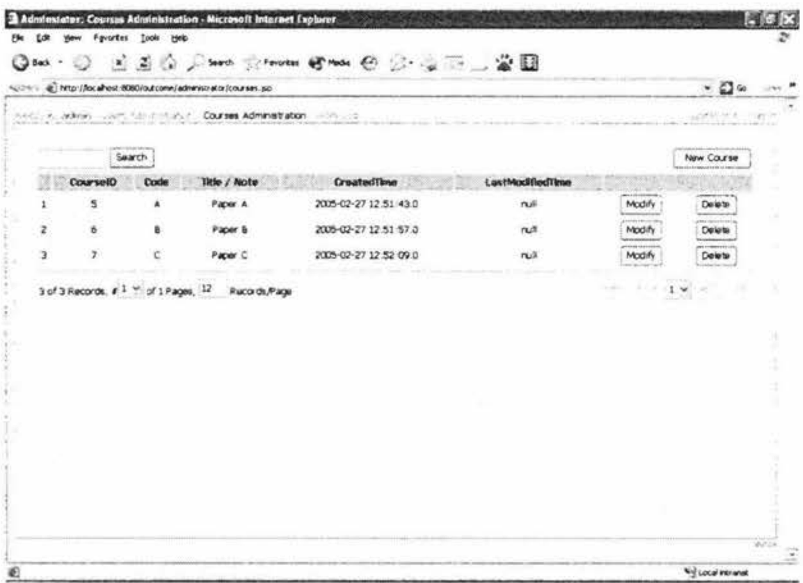


Figure 5-14: Interface to manage courses

The administrator also has the authority to create (Figure 5-13), modify, and delete the courses configuration for the system. The interface of Figure 5-14 shows the access for the administrator to access.

- **Lecturer**

Lecturer is the first role involved in the assignment management process. He sets the configuration of the assignment which triggers the beginning of the process. Therefore, the lecturer has the ability to manage the configuration of the assignment. After the assignment has been set, the assignment management process begins. The process begins with the time that is set by the lecturer.

1) Setting assignment configuration

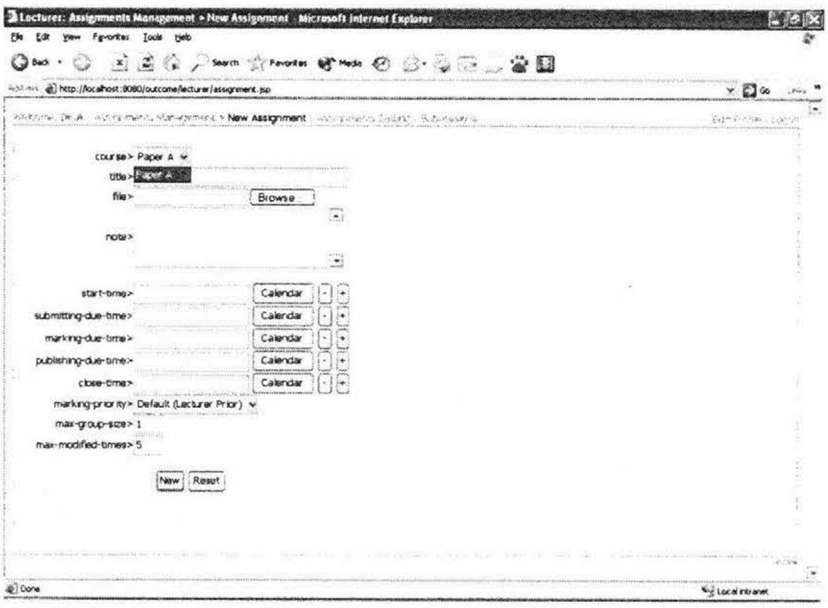


Figure 5-15: Interface to set the configuration of the assignment

2) Managing the assignment setting

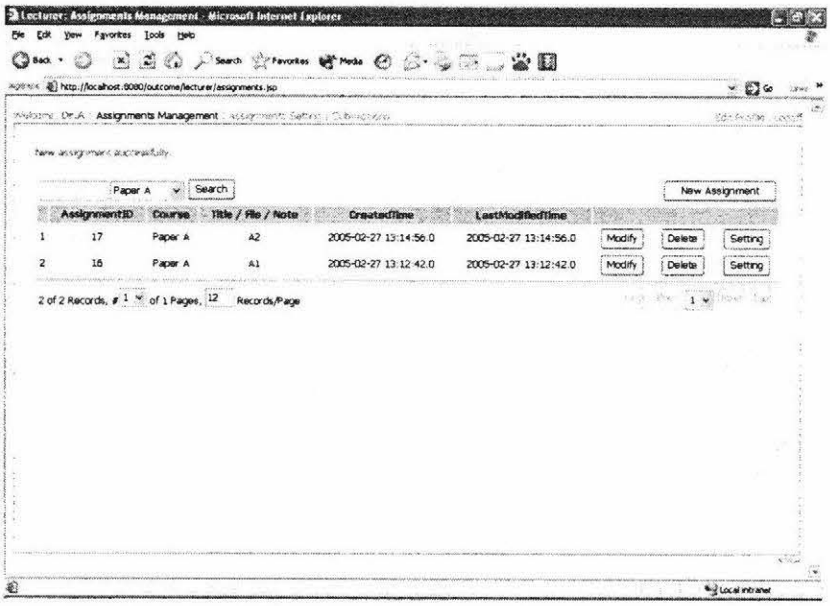


Figure 5-16: Interface to manage assignment

The lecturer has the capability to set the configuration of the assignment (Figure 5-15). The interface shown in Figure 5-15 is for the lecturer to set the time line and other configurations of the assignment. In addition, Figure 5-16 shows the operations for modifying and deleting the existing assignments. It also provides the access link to the detailed setting of the assignment (Figure 5-17). The setting link also provides the function for the extension of the assignment for a specific student. But the default setting is for the whole assignment in Figure 5-15.

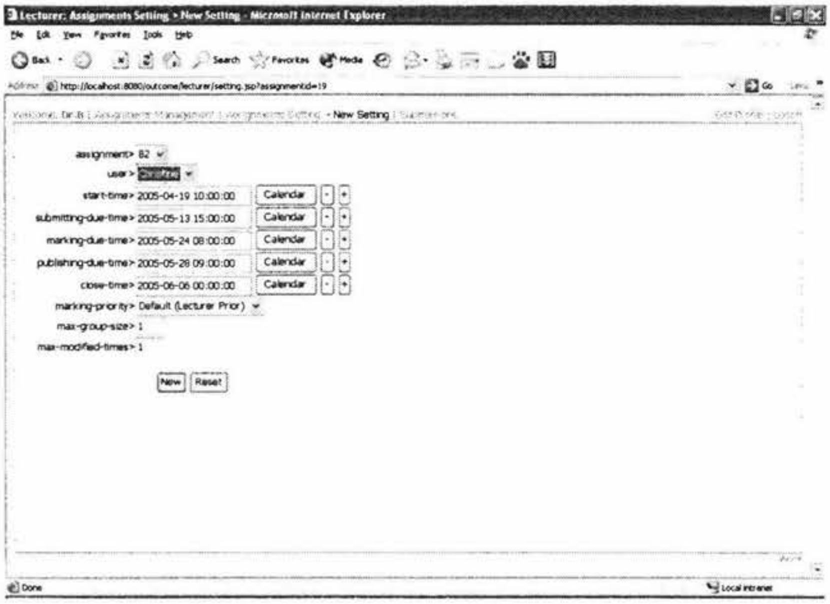


Figure 5-17: The interface to set the time line of the assignment

- **Student**

The student is involved in the process after the assignment is available. When the assignment is opened for students, students can download the instructions issued by the lecturer after the published day (Figure 5-18). Then, students may follow their own pace to do the assignment. Before the submission day of the assignment is due, students are allowed to submit their assignments only during the available time period, which means the time span between the assignment being published by the lecturer and the due day of the assignment. The students can submit their assignments through the access button labelled 'Submit'. It is worth mentioning that students may lose their access after the assignment due day, which means students cannot submit their assignments after the due day. If students already finish and submit assignments, they also will lose the access link to submit after the due day.

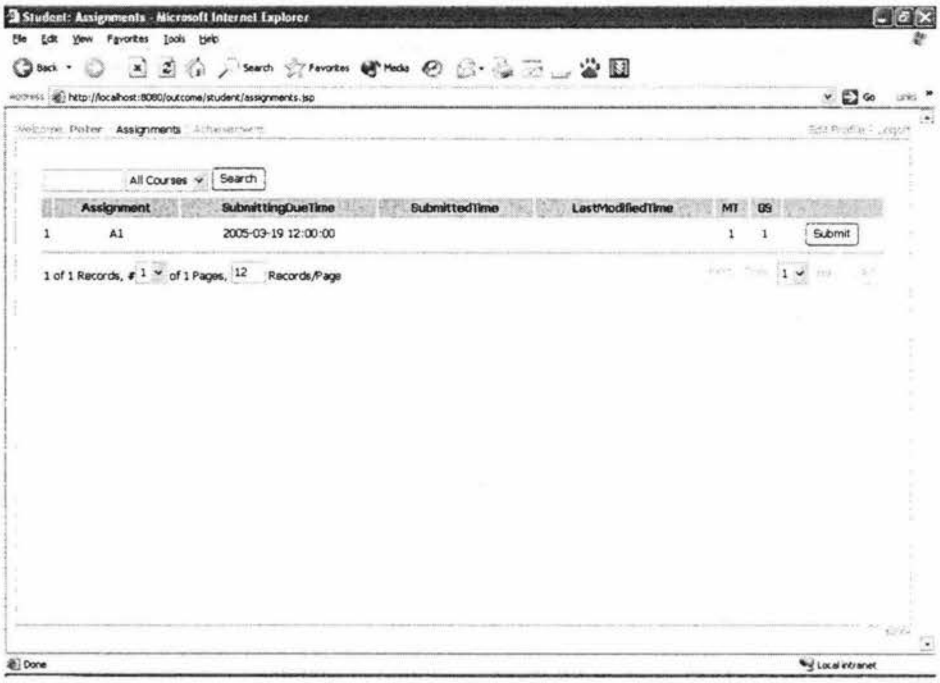


Figure 5-18: The interface to view the available assignments and link access for submission

- **Marker**

When the assignment is due for students, it automatically opens for the marker who is the next participant in this process. As soon as the marker logs in the system, the submitted assignments of students will be shown in the interface (Figure 5-19). From this interface, individual student's assignment is ready to be marked. After it has been marked, the result of the assignment will be shown in the column. There is a number labelled for each student's assignment. Therefore, the marker could not know whose assignment is being processed. It prevents plagiarism between the marker and the student.

Figure 5-19: The interface for the marker to view the submitted assignments

After the due day of marking, the marker cannot view the marking situation as students cannot submit their assignments after the assignment due day.

- **Secretary**

The secretary is the last role in the assignment management process. The responsibility of the secretary is to record students' results of the assignment. After recording these results, the final results will be opened for students to obtain (Figure 5-20). The button 'Publish' is to open the results to students.

Figure 5-20: The interface for the secretary to record the result of the assignment

5.5. Implementation

The implementation of the web-based assignment management system is elaborated in this section. The web-based assignment management system, as a part of the educational enterprise for dealing with the assignment management processes, is implemented based upon the workflow theories with the time-drive mechanism.

In this programme, it denotes that the workflow management technology is used to manage the lifecycle of assignments. It also implements role-based access controls by assigning different tasks to roles under certain periods of time. It means that different roles involved in the schedule of the assignment management process, from the assignments being generated by the instructor to the result being confirmed to each student, have exact time access and exit points of the process from the time axis. The participant of each role is responsible for the particular task in the process.

5.5.1. Roles in the Assignment Management Process

There are five role-players participating in the assignment management process: administrator, instructor, student, marker, and secretary. In fact, administrator can be defined as the system manager. He is responsible for managing the data of an assignment cycle but he is not directly involved in the assignment cycle process. Similarly, he is one of the roles involved for various educational processes data management, but not processes themselves.

The administrator manages information about users and classifies users with suitable priorities.

The instructor is the person who determines the lifecycle of an assignment from creation to cut-off, including configurations of the assignment. For example, he issues the assignment with a brief introduction and the exact tasks or questions to be tackled. Meanwhile, requirements of the assignment need to be outlined with associated supporting materials that can assist students to finish the assignment. In addition, the instructor also needs to divide the whole lifecycle of the assignment into several phases with time limits being set for students, the marker, and the secretary.

For a student who has enrolled in the paper, he can access the system if his username for accessing the system exists. However, he can view the assignment only after it has been issued by the instructor in the accessible time period of the student role, which has been illustrated in the time-driven mechanism for the assignment management system. Before the end date for students to access, they must submit their completed assignments. Otherwise, they cannot have the access to submit assignments until they get permission from the instructor for an extension.

The marker is active after the due date of the assignment for students, which is the beginning date time for the marker. If it is active, the marker can login the system and view submitted assignments. With time constraints, the marker has to complete marking before the end date of the marking period.

Then, the secretary comes to play. After the marking period, the secretary can retrieve final results of assignments. After results have been published, students are able to view their results before the cut-off date of the assignment.

Here, it must be emphasised that the instructor always has the highest priority of the process no matter in which state the assignment is located. The instructor may access this management process at any time and at any stage.

5.5.2. Programme Mechanism

In this section, the architecture of the web-based assignment management system with five parts (Figure 5-4) will be elaborated in detail.

The database stores all information needed in the system, such as users' data about courses, assignments, submissions, and so on. For all data, the programme provides the area for communication, such as getting data from the database, setting value to the database, or creating a new record.

Java programming is integrated in the JSP technology. JDBC offers connection between the programme and database. The basic communication with the database is achieved through *get* and *set* methods operating on tables of the database. As the view part of the system, .jsp files are required when a user logs in. The dynamic content will be inserted into HTML with a *<jsp>* tag and programmed fetch data methods with complicated parameters that are generated in encapsulated classes called *beans*. The dynamic content of .jsp files must be retrieved from the database via *beans*. The dynamic content always is a set of data consisting of columns from different tables with certain requirements, which is retrieved by SQL statements. The requirements or conditions for communication between the database and programme are the basic communication methods. However, the static content can be represented with HTML. On the other hand, the basic fetch and set methods of tables in the database also are bridges for resetting the value or creating a new record for the users' requirements and the database.

In addition, to maintain the same style of all pages in the system, a .css file defines the style for every page. Moreover, Java Script is the associated language for pages to present data.

5.6. Scenarios in Time Petri Nets Modelling

In this section, time Petri nets are used to illustrate the statuses of the assignment management process. The assignment is the token travelling in the process. In this process, time is the trigger to fire the event and makes the process move forward to the next stage of the process. At first, the assignment is held by the instructor who generates the new assignment (Figure 5-21).

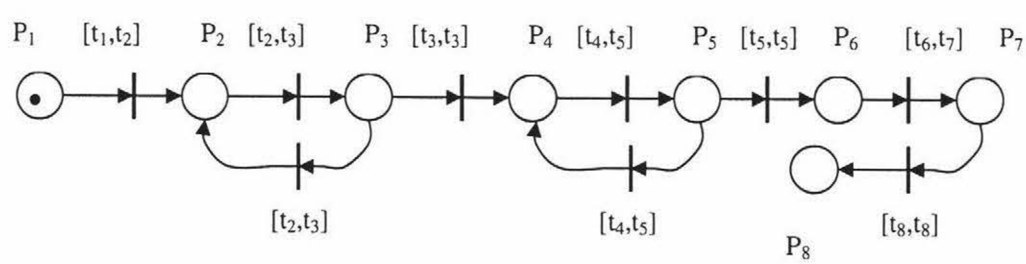


Figure 5-21: The status for instructor to generate the new assignment

After the assignment has been issued by the instructor, it is opened and available for students. Then, students have time period from t_2 to t_3 to do the assignment (Figure 5-22). If students finish their assignments, they may submit them before the due day t_3. In addition, they can retrieve back their assignments before t_3.

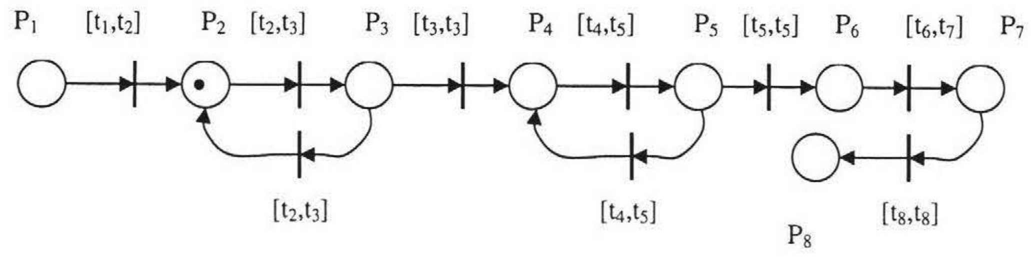


Figure 5-22: The status for students to complete the assignment

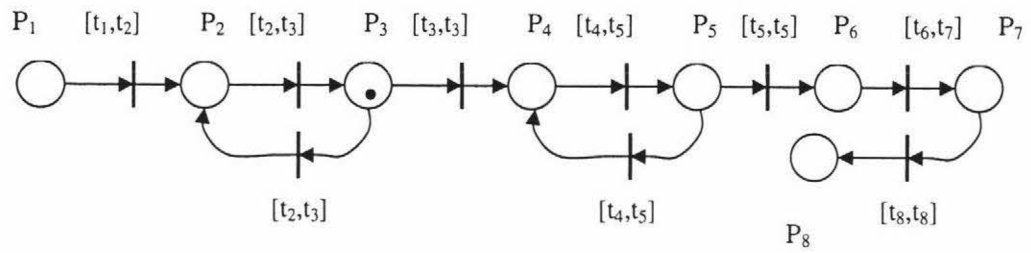


Figure 5-23: The status for students submitting the assignment before due day

When the time is up, the assignment has to move to the next stage (Figure 5-23). Students have to submit their finished assignments before t_3 arrives. After t_3 has arrived, the marker is the next person in charge of the process (Figure 5-24).

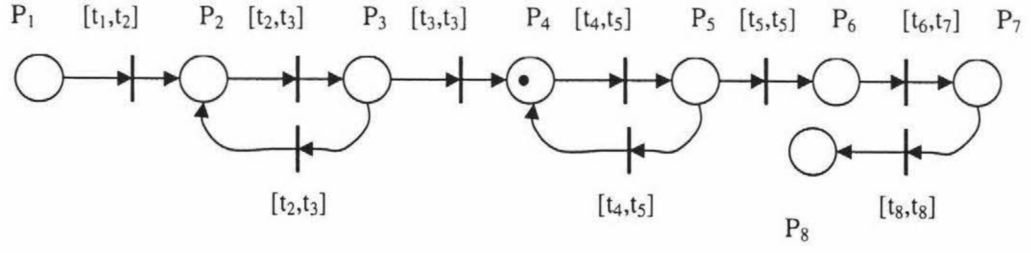


Figure 5-24: The status for the submitted assignment and for marker to mark

Similarly to students, the marker also has the time span $[t_4,t_5]$ to mark the submitted assignment (Figure 5-24). Before the due day of marking t_5 is coming, the marker is allowed to remark these assignments (Figure 5-25). However, the marker must complete the marking task before t_5 (Figure 5-25). Otherwise, the process will be delayed because of unfinished tasks.

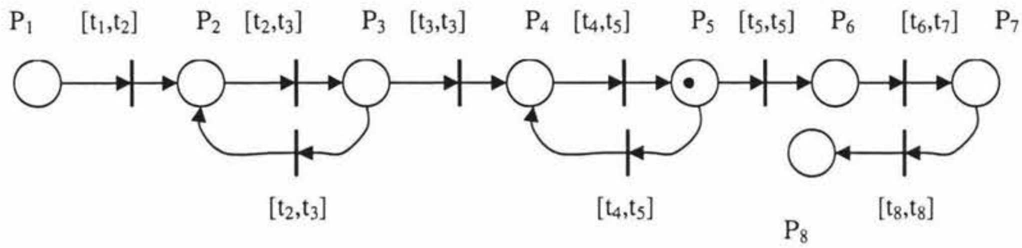


Figure 5-25: The status for marker to complete all marking tasks before due day

When the due day (t_5) for the marker comes, the secretary has the right to get the results of marked assignments (Figure 5-26).

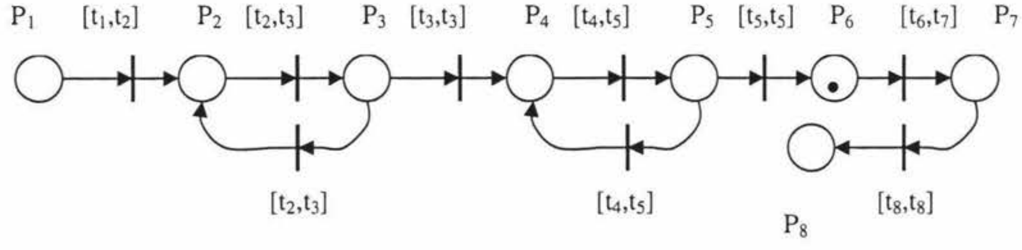


Figure 5-26: The status for secretary to process the publishing results of assignments

During the time period $[t_6,t_7]$, the secretary has to record the results of the assignment and publish these results. Therefore, results are ready for students to reach as they stay in P_7 (Figure 5-27).

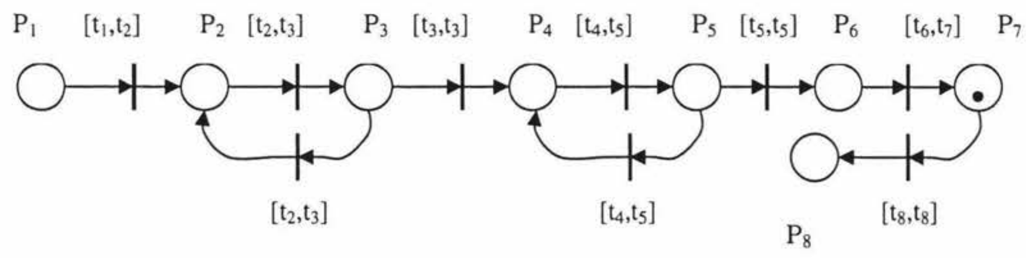


Figure 5-27: The status for students to retrieve the results of assignments

When time (t_8) has arrived, the end of the assignment is reached (P_8) (Figure 5-28).

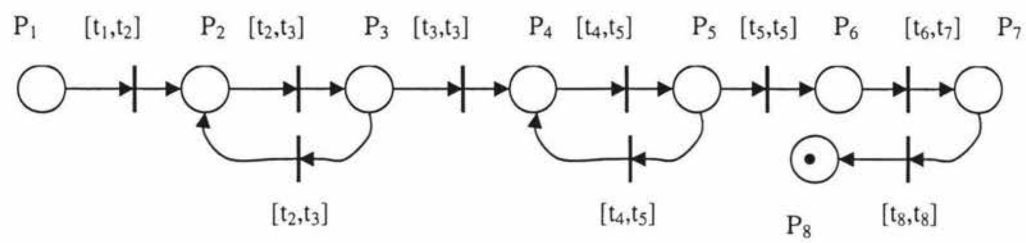


Figure 5-28: The end status of the assignment's lifecycle

Once the assignment gets to P_8, the life of this specific assignment is ended (Figure 5-28).

5.7. A Sample Scenario with Interface and Time Petri nets

A scenario is given to demonstrate how the assignment management system works with the workflow management technology associated with the time-driven mechanism.

Initially, the information about a few students, instructors, and papers should be stored in the MySQL database via the administrator.

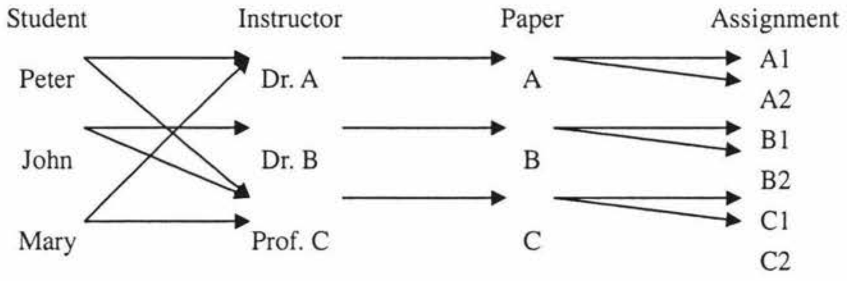


Figure 5-29: The relationship among student, instructor, paper, and assignment

Figure 5-29 shows which paper has been chosen by students and how many assignments are set for each paper. In addition, it indicates the instructor who is responsible for the paper.

Assignment	**Date available**	**Date due**	**Marking finish**	**Result published**	**Cut-off date**
A1	1 Mar 10:00	19 Mar 12:00	26 Mar 08:00	30 Mar 09:00	18 Apr 00:00
A2	19 Apr 12:00	12 May 17:00	24 May 08:00	28 May 09:00	6 Jun 00:00
B1	1 Mar 09:00	19 Mar 13:00	26 Mar 08:00	30 Mar 09:00	18 Apr 00:00
B2	19 Apr 10:00	13 May 15:00	24 May 08:00	28 May 09:00	6 Jun 00:00
C1	8 Mar 12:00	26 Mar 14:00	2 Apr 08:00	6 Apr 09:00	18 Apr 00:00
C2	19 Apr 09:00	14 May 09:00	24 May 08:00	28 May 09:00	6 Jun 00:00

Table 5-3: The time points for assignments

Each assignment has been configured with several time points to indicate different roles with available time spans in the assignment management process (Table 5-3). For example, the available date and due date for students to complete assignments are set out in the first two columns. Moreover, a time span is set for the marker to mark assignments, as well as for the secretary to publish the marked assignments for students. In this scenario, Rose and Christine are the names given for the marker and the secretary.

After illustrating the configuration of these six assignments, it is necessary to describe them with associated time Petri nets models. Although each assignment has its own setting on the flow, it has the same flow and route from the beginning to the end. Therefore, one model with different time ($t_{i[\text{from } 1 \text{ to } 8]}$) is adequate to describe these six assignments (Figure 5-30 & Table 5-4) .

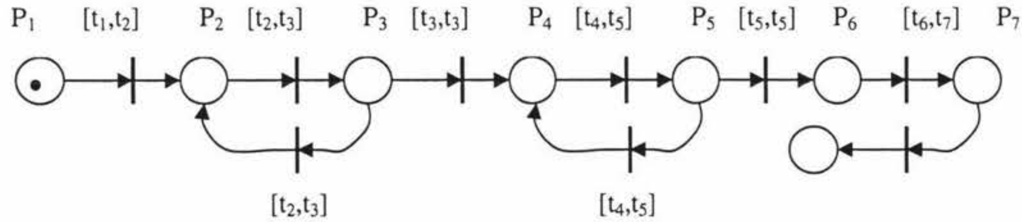


Figure 5-30: Generic time Petri nets model of the assignment

Assignment		Date available	Date due	Marking finish	Result published	Cut-off date
	t1	t2	t3/t4	t5/t6	t7	t8
A1	The time Before t2	1 Mar 10:00	19 Mar 12:00	26 Mar 08:00	30 Mar 09:00	18 Apr 00:00
A2		19 Apr 12:00	12 May 17:00	24 May 08:00	28 May 09:00	6 Jun 00:00
B1		1 Mar 09:00	19 Mar 13:00	26 Mar 08:00	30 Mar 09:00	18 Apr 00:00
B2		19 Apr 10:00	13 May 15:00	24 May 08:00	28 May 09:00	6 Jun 00:00
C1		8 Mar 12:00	26 Mar 14:00	2 Apr 08:00	6 Apr 09:00	18 Apr 00:00
C2		19 Apr 09:00	14 May 09:00	24 May 08:00	28 May 09:00	6 Jun 00:00

Table 5-4: The time points for assignments in time Petri nets

When the administrator logs into the system, the system offers this interface for him to manage information for system users and papers (see Figure 5-31 and Figure 5-32).

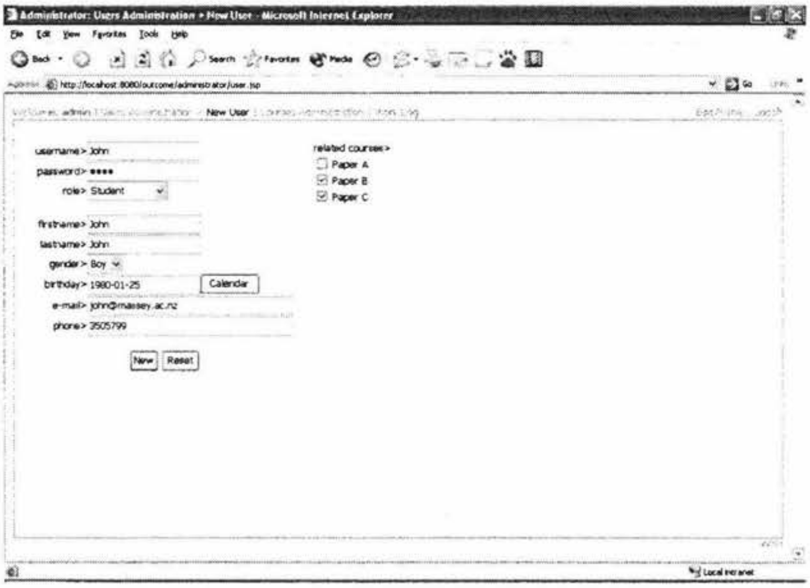


Figure 5-31: Edit information about a user

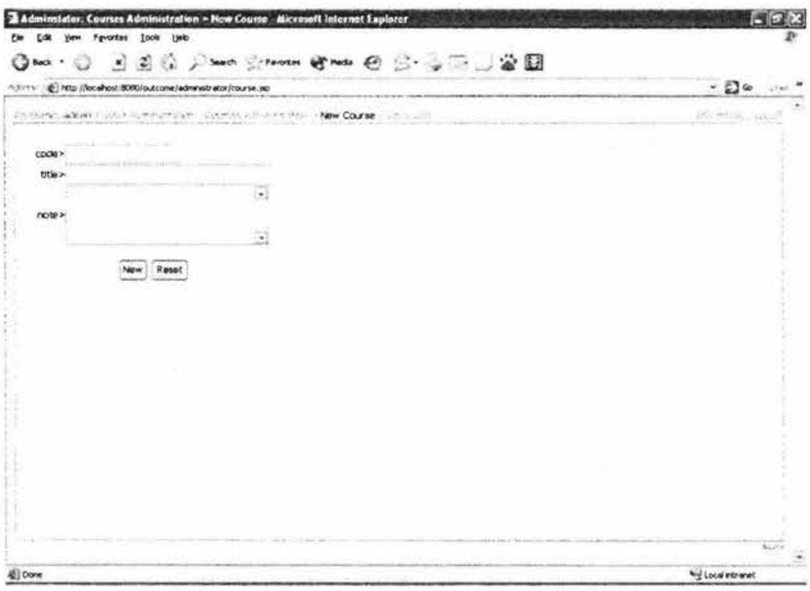


Figure 5-32: Interface for entering information about a course

Different users may have different role authorities. Figure 5-33 shows the interface to manage roles for the individual user.

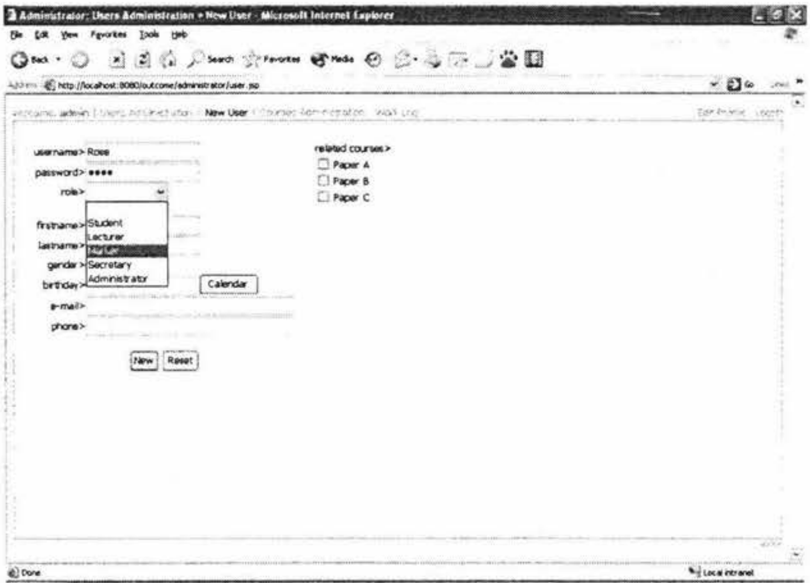


Figure 5-33: Role management for a user

Then, the instructor has the ability to manage and edit information for assignments if he teaches the paper. The interface for the instructor to manage the information for the assignment is depicted in Figure 5-34.

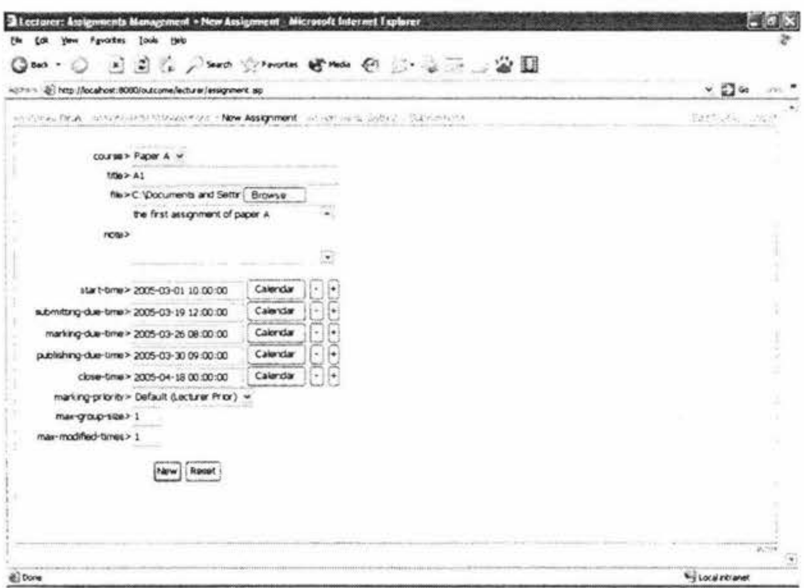


Figure 5-34: Configuration interface for an assignment

At this stage, before time t_2 has arrived, the instructor may upload the assignment for the specific paper that he teaches (Figure 5-35).

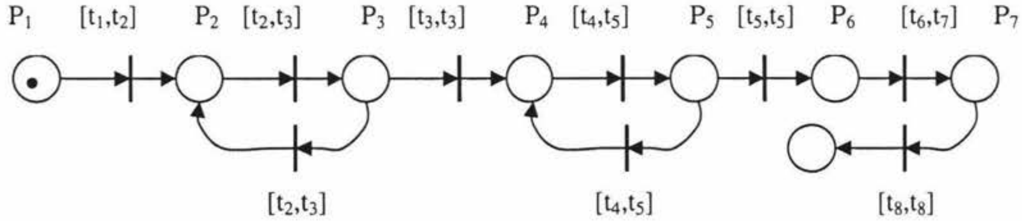


Figure 5-35: The status for new assignment uploading

The system is running in the server side. When users login to the system, they will have a serial of server time automatically, which shows how the time-driven mechanism works and the state of assignments in the running process.

- When Peter logs into the system on 27th Feb, there is no assignment available for him, even for Mary and John, because the earliest available assignment for him is A1 at 1st Mar 10:00 a.m. The time is still between t_1 and t_2. The status of time Petri nets is still in Figure 5-35, which is not ready for students yet.

- After 1st Mar 10:00 a.m., assignment A1 is available for Peter to do.
  Then, the time is between t_2 and t_3. The status of time Petri nets changes accordingly (Figure 5-36)

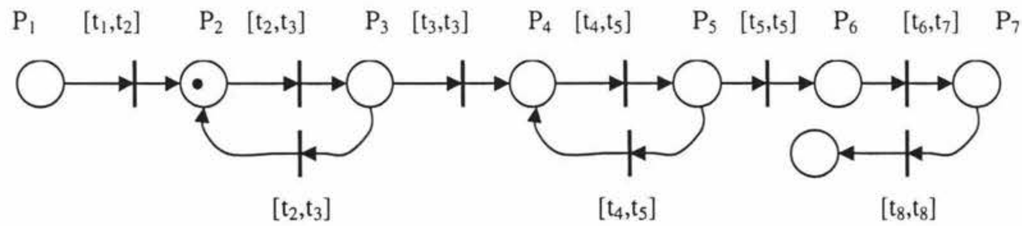


Figure 5-36: The new assignment is ready for Peter to complete between t_2 and t_3

- After 8th Mar 12:00 p.m., two assignments, A1 and C1, are available for Mary (Figure 5-37), who enrols in the same papers as Peter does. The status of assignment A1 is showing in Figure 5-36, whereas the status of assignment C1 is still stating as Figure 5-35.

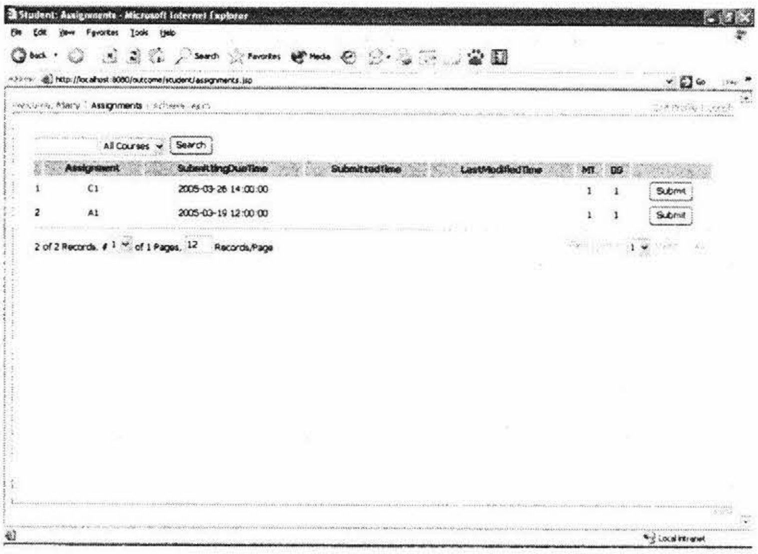


Figure 5-37: Available assignments for Mary

- Assuming Peter submits his assignment before the due date of A1 on 18th Mar (Figure 5-38).

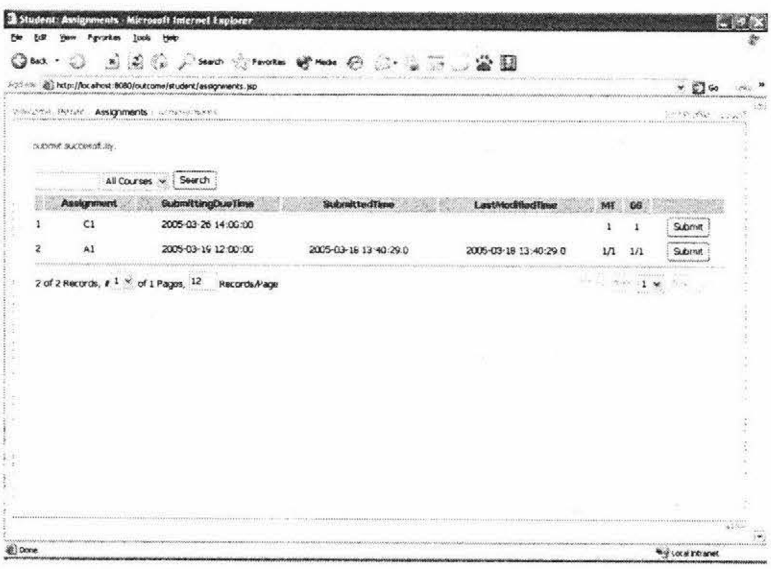


Figure 5-38: Peter submits his assignment before the due date

Although Peter has submitted the completed assignment, the assignment still stays with Peter and is not available for the marker because the marking period has not begun. Because t_3 has not arrived yet, the status of assignment A1 in time Petri nets is in Figure 5-39 when the assignment has been submitted.

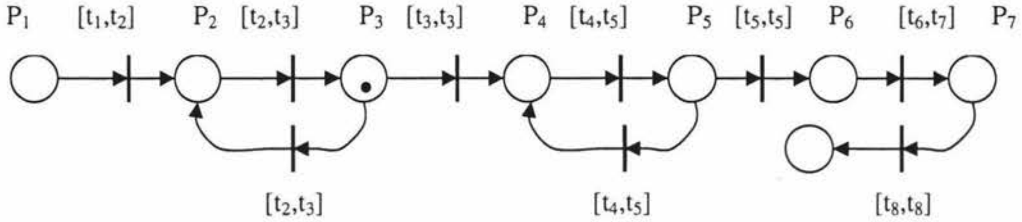


Figure 5-39: The assignment has been done and submitted before t_3

- At 19th Mar 1:45 p.m., assignments A1 and B1 are overdue. Therefore, John cannot access the link for submission of assignment B1 and Mary cannot submit her assignment for A1. The only way for them to gain the access back for the assignment is to get extension permission from their instructors. For example, John gets the extension for assignment B1 to 20th Mar 00:00 a.m. (Figure 5-40).

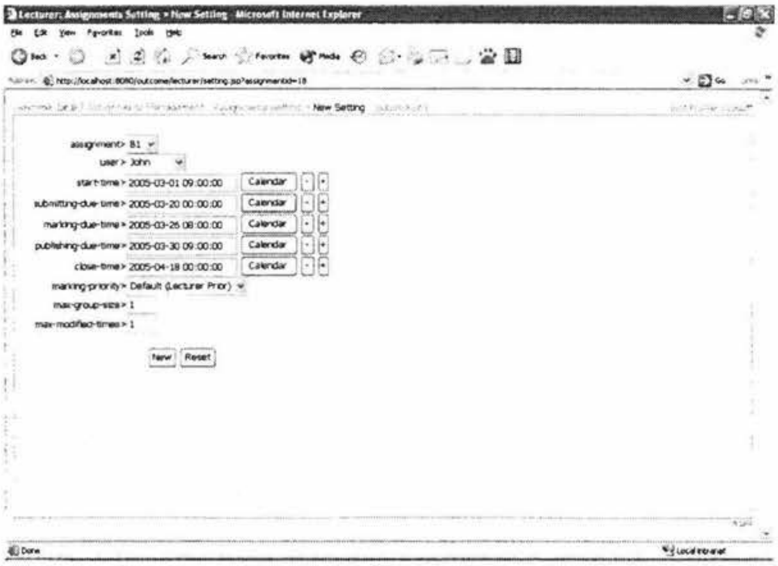


Figure 5-40: Extension permission from the instructor

After the assignment A1 and B1 are due, the status of these assignments in time Petri nets shows in Figure 5-41.

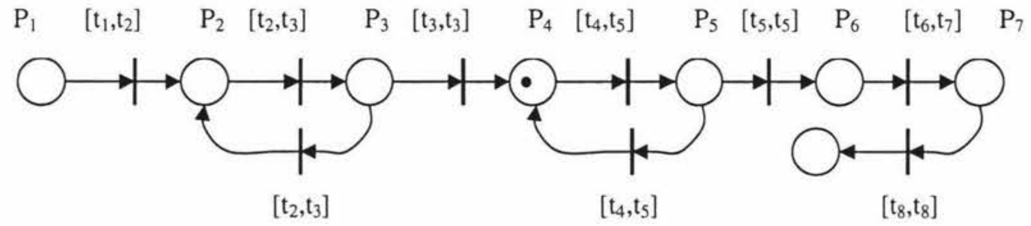


Figure 5-41: The assignment A1 and B1 are ready for Marker to reach between t_4 and t_5

In addition, students have asked for extension for assignments A1 and B1. Therefore, for these two students the statuses of assignments in time Petri nets are still located in Figure 5-36 and time point (t_3) of the assignment has been extended to the suitable time for these two students.

Then, John regains the access for assignment B1 when he logs in on 19th March 5:40:30 p.m (Figure 5-42).

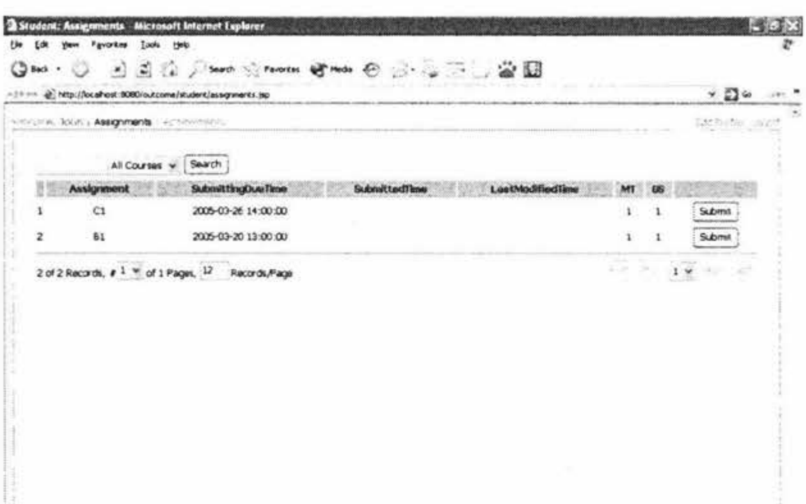


Figure 5-42: Access link for B1 is set back for John

- At the same time, 19th Mar 1:45 p.m., the submitted assignment A1 from Peter is available for the marker, Rose (Figure 5-43) and the status in time Petri nets is shown in Figure 5-41.

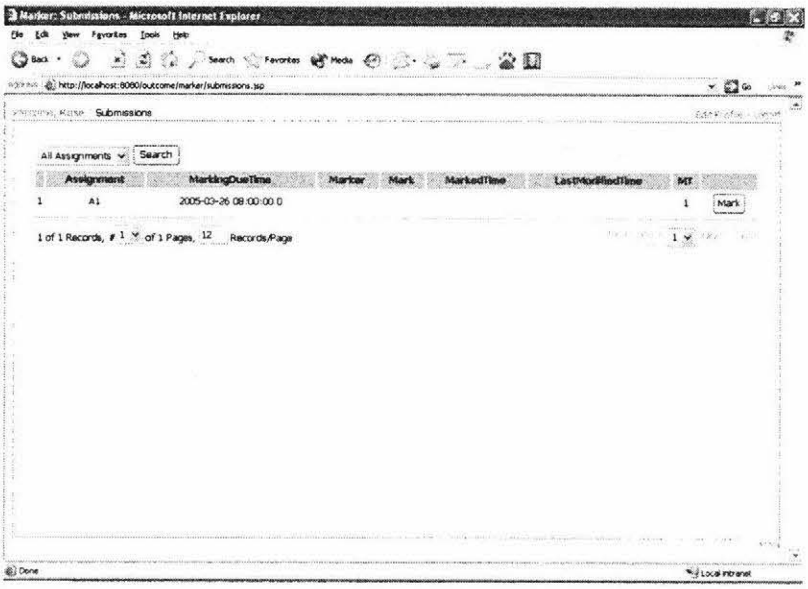


Figure 5-43: The submitted assignment is available for Rose

- On 22nd Mar, two assignments are available for Rose (Figure 5-44). But owners of assignments are not shown for Rose, which is the strategy to prevent plagiarism. And she gives the mark for A1.

Figure 5-44: Available assignments for Rose to mark on 22nd Mar

- After the end time of the marking period, Rose is not allowed to mark assignments any more. The unmarked assignments are left for other markers or the instructor. Alternatively, like John to regain the access linkage, Rose should ask for a marking extension from the instructor.

When the assignment has been marked and the time is before the due day of the marking period, the status of the assignment in time Petri nets is showing as Figure 5-45.

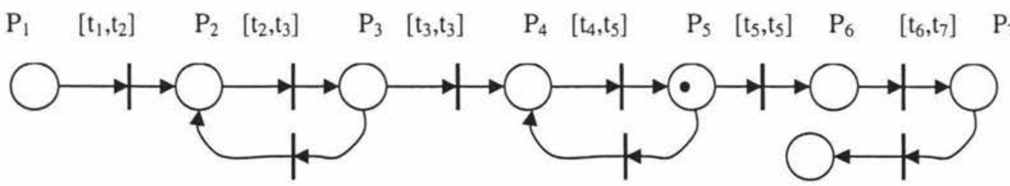


Figure 5-45: The status for the marked assignment

After t_5 is reached, the assignment is ready for the secretary to get and publish online.

The status of time Petri nets is showing in Figure 5-46.

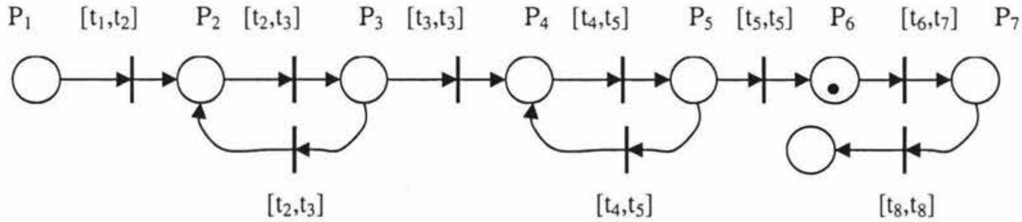


Figure 5-46: The assignment is ready for the secretary to process after t_5 arrives

- On 27th Mar, Christine is able to access the system and see the available marked assignment (Figure 5-47).

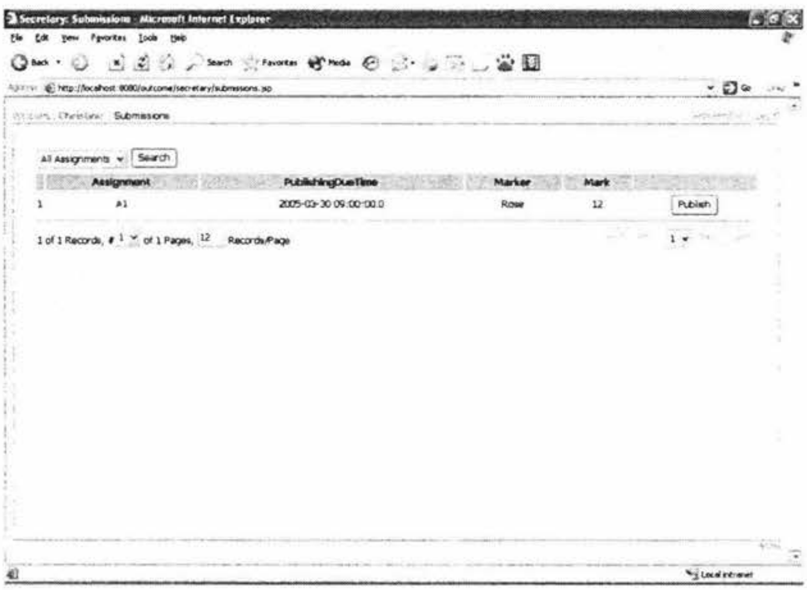


Figure 5-47: The marked assignment is waiting to be posted

During the period from t_6 to t_7, the secretary has the right to record the information of the completed and marked assignments for individuals (Figure 5-46).

- After the period for the secretary, Peter can view his result till the cut-off day of the assignment (Figure 5-48).

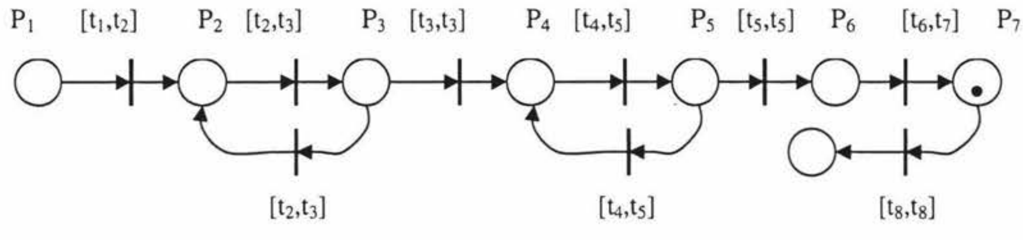


Figure 5-48: The results of marked assignments are opened for students to view

When t_8 comes, the lifecycle of the assignment is at an end and the token in time Petri nets arrives at the destination (Figure 5-49).

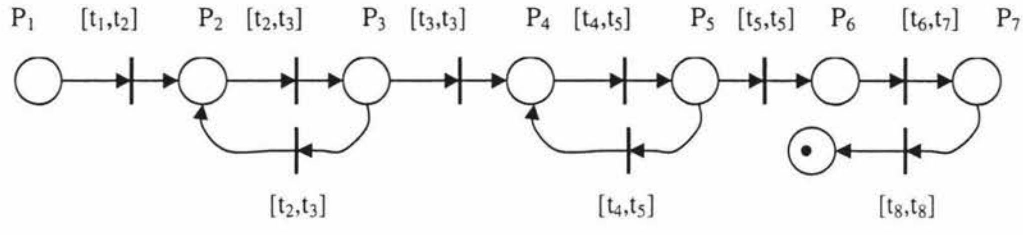


Figure 5-49: The end of the assignment lifecycle

The previous steps show how the time component works in the assignment management process. After the instructor sets the time configuration for the assignment, the process is managed by different roles under time restrictions. The assignment is available for the particular user only during the authorised time period of this user.

5.8. Evaluation

In this section, the evaluation will be illustrated between the system developed in this research and the assignment management part of WebCT. After evaluating in terms of time management, role management, and flow control, the advantages of the system developed in the research are easy to discover.

Time management

- WebCT has time components in their system, but it only adds time stamps associated with each activity. For example, when students submit their assignments to the system, there is only the submitted time associated with the assignment that is shown to the marker. It does not have any time control in the process of assignment management. In the WebCT system, the lecturer may set the time constraints to the availability of the assignment for students to reach. They are the beginning and end date and time of the assignment. During this period, students must finish the assignment and hand it in before the last day valid for the assignment. It is a compulsory time period for students to complete the assignment. In fact, the time constraints are the information which students must notice to know what the duration of the assignment is. It informs students to finish the assignment on time. Otherwise, the mark of the assignment will be reduced owing to the delay. The time constraint set here does not affect the pace of assignment management process. It also is not the trigger for the process to move forward.

- The system developed in the research shows the function of time. It uses time to define the process. When the time reaches the constraint, the process will go to next phase that is in charge of another role. For example, when the assignment is due, the marker will take over the process and students lose their previous status of the main role who is playing in the process. Only the marker can process these assignments and students only have the rights to view the status of the assignments. In this system, time has been emphasised and it is the separator for different phases of the process. In addition, the time management reduces the turn-around time. For example, the marker may have plenty of turn-around time to spend owing to personal issues. When the marker is in charge of the assignment management process, he alone can take his time to process the submitted assignments. The other tasks irrelevant to the marking issues should already be taken and finished before or after the marking period.

Role management

In WebCT, it supports the definitions of different roles in a learning environment. Different roles have different functions to set courses tasks. For example, the lecturer has the right to offer examinations and assignments. The tutor has the right to set up quizzes and additional materials for students to study. Students only have the right to view the items set by lecturer and tutor. Each role has personalised pages to access suitable materials.

However, the online assignment management system defines different roles for the assignment management associated with time. In each different time period, a different role takes over the phase of the process. Other roles are not in charge of the process. Roles have been defined with different functionality in one specific phase. Therefore, in different phases, one role may have different functionalities to process his tasks. For example, during the period of assignment from the published date to the due day, students have rights to view and download the assignment at first. Then, they must finish their assignment before the due day of doing it. After that due day, students only have the right to view the status of submitted assignments.

Flow control

In managing workflow, an important component that needs to be emphasised is process control. In this research, time is being considered as the main parameter for process control. In WebCT, however, the beginning of one paper process starts since it has been established by the lecturer. It has different roles involved in this paper process. But for the flow of this paper process, no matter what the paper is, double semester paper or research project paper, there is no trigger for the process to move. Time is supposed to be a natural feature in teaching a paper. As time goes by, different roles take up their responsibilities to do their jobs. For instance, the lecturer gives lectures according to the timetable; occasionally puts some materials to the WebCT associated with the content being taught in the lecture; provides some special topic in the discussion forum for students to participate, and so on. All of these activities have been done with the initiative of the lecturer only or even predefined by the lecturer's own teaching schedule. In the WebCT, there is no feature for the lecturer to define his teaching schedule. Therefore, all activities of the lecturer cannot be defined at the beginning in the WebCT with a timeline. It provides entries for lecturers to list materials with specific catalogues that they need for teaching. In this research, according to the purpose of the paper, different participants are involved in and materials related to this paper are required in the process of paper teaching. Each lecturer may have his own teaching schema to effectively teach the paper. In WebCT, it provides the space and links for the lecturer to upload materials and arrange items and tools for students or other staff to reach. But the system does not give any reminder and requirement for the lecturer to follow. All activities that the lecturer will take are set randomly depending on his own choice. The lecturer makes decisions on when and what materials and tools should be uploaded and added into the system. It is different from the personal process discussed in Chapter 2 and Chapter 4, which presents participants performing their tasks with serial activities that can be carried out in their own pace. Scheduling activities is an effective way to reduce the effects of human beings on the work, which makes the flow run efficiently.

5.9. Summary

Generally, assignments are not only practice for students to utilise the knowledge from materials and instructors, but also are effective measurements for instructors to measure the levels of understanding for the individual students. Owing to the importance of setting assignments in education, the management of assignments is an important part in the educational process. Actually, modelling educational processes is the aim of this research. Each process has been divided into several phases with time constraints. The state of the process is changed while time goes through the time threshold. Because the duration of the assignment management process is shorter than the learning/teaching process and it is a subprocess of the learning/teaching process, the assignment management process is exemplified and modelled with tasks in detail in this chapter. The advantage of using a time-driven mechanism in the process has been illustrated to reduce turn-around time (5.1&5.2) connecting different phases and to classify responsibilities and authorities for users. Time Petri nets have been used in designing and modelling the assignment management process.

In addition, based on the model of the assignment management process, an actual development of a system has been done. Although time information is required to be stored in a temporal database, recording the timestamp for each record of the database and operation is sufficient for the development of a simple and shorter assignment management process. Consequently, JSP with general MySQL has been utilised to develop the system. Meanwhile, the system can communicate with the database via SQL. After modelling the educational process in Chapter 4 and developing the model of the assignment management process in this chapter, in the following chapter the conclusion drawn from this research will be illustrated, and avenues for further research will be suggested.

Chapter 6. Conclusion and Future Work

In this chapter the research reported in this thesis is reviewed and further research is identified. The research investigates the possibility and validity of using workflow management technology to model the educational process under time constraints.

6.1. Conclusion and Contribution

According to the nature of educational processes, the workflow management technology has the capacity to be applied to model it. In addition, time is a significant concept and component in the educational process. Therefore, this thesis aims to utilise the workflow management technology, extended with a time component, to model educational processes. It has instant advantages to manage various educational activities and cause these activities to be carried out and completed efficiently.

After analysing a variety of educational processes, they are divided into three groups owing to their distinguishing functionality: learning/teaching paper, dealing with all kinds of people's applications, and realising people's own purposes in the educational sphere. Each process has one particular unique aim within it. For example, the paper is the only object in the learning/teaching process. No matter how many additional materials are required to help students or instructors to learn or teach this paper, there remains one unique aim of teaching the paper from the beginning to the end.

In addition, the time concept is important in the educational process so time information has to be stored. Therefore, the temporal database has been discussed to store the time information for the educational process. In the previous chapter, a small process about an assignment management is implemented to show how important the time is in the educational process as a case study. In this case study, there are only a few roles and a few events involved. Therefore, a temporal database is not necessary to be set up for such small process. Potentially, the temporal reasoning shows the possibility to fulfil the requirement of the process in the future according to the characters of educational processes and various education activities.

Moreover, time has been used in modelling the process owing to the time character of the educational process. Along with the graphic modelling tool—Petri net (which is an ideal tool to model workflow processes) with time extension, it was chosen to model the educational process with time dimensions. Therefore, time Petri nets are used to model these three classified educational processes. Thus, the architecture of the workflow educational process management system can be established on top of these modelled workflow processes.

Actually, the mechanism for firing transitions of the time Petri nets is the same as a time-driven mechanism. Furthermore, in this mechanism, the time has been described as the condition or restriction for triggering events. The enabling events result in the movements of phases from the first to the end. This means that participants have to complete the certain tasks under the time constraints. On the other hand, to utilise the advantages of the event-driven mechanism in dealing and shortening the time consumption for the process, it can be considered as another format of the time-driven mechanism in this thesis. For instance, no matter which activity is carried out, there is a particular time record for this activity. This time record can be converted into the trigger for the time-driven mechanism. From the research on the time Petri nets in this research, there are a few contributions which should be mentioned.

- **The notation for the time constraint of time Petri nets**

  The notation is defined with the nature of the education (see Table 4-1). It defines the beginning and the end date time for each education activity in iterated date time expression like [every Thursday 1:00 p.m., every Thursday 3:00 p.m.], for instance. In the lecture timetable, it always shows in a weekly or biweekly schedule. Here, we use every Thursday with a specific start time and end time which can express the lecture precisely. However, for the other time span like the beginning and end semester time, traditional time notation is adequate.

- **The time-driven and event-driven mechanism**

  The time-driven mechanism is adopted in modelling an educational process according to the time Petri nets firing mechanism. In addition, owing to the characteristic of educational processes, human factors are highly intertwined with each education activity. Relying on event-driven mechanism for the movement of the educational process may be interrupted and delayed easily. Therefore, time-driven mechanism has been emphasised especially for educational processes in this thesis. Event-driven mechanism can be treated as the alternative expression for the time-driven mechanism.

To present the possibility and validity of the implementation in educational workflow processes, the assignment management process, which is a subprocess of the learning/teaching process, has been chosen as the case study. It is the process which manages assignments once the assignment has been issued in its life duration by the instructor. During this subprocess, the assignment is the only object transferring in the process from beginning to end. In addition, four roles are involved in this process: instructor, student, marker, and secretary (the administrator is not really involved in the process, but manages the system). Time Petri nets demonstrate the modelling method for the process. JSP technology associated with MySQL database is integrated together to implement how the workflow management technology has been applied in the educational process and how to schedule the process with the time Petri nets and to discover the way that time-driven mechanism works.

Thus, the workflow management technology not only can be used for modelling business processes, but also has the possibility to be utilised to model educational processes. The contribution of this thesis offers a perspective to develop an educational information management system from a work and information organisation into a process-oriented structure. Because of the importance of time, it has been integrated with the technology to model the educational process.

6.2. Future Work

Regardless of the educational processes modelling with the workflow management technology and the time, further research can be expanded to realise the modelling methods. Although it is too ambitious to set up an entire educational system in this thesis, it is worth developing a workflow-based system upon modelling many educational processes for further development.

In addition, mobile technology also can be integrated into the workflow management system to reduce the time consumption on receiving messages via the wire network. Instant messages can be delivered directly to mobile devices for participants with the same tasks, when the process has to be moved into the next phases. Activities of the educational process discussed here happen around campus. Therefore, it is inconvenient for participants to access the Internet or the system from the computer in the lab all the time to get instant messages. They may complete the required activities through mobile devices.

Then, for the implementation, further efforts are required on the workflow visualisation. Although there is a graphic design tool being used in the modelling stage, the visualisation in the executive system is ideal to have. Users may drag an icon or sign to generate the flow of the process.

Furthermore, associated tools or applications are required for different participants to finish their tasks within the time period. For example, an effective teaching method encourages students to learn. These teaching methods include providing materials in a variety of formats according to the features of materials. Moreover, to link material in different formats, appropriate tools and applications need to be integrated as a part of the workflow system to assist the instructors.

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Appendices

A. User manual

This manual illustrates the execution environment for the Web-based Assignment Management System and its functionality of interfaces for various users. Java programming language, JSP technology, and Struts technology are integrated and developed into this web-based system. The system must be deployed into the server with a MySQL database. Clients may view information and operate data through a standard browser, like Internet Explorer 4.0 or higher.

A1. Deploy System

There are five different groups of participants involved in the assignment management process: administrator, instructor, student, marker, and secretary. Each type of user may access the process in different time spans with different authorities except for the administrator who is the person to manage data of the system. JSP pages are classified into different folders for different roles as shown in Figure A-1 with the name 'administrator', 'lecturer', 'student', 'marker', and 'secretary'. All JSP pages are interfaces for them to browse and retrieve information from the MySQL database. The java classes, as java beans for JSP pages to communicate with database, have been deployed into class folders, which is accessible by certain JSP pages.

In this research, the web-based assignment management system is programmed as a web application in the Jbuilder environment. The deployment of this web application to Tomcat is showing as following, which demonstrates how a web application works in the web server:

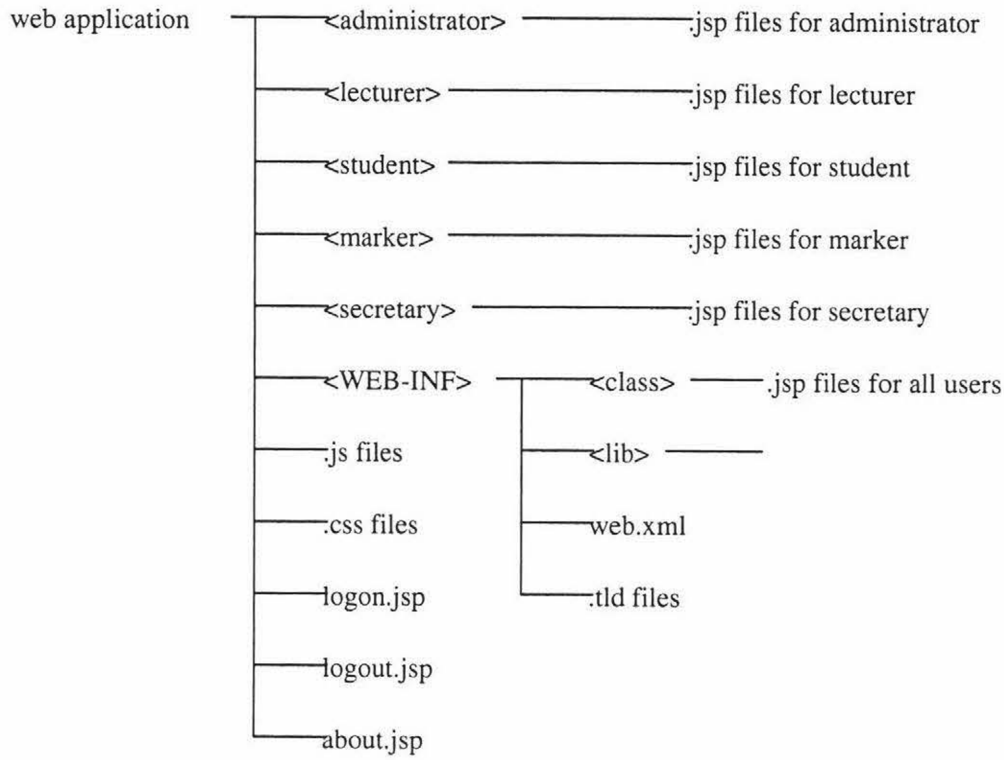

Figure A- 1: The deploying structure of the web application

A2. Database Description

- **Description of Tables**

The ASSIGNMENT table records information about all assignments created by the instructor

attribute	description
assignmentid (pk)	The id number of assignment, it is automatically increased.
lecturerid (fk)	The id of lecturer
courseid (fk)	The id of course
title	The title of assignment
file	The location of assignment
note	The description of assignment
createdtime	The time record created
lastmodifiedtime	The time record modified

pk: primary key; fk: foreign key.

Table A- 1: The ASSIGNMENT table

The USERS table records all information of users who log on the system

attribute	description
userid (pk)	The id of user
username (ak)	The username for user to use when logging on
password	The password for user to enter system
role	The role of user: student, marker, lecturer, administrator
createdtime	The time record created
lastmodifiedtime	The time record modified
lastlogontime	The time of last log on
lastlogofftime	The time of last log off

Table A- 2: The USERS table

The PROFILES table records the extended personal information of users

attribute	Description
userid(pk,fk)	The id of user
firstname	The first name of user
lastname	The last name of user
gender	The gender of this user
birthday	The birthday of this user
email	The email of user
phone	The telephone of user

Table A- 3:The PROFILES table

The SETTINGS table records the default features of the assignment and the special case of a student who applies for the extension

attribute	description
settingid (pk)	The id of assignment setting
assignmentid (pk,fk)	The id of assignment
studentid (fk)	The id of student
starttime	The process start time
submittingduetime	The due date of assignment submission
markingduetime	The due date of assignment marking
publishingduetime	The due date of publishing result
closetime	The time of end process
markingpriority	The priority of marking
Maxgroupsize	The maximum members of group
maxmodifiedtimes	The maximum times of update of the submitted assignment

Table A- 4: The SETTINGS table

The SUBMISSIONS table records the information of submitted assignments

attribute	Description
submissionid (pk)	The submission id of assignment
assignmentid (fk)	The id of assignment
file	The location of submitted assignment
note	The description of submitted assignment
submittedtime	The first time assignment submitted
lastmodifiedtime	The last time assignment submitted after being modified
modifiedtimes	Update submitted times
status	The state of assignment after submitted. Submitted, marked, published, (resubmitted, remarked,) closed

Table A- 5: The SUBMISSIONS table

The COURSES table records the information of courses.

attribute	Description
courseid(pk)	The id of course
title	The name of course
note	The description of course
code(ak)	The code of course (unique code)
createdtime	The time record created
lastmodifiedtime	The time record modified last time

ak: unique ky;

Table A- 6: The COURSES table

The MARKINGS table records the marking information about the submitted assignment.

attribute	Description
submissionid (pk,fk)	The id of submission
markerid (fk)	The id of marker
mark	The result of assignment
comments	The comments of this assignment
markedtime	The marking time of assignment
lastmodifiedtime	The time record modified last time
modifiedtimes	Modified times of remarking

Table A- 7: The MARKINGS table

The OPERATIONS table records all operations on the database.

attribute	Description
operationid (pk)	The id of operation
operatorid	The id of operator
objectid	The id of object which is operated
type	The type of object which is operated
operatedtime	The time operation committed
note	Description of operation

Table A- 8: The OPERATIONS table

The RELATING table records the relation between users and courses

attribute	Description
userid (pk,fk)	The id of user
courseid(pk,fk)	The id of course

Table A- 9: The RELATING table

The SUBMITTING table records the submission id with students' id.

attribute	Description
studentid(pk,fk)	The id of student
submissionid(pk,fk)	The id of submission of assignment

Table A- 10: The SUBMITTING table

The relationships among these tables are presented in section 5.4.3 (Figure 5-8).

A3. Functionality of Interfaces

To illustrate the functionality of interfaces in the system, it would be better to state them grouped by the role's functionality.

- **Administrator**

As an administrator, he has interfaces:

Create new course: State the name, description, and information for the course (Figure A-2) .

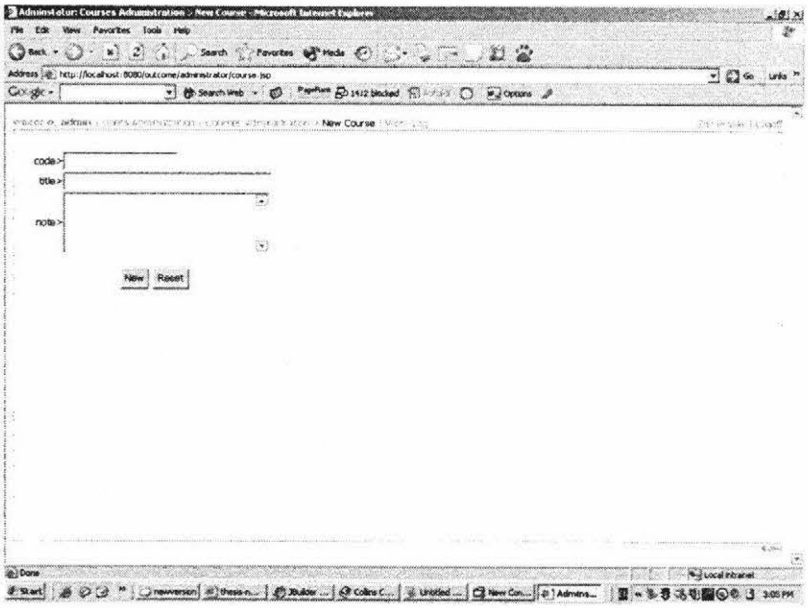

Figure A- 2: Interface for editing information of a new course

Manage courses: For existing courses, the administrator has the ability to operate them (Figure A-3). There are two buttons presented for administrator to operate on existing courses, labelled 'Modify' and 'Delete'. In addition, it provides the access for generating a new course with the button 'New Course'.

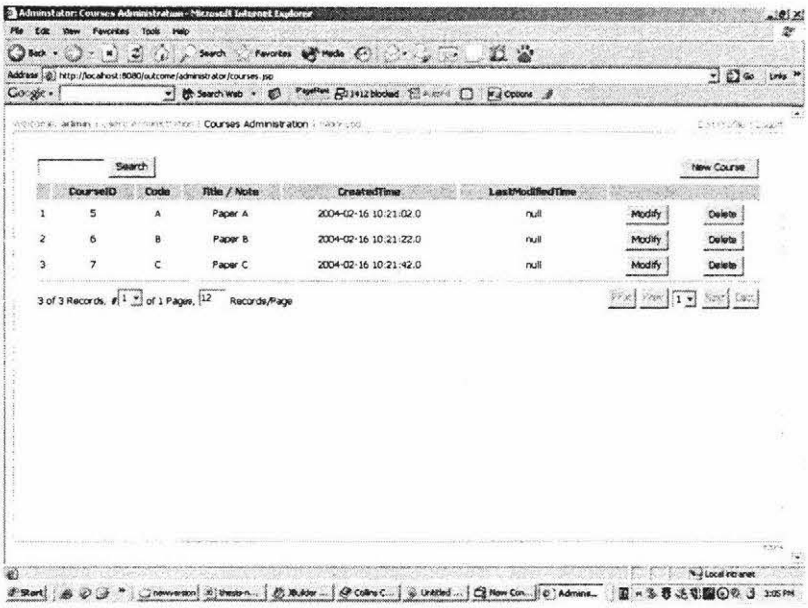

Figure A- 3: Interface for the management of courses

Create new user: Insert new user with personal information associated with corresponding priorities (Figure A-4).

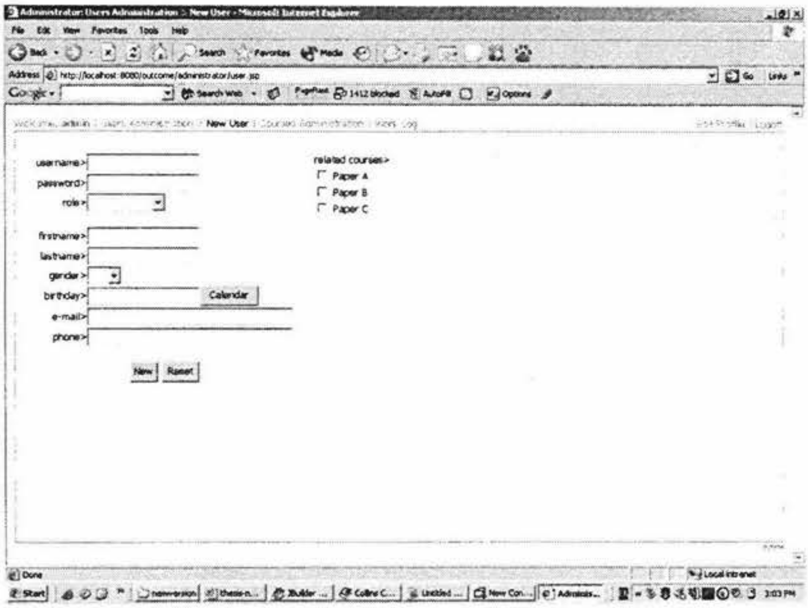

Figure A- 4: Interface for managing the new user

Manage users: Manage existing users with general operation like delete and modify operations (Figure A-5). A linkage to generate new user interface is offered with button 'New User'.

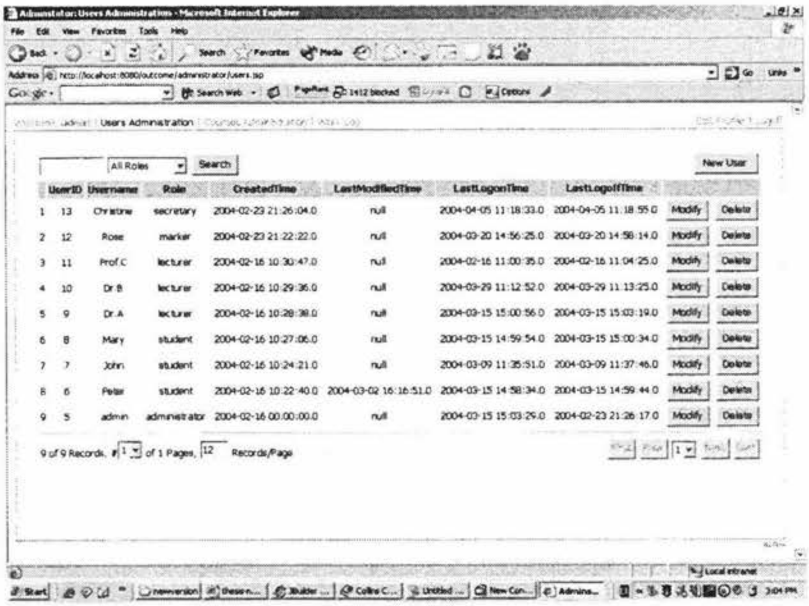

Figure A- 5: Interface to manage existing users

Log file: View the history file for the past operations' records (Figure A-6).

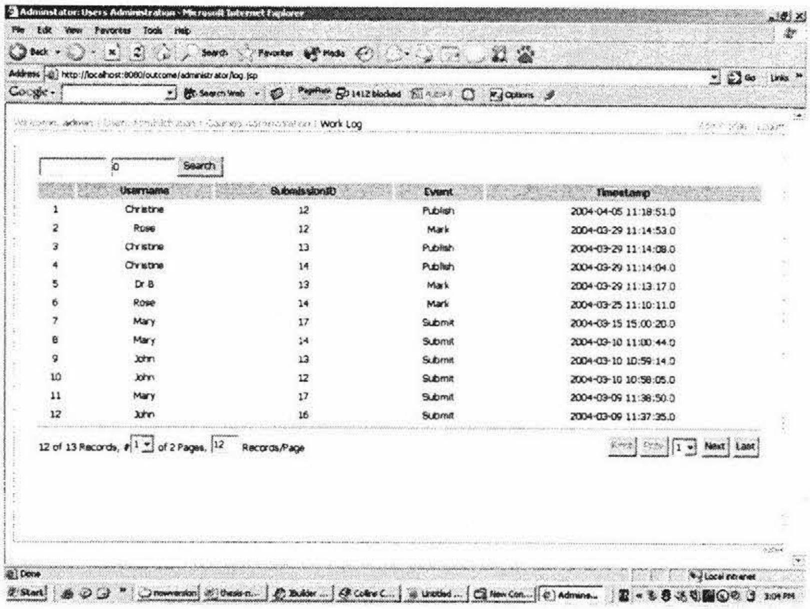

Figure A- 6: Interface for viewing operations of the system

Profile: View own personal information. The interface is shown in Figure A-16.

- **Instructor**

Interfaces of the instructor must show the functions of the instructor role.

Create assignment: Create a new assignment for the particular paper taught by the instructor (Figure A-7). In addition, assignment information should be included. Therefore, the lifecycle of the assignment is set.

Initially, the items listed in the drop-down box are papers that the instructor taught. Button 'Browse' is for him to upload materials for the assignment. 'Calendar' is to provide tool for choosing date. '+' and '-' buttons are for operating time. The date and time set for the assignment are accurate to the hour.

Figure A- 7: Interface to edit information for a new assignment

Manage assignments: Manage existing assignments along with papers that the instructor taught (Figure A-8). Generally, button 'Modify', 'Delete' and 'New Assignment' are for modifying, deleting and accessing to edit a new assignment. The additional button 'Setting' is used to change generic configuration of an assignment or change partial configuration of assignment for particular person(s).

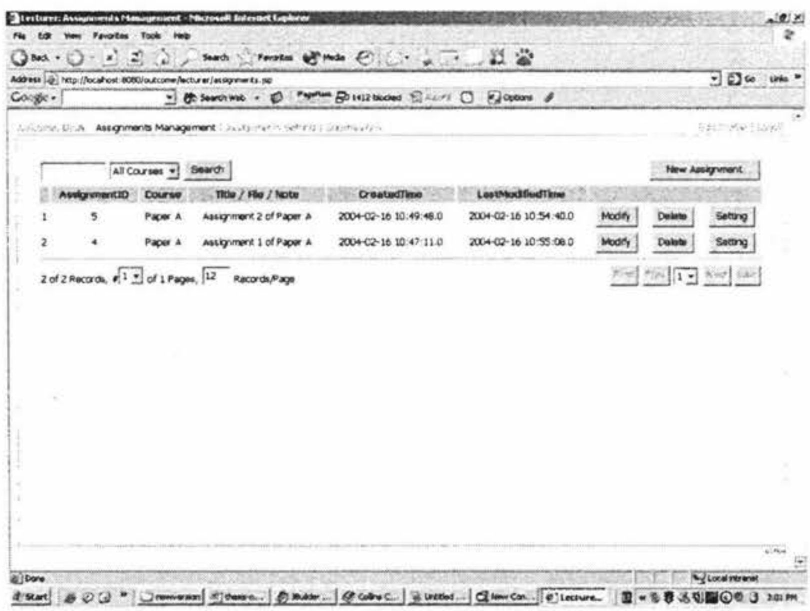

Figure A- 8: Interface for managing existing assignments

New setting for assignment: Compared with the general time schedule of the assignment lifecycle defined in editing new assignment interface (Figure A-9), a new setting can be shown for the particular student who asks for extension, which will result in the delay of the whole assignment lifecycle. Of course, the generic configuration also can be changed without selecting a particular person. The button 'Calendar', '+' and '-' have the same operation as in the previous interface (Figure A-8).

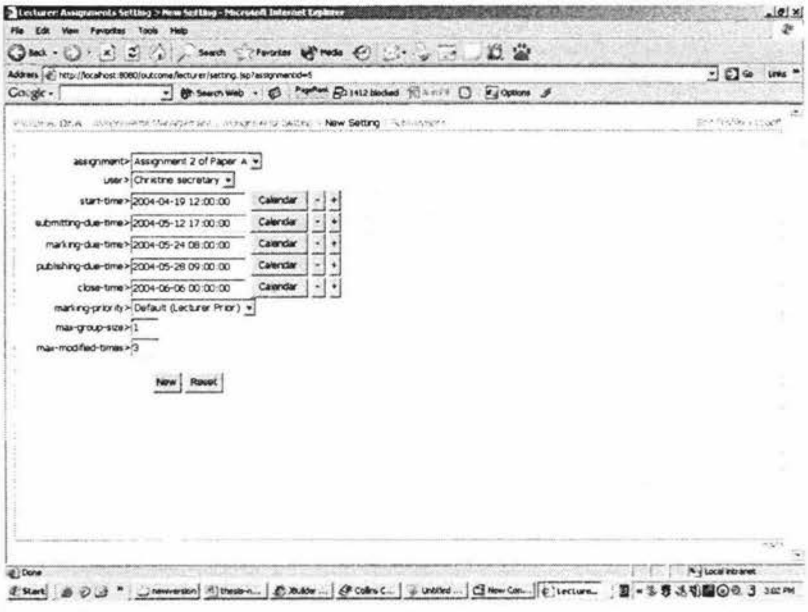

Figure A- 9: Interface to manage the configuration of an assignment

Manage settings of assignments: Manage all assignments that the instructor sets (Figure A-10). The management must include the general and specification time schedule of the assignment. The operations allowed in this interface are to modify existing settings of the assignment. Moreover, the linkage to the interface of creating a new setting for the assignment is set with the button labelled 'New Setting'.

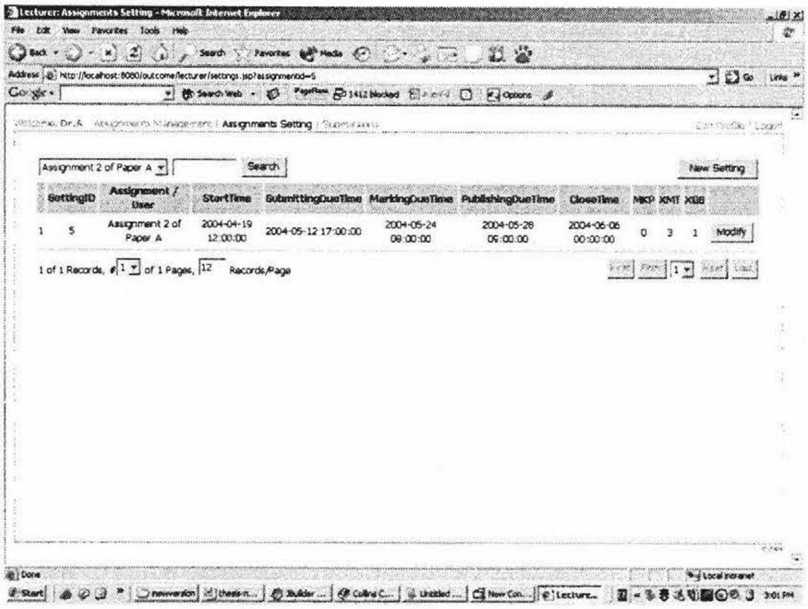

Figure A- 10: Interface to manage existing settings of assignments

Profile: view own personal information. The interface is shown in Figure A-16.

- **Student**

If a student has enrolled in a paper, assignments will be issued at a certain time. After that certain time, the student may have opportunities to view the requirements of the assignment and submit the assignment after he completes it, but before the due date. The next item that the student may view is the result of assignment after the secretary authorises it in the web.

View assignment: At the available login time, available assignments are shown in the page to notify the student when assignments are due. In the available time period, the items are listed in the table for the student until assignments are submitted (Figure A-11).

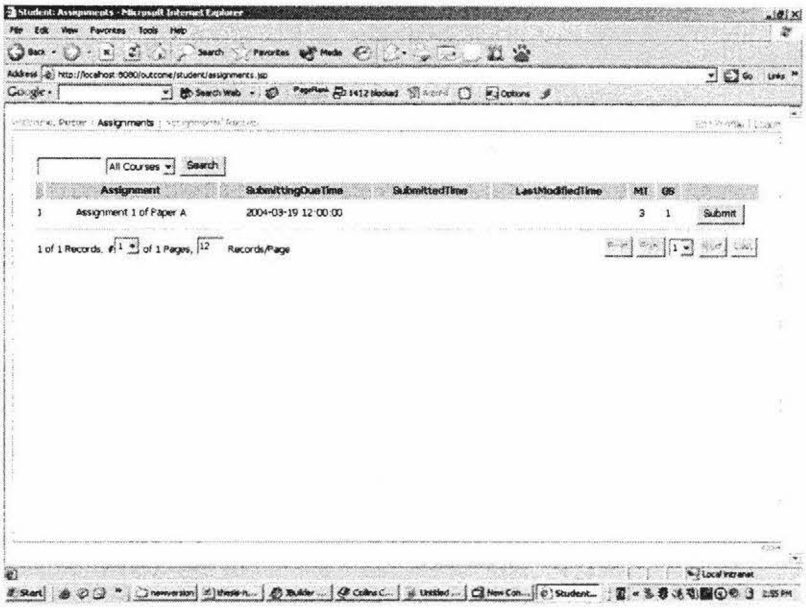

Figure A- 11: Interface to view assignments required to submit for the student

Select partner: Some assignments allow more than one student to work as a group. This interface is for students to pick up the partner(s).

Submitting assignments: Interface for students to submit their assignments before the due date. This interface is linked to button 'Submit' of Figure A-11. Upload completed assignment from 'Browse' button (Figure A-12).

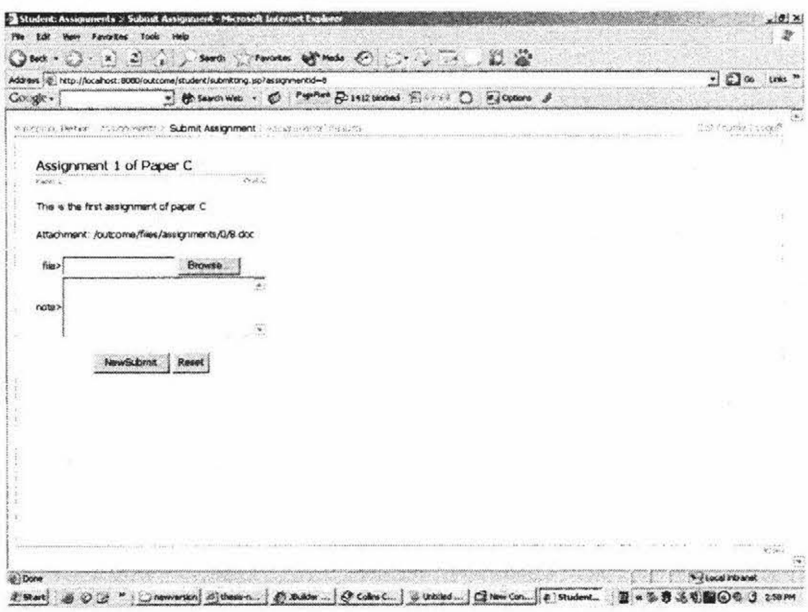

Figure A- 12: Interface to submit the assignment

View result: If the results of assignments are available, this interface allows students to view the final mark (Figure A-13).

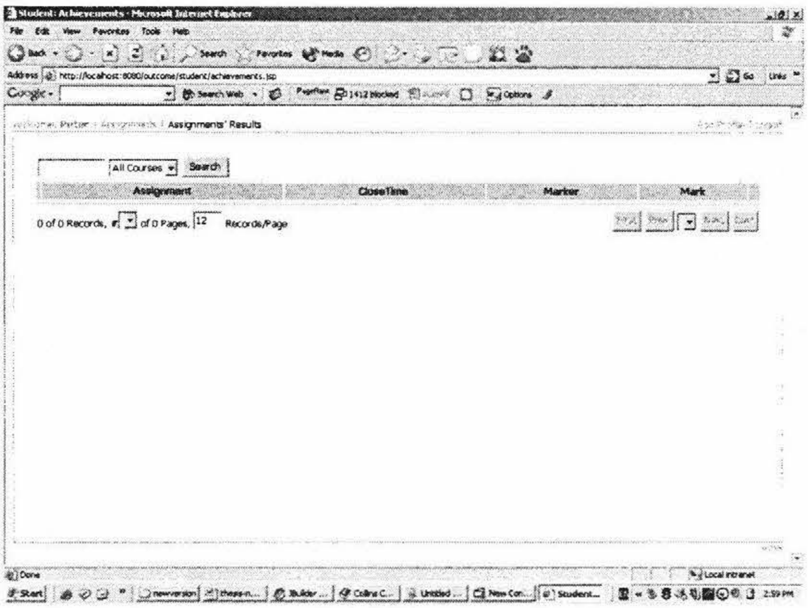

Figure A- 13: Interface to view final marks

Profile: view own personal information. The interface is shown in Figure A-16.

- **Marker**

The Marker alone can enter into the assignment management process in the marking period. During this period, the marker must mark every assignment before the due date of this period.

View submitted assignments: The interface (Figure A-14) for the marker to view the situation on the submitted assignment. Button 'Mark' links to another interface that gives the mark for one particular submitted assignment (Figure A-15).

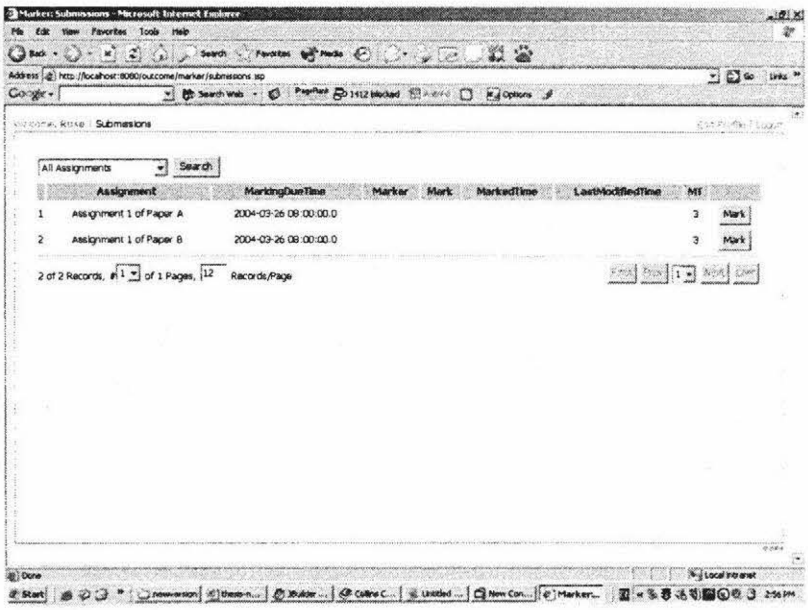

Figure A- 14: Interface to view states of submitted assignments

Marking: In the marking period, the marker marks the submitted assignments with mark and comments in this interface (Figure A-15).

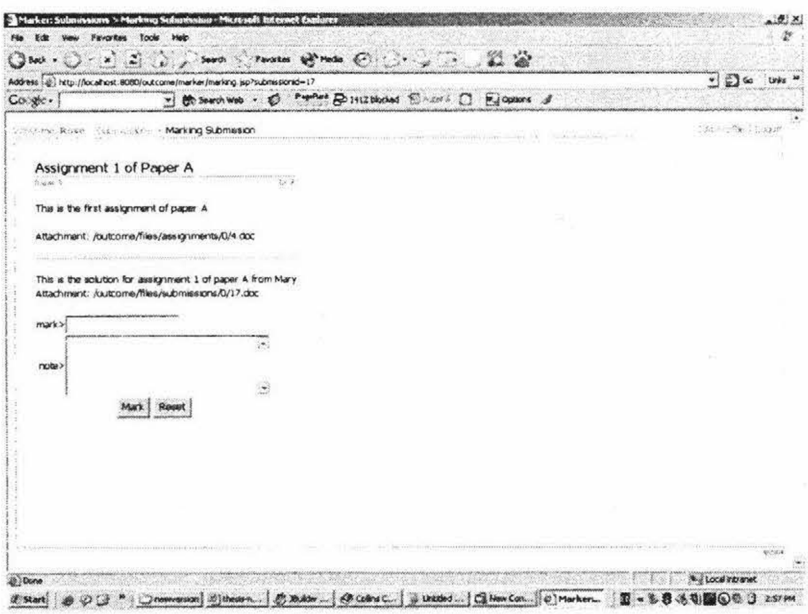

Figure A- 15: Interface for marking

Profile: View own personal information (Figure A-16). Every role has same interfaces on profile interface.

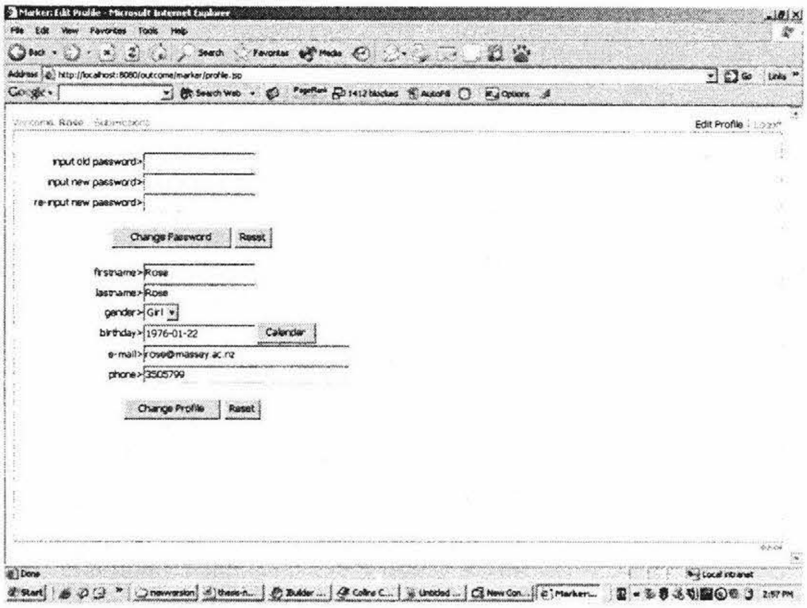

Figure A- 16: Interface to view and change the personal information

- Secretary

After the marking period is ended, the marked assignments are sent to the secretary node for the secretary to record marks. Therefore, the secretary has only one function interface to record results students get in their assignments. Another interface is similar to other roles to view own personal information. In the following graph (Figure A-17), all marked assignments have been published after the due date of publishing. Therefore, there is no assignment held in secretary's hand.

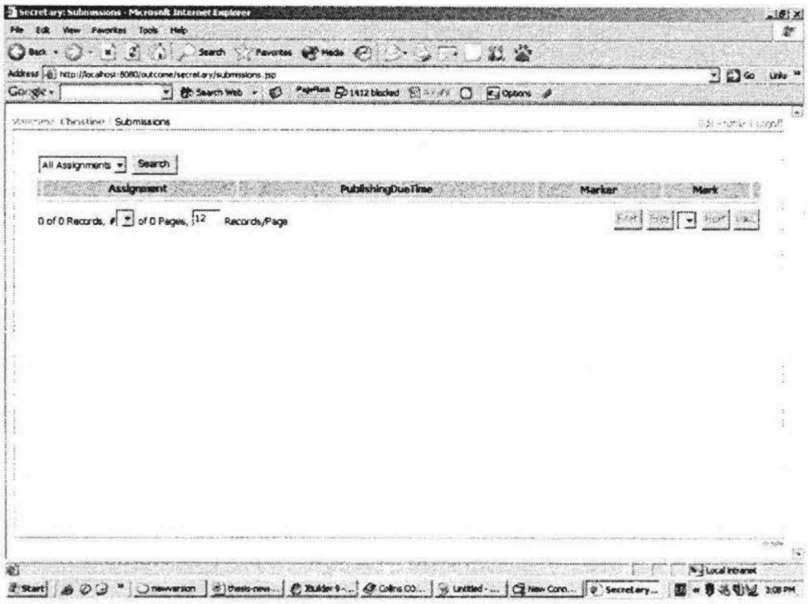

Figure A- 17: Interface to publish final marks

B. Publication

On Reasoning about Time in Educational Environments with Time Petri Nets

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Abstract

The concept of time plays a very important role in every part of our lives, not just education, but research on the timing dimension of an educational project has so far received very little attention. The major obstacle hindering course planners from reasoning about time is the lack of modelling tools with explicit time semantics. To address this problem, the paper presents a formal model, namely time Petri-net, as a tool of modelling temporal relationships among various educational activities. The technique provides a high-level visualization tool for the course planner to model both the system's structural and temporal behaviour in an integrated manner. By examining the model, the course planner can verify the course plan at design time; monitor the administration of the course at run time and take

necessary actions should unplanned events happen. We will report the application of the formalism in an assignment submission management system.

1. INTRODUCTION

The growth in the complexity of modern learning institutes creates numerous problems and challenges for course planners. Issues such as classrooms and instructors scheduling, synchronising internal and external course offering and streamlining different degree routes may lead to a suboptimal learning environment if they are not addressed properly. In the planning stage, one is confronted with increased capability of these systems due to the unique combination of hardware (the campus) and software (the instructors), which operate under a large number of constraints arising from the limited system resources. In view of the capital intensive and complex nature of modern educational institute, such as universities, the design and operation of these systems require modelling and analysis in order to select the optimal design alternative, and operational efficiency.

Among others, curricula and pedagogy are generally considered as the two fundamental building blocks in an educational enterprise. The former focuses on *what* to teach whereas the latter emphases *how* to teach but these two issues are often intertwined together in course design and in determining the roles of information and communication technology (ICT) can play in the course. Nonetheless, one factor we often overlook in course planning is time and the authors discovered very few papers on the '*when*' dimension which affect every aspect of our lives. Students need to get to the classroom before 9am. Assignment is due in two weeks. Complete the examination paper within three hours. An online learning website is closed after a certain date. Course A and B cannot be taken at the same time. Course C has to be completed and passed before taking course

D. The list can go on and all of these are related to the temporal relationships among educational activities which must be handled with great care. Without a comprehensive planning on the timing constraints and implications, a top-notch paper taught by a world-class professor may be of limited value to the students. It is not uncommon to see that some students are unable to take some papers they really like because of the clashing of timetable with other papers. One major obstacle which hinders curricula designers from spending more effort on timing is, we argue, the lack of modelling instrument which has built-in time semantics. We need a tool which not only provides a high-level descriptive components on modelling both the static and dynamic behaviour of a learning system but should also allows designers to reason about the temporal relationships among individual learning activities, i.e. how does the system and its components react with respect to the passage of time?. To this end, the authors argue that a modified version of Time Petri Net [4] serves such a purpose elegantly. Section 2 of this paper discusses the natures of a learning system and section 3 will formally define Time Petri Net. In section 4, we discuss a specific scenarios where the model has been used and section 5 concludes with the educational implications of the formalism.

2. CHARACTERISTICS OF COMPLEX LEARNING SYSTEMS

An important desiderata for a modelling technique to be useful in a learning enterprise is clear representation of the typical and critical characteristics of the system behaviour. The following list of characteristics, we argue, are essential in any large scale educational project which must not be overlooked.

- *Highly concurrent behaviour*

While the majority of learning activities can be analysed and handled individually and are generally sequential, it is not unusual for some of these activities to be carried out concurrently to make the whole process more efficient.

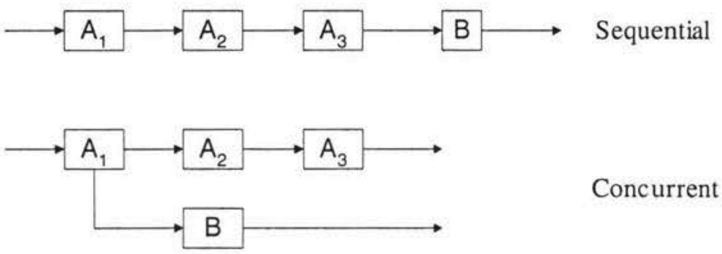


Fig. 1

For example (see Fig.1), when instruction on topic A is completed (A_1), students may have to work on an assignment relevant to the topic (A_2) and then do revision for an upcoming test (A_3). Meanwhile, instructions on topic B, a post-A topic, can be concurrently carried out with A_2 and A_3. It would be highly cost ineffective to delay B until every A-related activity is completed.

- *Asynchronous coordination of subsystems.*

Many concurrent activities often proceed at their own paces. At some points, however, some activities cannot proceed until some other activities have reached a certain stage and they need to be aligned in a coordinated fashion. For example, topic A and B can be independently carried out in parallel (Fig. 2) but both of them must be completed before C because they are the prerequisite of C:

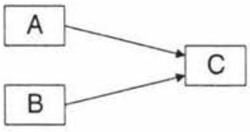


Fig. 2

- *Alternative behaviour of subsystems (decision making).*

Each of the many concurrent activities of the subsystems may have interaction paths and sometimes a subsystem to be followed is fully determined by the activities of other subsystems. For example, a student initially enrolled for a computer science degree might need to change course after a year because of poor performance in a foundational programming paper but performing well in written communications. So the system allows him to take an alternative route, say Journalism, to complete.

- *Quantitative representation behaviour.*

The technique should be able to represent quantitative information, particularly temporal information which encodes the timing constraints imposed on each activity. This behaviour will greatly affect not only the feasibility of completing a whole learning programme within available time resource but also a seamless synchronisation of related activities.

3. DESCRIPTION OF PETRI NETS

3.1 CLASSICAL PETRI NETS

Developed by Carl A. Petri in 1962, Petri Nets (PN) has been widely used in industry [5] for process modelling and control but not very much in education. As an abstraction tool, a PN can be described mathematically to reflect the dynamic behaviour of the system. This opens a possibility for the formal analysis of the model such as precedence relations amongst events, concurrent operations, appropriate synchronization, freedom from deadlock, repetitive activities and mutual exclusion of shared resources, to mention a few. There are different definitions and terminology of PN and this paper follows the notations defined in [2]. Formally, a PN is defined as a tuple (*P*, *T*, *I*,

O, M_o) where

- $P = \{ p_1, p_2, \ldots, p_n\}$ is a finite non-empty set of places,
- $N = (t_1, t_2, \ldots t_n)$ is a finite non-empty set of transitions, $P \cup T = \varnothing$ and $P \cap T = \varnothing$;
- $I : (P \times T) \rightarrow N$ is an input function that defines directed arcs from places to transitions, where N is a set of nonnegative integers;
- O: $(P \times T) \rightarrow N$ is an output function which defines directed arcs from transitions to places, and
- M_o: $P \rightarrow N$ is the initial marking function which defines the number of token in each place before the system start behaving.

A graphical representation is often used to illustrate Petri nets and Fig. 3 shows an example. A place is represented by a circle "○" whereas a bar "|" denotes a transition. Directed arcs from places to transition define the places to be the inputs to the transitions. Similarly, an output place is indicated by a directed arc from the transition to the place.

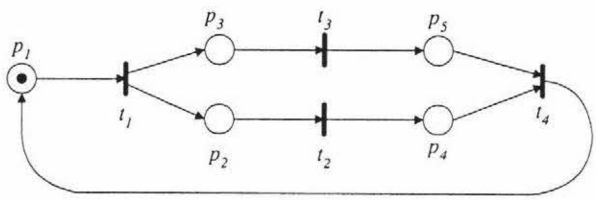


Fig. 3

The dynamic aspects of PN are denoted by markings which are assignments of *tokens* ("•" in the graphical notation) to the places. The execution of a PN is controlled by the number and distribution of tokens in the net. A transition is enabled if and only if each of its input places contains at least as many tokens as there exist arcs from that place to the transition. When a transition is enabled, it may fire. When a transition fires, all enabling tokens are removed from its input places, and a token is deposited in each of its output places. Transition firings continue as long as there exists at least one enabled transition.

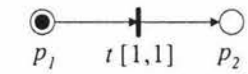
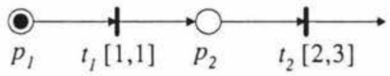
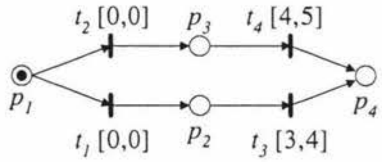
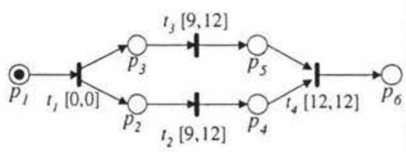
3.2 TIME PETRI NETS

The concept of time was not explicitly mentioned in the original Petri net model and so far there exist two approaches to introducing timing: Timed Petri net [3] and time Petri net [2]. In timed PN, a finite time delay is associated with each transition and the firing rule is modified to account for the time it takes to fire a transition. This model was mainly used for system performance evaluation. Time PN (TPN) are more general than timed PN as the latter can be modelled by the former but not the converse. TPN has been proved [4] very convenient for expressing all of the temporal relations between two events described in [1]. In a TPN, two non-negative integer rational numbers *a* and *b* (where $a \leq b$) representing two time values are associated with each transition. *a* is called the Earliest Firing Time (EFT) and *b* is called the Latest Firing Time (LFT).

- a ($0 \leq a$) is the minimal time that must elapse, starting from the time at which transition t is enabled, until this transition can fire, and
- b ($0 \leq b \leq \infty$), denoted the maximum time during which transition *t* can be enabled without being fired.

Times *a* and *b* for transition *t* are only relative to the moment at which transition *t* is enabled. Assuming *t* has been enabled at time τ and continuously enabled, *t* cannot fire before time $\tau + a$ and must be fire before or at time $\tau + b$ unless it is disabled before its firing by the firing of other transitions. Table 1 shows four example TPN models. Note that the time unit is arbitrary and is scenario specific.

Scenario	Notation	Time Petri Net

<table>
<tr><td>Tom attends a lecture for 1 hour before doing his experiment in the lab.</td><td>p_1: Attend lecture
p_2: Laboratory work</td><td>
</td></tr>
<tr><td>Tom spends one week on topic A and 2 to 3 weeks on B.</td><td>p_1: Studying topic A
p_2: Studying topic B</td><td>
</td></tr>
<tr><td>Tom can get a degree in at least 3 years but no more than 4 years or he can get an honours degree in at least 4 years but no more than 5 years.</td><td>p_1: Enrolment
p_2: General degree
p_3: Honours degree
p_4: Graduated</td><td>
</td></tr>
<tr><td>Tom takes paper C and D in Term 1 which are the pre-requisites of paper E in Term 2. Term 1 lasts for 12 weeks. To qualify for E, Tom needs to pass two tests on C and D respectively which can be taken at any time between week 9 and week 12.</td><td>p_1: Enrolment
p_2: Studying paper C
p_3: Studying paper D
p_4: Test on paper C
p_5: Test on paper D
p_6: Studying paper E</td><td>
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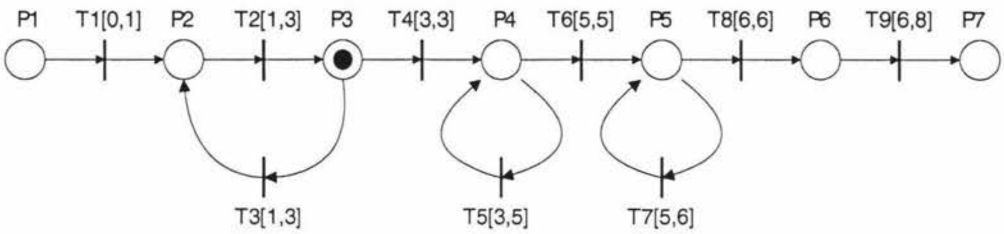
</table>

Table 1: Example Time Petri Net Models

4. ASSIGNMENT SUBMISSION MANAGEMENT SYSTEM

Since online learning became popular and more courses are being offered as web-based, course administers have been very keen on replacing the traditional way of paper-based assignment submission with electronic submission. Paper-based assignments submission has long been acknowledged as tedious, inconvenient and vulnerable to human errors. It was not uncommon to hear students complaining about their submissions being lost. After submitting their assignments, some students retrieved them back as they wanted to make some amendments to their original submissions and planned to hand in better versions before the due date. This request is reasonable but creates a potential logistic problem. The most tricky issue is keeping the whole assignment submission process on track with the timing requirement. Some assignments require a longer period to complete and some students were granted extension due to legitimate reasons such as sicknesses. The current generation of electronic submission supported by online learning systems such as WebCT or Blackboard only relieve the problem of piling up papers on the secretary's desk. Essentially these tools are merely an electronic repository which allows the students to upload their assignments to a secure storage place. Management features such as controlling the total number of submissions, retrieval and re-submit, and enabling/disabling some features with respect to the passage of time are not supported.

To provide a long term solution, we initiated a project which aims to provide an electronic assignment management system to oversee the entire life-cycle of assignments including tool for the markers to mark, comment and grade the e-assignment electronically. The first project objective is to provide temporal control on the workflow of a student submission. With respect to the current time, we would like to allow all parties to take allowable actions (such as submitting, retrieving or querying current status) without sacrificing the temporal integrity of the system. Shown in Figure 4 is a TPN for monitoring the submission process of a typical assignment. Each transition represents an event such as clicking a 'submission' button on screen whereas each place represents the current stage of a student's assignment. For example, P3 in Figure 4 is currently marked indicates the assignment has been submitted. When the assignment date is due, for example week 3 in the case of Figure 4, T4 will be fired accordingly and move the token forward to P4. Failing to submit (or re-submit in cases of retrieval) on or before week 3 will ending up P3 unmarked and consequently the system will not be able to further process the student's assignment. In other words, the student's assignment submission has been disqualified due to his lateness.



Place	Interpretation	Transition	Interpretation
P1	Instructor is setting the assignment	T1	Upload assignment specification at week 1
P2	Student is working on the assignment	T2	Upload assignment submission (week1 – 3)
P3	Assignment submitted	T3	Retrieve assignment back (week 1 – 3)
P4	Assignment is in the process of marking	T4	Assignment is due (week 3)
P5	Marking and grading in progress.	T5	Querying marking status (week 3 – 5)
P6	Marked assignment is ready for retrieval	T6	Marking completed (week 5)

P7	Marked assignment retrieved	T7	Querying grading status (week 5 – 6)
		T8	Grading completed (week 6)
	Fig. 4	T9	Graded assignment collected (week 6 -8)

5. CONCLUDING DISCUSSION

In this paper, we argue the significance of timing in the process of educational management and have presented a unified TPN model for representing temporal information among educational activities. Of particular important is the model incorporates metric, qualitative and repeated activities. We cast the framework in the context of course plan advising and assignment submission management and got some results in justifying the effort of paying attention to the timing dimension of an educational enterprise. Knowledge representation and reasoning for temporal information are of considerable fundamental interest in artificial intelligence but this issue has not fully addressed in the perspective of education. Our work reported here is by no means perfect but we hope that it could be the first stepping stone in stimulating more research in this direction. So far the TPN models in our work were manually crafted and therefore we are looking at developing a visual tool for course planner to do the modelling automatically. Verification on the models was also done manually and we are interested in exploiting the formal aspects of TPN to design a formal model verification tool.

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