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TIME TABLE GENERATION SYSTEM

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TIME TABLE GENERATION SYSTEM

By

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DECLARATION

I, the undersigned here, declare that this dissertation is entirely my own original work and that, to the best of my knowledge, it has not been presented or submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

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DEDICATION

This work is dedicated to my late brother, Chrispin Biemba Jr. who really wanted to pursue a career in Computer Science but time was insufficient for him on this earth. The pain my family and I went through was too much to handle and compelled me to do something that would make him look down on me and smile where he is now.

This is also for my mother, father, brothers and sisters who so unconditionally love me and have always believed in my abilities from inception. I will always reserve a special place for them in my heart. May God bless them all!

ABSTRACT

Timetabling is the allocation, subject to constraints, of given resources to objects in space-time domain to satisfy a set of desirable objectives as nearly as possible. Particularly, the university timetabling problem for classes or lectures can be viewed as fixing in time and space a sequence of meetings between instructors and students, while simultaneously satisfying a number of various essential conditions or constraints.

The timetabling problem concerns virtually every educational institution, be it high school, college, or university and thus requires to be solved effectively. This is usually done ‘by hand’, taking several days or weeks of iterative repair after feedback from lecturers complaining that the timetable is unfair to them in some way.

The basic challenge is to schedule lectures over a limited time period so as to avoid conflicts and to satisfy a number of side constraints. The problem, in its simplest form, is one of assigning lectures to periods and rooms such that either no conflicts or a minimum number of conflicts occur. By "conflicts", I mean when a lecture is scheduled to be lectured in two or more places at the same time or when two or more lectures are scheduled to be lectured in one place at the same time. Computer timetabling and administration systems do exist to ease this burden but each timetabling problem is as individual as the institution from which it originates.

In this project, a program that uses an optimal algorithm is to be developed that provides a solution to the lecture timetabling problem. The system, to be developed in Java, Microsoft Access and an XML Knowledge Base, is a replacement of the traditional manual way used to create lecture timetables. The system will be tested using input from various departments at the University of Zambia. Ideally, the system is expected to be generic and thus accommodate various sets of requirements and be able to work in other universities and colleges.

This system aims to schedule different lectures given a set of classrooms, lecture theatres, halls or labs in a specified time frame, say for instance, from 08:00 hours in the morning to 17:00 hours in the afternoon from Monday to Friday. Lunch break or any other break can be easily set, say from 13:00 to 14:00 hours according to a user's preference. It will take various inputs like details of students or student groups, courses, classrooms/halls and lecturers available. Depending upon these inputs, it will generate a possible time table which can be exported to html or pdf, making optimal utilization of all resources in a way that will best suit any of the constraints or university rules. The system will have room for extension/expansion and shall be able to accommodate as many requirements as possible.

The system is expected to produce significantly better timetables than those that were actually employed (produced by hand), and should always take a considerably short period of time to generate them. The application will provide an easy, time-saving way to generate lecture timetables within given constraints.

LIST OF ACRONYMS

CLP	Constraint Logic Programming.
DBMS	Database Management System.
DSATUR	Degree of Saturation.
GB	Giga Byte.
GHz	Giga Hertz.
GraphML	Graph Markup Language.
GUI	Graphical User Interface.
HCI	Human Computer Interaction.
HTML	HyperText Markup Language.
IDE	Integrated Development Environment.
IP	Integer Programming.
JDBC	Java Database Connectivity.
JDK	Java Development Kit.
JNA	Java Native Access.
JNI	Java Native Interface.
JVM	Java Virtual Machine.
KB	Knowledge Base.
LP	Linear Programming.
MathML	Mathematical Markup Language.
MB	Mega Byte.
Ms	Microsoft.
MusicXML	Music Extensible Markup Language.
NP	Non-deterministic Polynomial-time.
ODBC	Open Database Connectivity.
PDF	Portable Document Format.
P_M	Probability of Mutation.
P_R	Probability of Crossover.
PROLOG	Program Logistics/Programming in Logic.
RAM	Random Access Memory.
RAPS	Review of Automated Personnel System.
RIA	Rich Internet Application.
RSS	Rich Site Summary.
RUP	Rational Unified Process.
SGML	Standard Generalized Markup Language.
TTGS	Time Table Generation System.
UML	Unified Modeling Language.
UP	Unified Process.
USDP	Unified Software Development Process.
VDU	Visual Display Unit.
VGA	Video Graphics Array.
W3C	World Wide Web Consortium.
XHTML	Extensible HyperText Markup language.
XML	Extensible Markup Language.

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1 CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Time table scheduling has been in human requirements since they thought of managing time effectively. It is widely used in schools, colleges and other fields of teaching and working like crash courses, couching centers, training programs etc. In the early days, time table scheduling was done manually with a single person or some group involved in the task of scheduling it with their hands, which takes a lot of effort and time. Scheduling even the smallest constraints can take a lot of time and the case is even worse when the number of constraints or the amount of data to deal with increases. In such cases, a perfectly designed time table is reused for the whole generation without any changes, proving to be dull in such situations. Other cases that can cause problems is when the number of employers or workers is weak, resulting in rescheduling of the time table or they will need to fill on empty seats urgently.

Academic Institutions (Schools, Colleges, Universities, etc.) are the regular users of such time tables. They need to schedule their courses to meet the need of current duration and facilities that are available to them. However, their schedule should meet the requirement of new course addition and newly enrolled students to fresh batches. This may result in rescheduling the entire time table once again for its entire batches and to be scheduled in the shortest possible time before the batch courses start.

Timetable generation is an NP-hard problem .i.e. there is no specific algorithm which can be used for creating timetables. As constraints for timetables vary from institute to institute, a separate algorithm has to be defined for each one of them. To get the best performance out of our algorithms, we allot slots to subjects in such a way that either they get their final positions or remain unalloted which is allotted later after other subjects are allotted. Also the arrangement of teachers plays a major role in the methodology to be used as most of the subject constraints as well as teachers are validated while assigning teachers.

Basically, this problem depends on the lecture-room, lecturer-lecture relations. Solution of this problem is to schedule all lectures in a timetable by considering the rooms/labs/lecture theatres that will be used and the lectures that will be offered. This problem has some specific constraints. In literature they are known as “hard‟ and “soft‟ constraints. Hard constraints are important and they have to be satisfied in order to have a feasible solution. Soft constraints do not have to be satisfied but they make the solution more applicable.

The timetable problem can be categorized into various types (e.g., rail timetable, examination timetable, school timetable, course timetable etc.) by considering different specific constraints, processes and resources. The particular instance chosen for implementation in this project is the lecture timetable. The lecture timetable problem is to organize Subject, Teacher, Room, and Period in order to satisfy the set of constraints. The problem formulation is as follows:

- Set of subjects $S = \{s_1, s_2, \ldots, s_n\}$
- Set of teachers $T = \{t_1, t_2, \ldots, t_m\}$
- Set of rooms $R = \{r_1, r_2, \ldots, r_o\}$
- Set of periods $P = \{p_1, p_2, \ldots p_k\}$

A combination (a, b, c, d) in which a ϵ **S**, b ϵ **T**, c ϵ **R**, d ϵ **P**, can be stated as “teacher b teaches subject a in room c during period d”. The relation of subjects and teachers are fixed in all tuples. The lecture timetable problem can be interpreted as the scheduled rooms and periods in tuples and the solution of this problem is a set of tuples which satisfy all constraints.

Assigning lectures to time periods is equivalent to the graph colouring problem. This is one of the approaches or algorithms that shall be investigated. Another approach, a heuristic algorithm, will also be looked at in great detail.

1.2 MOTIVATION

The motivation to develop this Timetable Generation System came from the fact that Lecture Timetable Scheduling is still mostly done manually due to its inherent difficulties. Universities, colleges, high schools and other academic institutions are supposed to make time tables for each semester or term. Manually creating timetables is a very boring, tedious and a pain staking job. Hence the project’s idea to computerize this hectic process.

1.3 PROBLEM STATEMENT

The manual solution of the timetabling problem usually requires many person-days of work. In addition, the solution obtained may be unsatisfactory in some respect.

How can lectures be scheduled or assigned to periods and rooms over a limited time period such that either no conflicts or a minimum number of conflicts occur and to satisfy a number of side constraints?

1.4 AIM

The aim of this project is to develop a simple, easily understandable and efficient program using an effective and optimal algorithm, which automatically generates good quality time tables within seconds, while considering all constraints and violating none of the hard constraints.

1.5 OBJECTIVES

- To use the timetabling problem of various departments at the University of Zambia (UNZA) to investigate the process of solving a real world problem.

- To minimize or completely avoid conflicts or clashes, which occur when lectures involve common students, common lecturers or require the same classrooms/labs/halls.

- To research on various types of timetabling problem algorithms and determine the most efficient, effective, fastest and optimal algorithm.

1.6 SCOPE

The project is particularly focused on tackling the school lecture timetabling problem and will not consider exam scheduling. It will be tested in various departments at the University of Zambia and thus will consider varying requirements depending on the type of courses, lecturers, rooms and labs associated with a concerned department.

Efforts were put in place to ensure that the system developed is generic enough to accommodate the varying constraints that come along with each specific academic institution. With this system, there is no need to modify or redesign the algorithm for any particular institution. Therefore, this system is expected to work for most if not all departments at the University of Zambia and many other universities and colleges.

1.7 EXPECTED BENEFITS

The system to be developed is expected to generate conflict free timetables (while satisfying all the hard constraints concerned) in less time (just a matter of seconds), with less effort and with more efficiency. It will allow users to work on and view time tables in different platforms and view different information simultaneously. It will have a simple interface and hence will be so easy to use.

1.8 REQUIREMENTS

Included in this section are the minimum requirements a computer system should have in order to make this software system work. This software works fine in any operating system in which the developer tools or the user tools can be installed. So usually the requirement specification will be same as that of the operating system. So a standard specification will be provided.

1.8.1 HARDWARE REQUIREMENTS (SYSTEM CONFIGURATION)

- Processor: minimum 1 GHz x86/x64 processor, Pentium III or higher.
- RAM: 512 MB or more.
- 5 GB of hard-drive space.
- Monitor (Screen/VDU) to display output.
- Keyboard/Mouse for data input.

1.8.2 SOFTWARE REQUIREMENTS (DEVELOPER TOOLS)

- **Operating System**: Windows XP or Newer
- **Front end**: Java
- **Back end** : Microsoft Access, XML Knowledge Base, JDBC - To - ODBC Bridge.
- **IDE:** Eclipse IDE with Sun's/Oracle Java Development Kit (JDK).

1.8.3 USER TOOLS

- Sun's/Oracle Java Run Time Environment.
- Ms Access, ODBC connector.

1.8.4 TOOLS FOR DOCUMENTATION

- Microsoft Word 2013.
- Visual Paradigms For UML (Community Edition).
- Microsoft Project 2007.
- XML Notepad 2007.

1.8.5 METHODOLOGY

- Rational Unified Process (RUP)

1.8.6 ARCHITECTURE

Three-tier Client-Server Architecture.

1.9 CONSTRAINTS

The lecture timetabling problem consists of scheduling all lectures of a set of courses into a weekly timetable, where each lecture of a course must be assigned a period and a room in accordance with a given set of constraints. In this problem, constraints are considered in two types. One of them is called hard constraints. Hard constraints are those constraints that must be met by the timetable in order for the lecture timetable to be feasible. For example, there should not be any clashes, i.e. lecturers should not be required to be in two different rooms at the same time. Every acceptable timetable must satisfy these constraints. On the other hand, there are some conditions that are considered helpful but not essential in a good timetable. The more these conditions are satisfied, the better the timetable will be. They are called soft constraints and therefore they will have a weight in the objective function. Soft constraints are constraints that we would like the timetable to satisfy, but can be broken if necessary. For example, lectures must be well spaced over the timetable. It is highly unlikely that all the soft constraints will be met by a timetable as those are usually contradictory. All hard constraints must be strictly satisfied and the number of soft constraint violations should be minimized. A feasible timetable is one in which all lectures have been scheduled at a period and a room, so that the hard constraints are satisfied. The four hard constraints H1~H4 and four soft constraints S1~S4 are defined as follows:

- **H1. Lectures.** All lectures of a course must be scheduled to a distinct period and a room.
- **H2. Room Occupancy.** Any two lectures cannot be assigned in the same period and the same room.
- **H3. Conflicts.** Lectures of courses in the same curriculum or taught by the same teacher cannot be scheduled in the same period, i.e., any period cannot have an overlapping of students or teachers.
- **H4. Availability.** If the teacher of a course is not available at a given period, then no lectures of the course can be assigned to that period.
- **S1. Room Capacity.** For each lecture, the number of students attending the course should not be greater than the capacity of the room hosting the lecture.
- **S2. Room Stability.** All lectures of a course should be scheduled at the same room. If this is impossible, the number of occupied rooms should be as few as possible.

- **S3. Minimum Working Days.** The lectures of a course should be spread into the given minimum number of days.
- **S4. Curriculum Compactness.** For a given curriculum, a violation is counted if there is one lecture not adjacent to any other lecture belonging to the same curriculum within the same day, which means the agenda of students should be as compact as possible.

2 CHAPTER TWO: LITERATURE REVIEW

A large number of variants of the timetabling problem have been proposed in the literature, which differ from each other based on the type of institution (university or school) involved and the type of constraints. We classify the timetabling problems into three main classes:

- School timetabling: The weekly scheduling for all the classes of a school, avoiding teachers meeting two classes at the same time, and vice versa;
- Course timetabling: The weekly scheduling for all the lectures of a set of university courses, minimizing the overlaps of lectures of courses having common students;
- Examination timetabling: The scheduling for the exams of a set of university courses, avoiding overlap of exams of courses having common students, and spreading the exams for the students as much as possible.

Based on this classification, we develop a separate discussion for each of the three problems and we devote a section to each of them. However, such classification is not strict, in the sense that there are some specific problems that can fall between two classes, and cannot be easily placed within the above classification. For example, the timetabling of a specific school which gives large freedom to the student regarding the set of courses can be similar to a course timetabling problem (A. Schaerf, 1999).

In some cases, the timetabling problem consists of finding any timetable that satisfies all the constraints. In these cases, the problem is formulated as a search problem. In other cases, the problem is formulated as an optimization problem. That is, what is required is a timetable that satisfies all the hard constraints and minimizes (or maximizes) a given objective function which embeds the soft constraints. As shown later, in some approaches, the optimization formulation is just a means to apply optimization techniques to a search problem. In this case, what is minimized is the so-called distance to feasibility. Even when the problem is a true optimization problem, the distance to feasibility may be included in the objective function. This is generally done to facilitate the search for the best solution. In both cases (search and optimization), we define the underlying problem, which is the problem of deciding if there exists a solution, in the case of a search problem, and the problem of deciding if there exists a solution with a given value of the objective function, in the case of an optimization problem. When we mention the complexity of the problem, we refer to the complexity of the underlying decision problem (A. Schaerf, 1999).

As we will see later, the underlying problem is NP complete in almost all variants. Therefore, an exact solution is achievable only for small cases (e.g., less than 10 courses), whereas real instances usually may involve a few hundreds of courses. It follows that only heuristic methods (Pearl, 1984) are feasible, which have not guaranteed to reach the (optimal) solution.

Most of the early techniques (Schmidt and Strohlein, 1979) were based on a simulation of the human way of solving the problem. All such techniques, that we call direct heuristics, were based on a successive augmentation. That is, a partial timetable is extended, lecture by lecture, until all lectures have been scheduled. The underlying idea of all approaches is “schedule the most constrained lecture first", and they differ only on the meaning they give to the expression `most constrained'.

Later on, researchers started to apply general techniques to this problem. We therefore see algorithms based on integer programming, network flow, and others. In addition, the problem has also been tackled by reducing it to a well-studied problem: graph coloring.

More recently, some approaches based on search techniques used also in Artificial Intelligence appeared in the literature; among others, we have simulated annealing, tabu search, genetic algorithms, and constraint satisfaction.

In this research, the solution techniques are surveyed, putting the emphasis on the most recent approaches in general, and on Artificial Intelligence techniques in particular.

Notice that included in the list of techniques also are some items, e.g., logic programming, which are general tools for the development of the solution, rather than real solution techniques. In those cases, specified also is the technique implemented using the given tool.

Many authors believe that the timetabling problem cannot be completely automated. The reason is twofold: On the one hand, there are reasons that make one timetable better than another one that cannot easily be expressed in an automatic system. On the other hand, since the search space is usually huge, a human intervention may bias the search toward promising directions that the system by itself might be not able to find. For the above reasons, most of the systems allow the user at least to adjust manually the final output. Some systems however, require a much larger human intervention, so that we call them interactive (or semi-automatic) timetabling systems (A. Schaerf, 1999).

2.1 TIMETABLE SOLUTION GENERATION ALGORITHMS

2.1.1 GRAPH COLORING ALGORITHMS

The graph coloring problem is one of the classical NP-complete problems on graphs (Garey and Johnson, 1979, GT4, p. 191): Given an undirected graph G = (V, E), the problem consists of finding a partition of V into a minimum number of color classes (or simply colors) $c_1,\dots, c_k$, where no two vertices can be in the same color class if there is an edge between them. The simplest graph coloring heuristics is the following one (called SEQ in Johnson et al., 1991): Vertices $v_1,\dots, v_n$, and colors $c_1,\dots, c_k$ are ordered. Initially, vertex v_1 is assigned to color c_1. Thereafter, vertex v_i in turn is assigned to the "smallest" color that contains no vertices adjacent to v_i. Such method performs rather poorly in worst-case (see Johnson et al., 1991). Welsh and Powell (1967) propose a variant of the above method in which the vertices are ordered by degree (in decreasing order). That is, the vertices with highest degree are colored first. The underlying idea of this method is that the vertices with high degree are the most difficult to be colored. Other methods based on the same idea have also been proposed. For example, Leighton (1979) adds to the algorithm of Welsh and Powell the idea of recomputing the degree of the vertices at each step, eliminating the vertices already colored. A number of methods based on ordering the vertices by degree is discussed in (Carter, 1986).

A slightly different idea is used in the algorithm DSATUR by Brélaz (1979): At each step, DSATUR chooses the vertex to color next by picking the one that is adjacent to the largest number of distinctly colored vertices.

Hertz and de Werra (1987) propose the use of tabu search, whereas Chams et al. (1987) and Johnson et al. (1991) make use of simulated annealing. In particular, Johnson et al. (1991) propose three different simulated annealing implementations, and they compare such implementation with many other methods for a class of random graphs.

Coloring of weighted graphs may also be useful for timetabling applications. In fact, the weight of an edge may represent the degree of confliction between two lectures. The problem of coloring of weighted graphs and its application to timetabling are discussed in (Cangalovic and Schreuder, 1991; Kiaer and Yellen, 1992).

2.1.2 TABU SEARCH

Tabu search is a local search technique designed to solve optimization problems (Glover, 1989; Glover and Laguna, 1993). Local search techniques are based on the notion of neighbour: Given an optimization problem P, let S be the search space of P, and let f be the objective function to minimize (the case of maximization problems is analogous). A function N, which depends on the structure of the specific problem, assigns to each feasible solution s ϵ S its neighbourhood N(s) $\subseteq$ S. Each solution ś ϵ N(s) is called a neighbour of s.

A local search technique, starting from an initial solution s_{init}, which can be obtained with some other technique or generated at random, the algorithm enters in a loop that navigates the search space, stepping from one solution to one of its neighbours. The connectivity of the search space, w.r.t. the neighbour relation, is a necessary condition for the technique to work effectively.

In tabu search, the algorithm explores a subset V of the neighbourhood N(s) of the current solution s; the member of V that gives the minimum value of the objective function becomes the new current solution independently of the fact that its value is better or worse than the value in s.

In order to prevent cycling, there is a so-called tabu list, which is the list of solutions to which it is forbidden to move back. It is the list of the last k current solutions, where k is a parameter of the method, and it is run as a queue; that is, when a new solution is added, due to a move, the oldest one is discarded.
There is also a mechanism that overrides the tabu status of a solution: If a solution gives a large improvement of the objective function, then its tabu status is dropped and the solution is accepted as

new current one. More precisely, we define an aspiration function A that, for each value of the objective function, returns another value for it, which represents the value that the algorithm aspires to reach from the given value. Given a current solution s, the objective function f, and the best neighbour solution ś, if f (ś) < A (f(s)) then ś becomes the new current solution, even if ś is a tabu move.

The procedure stops either when the number of iterations reaches a given value or when the value of the objective function in the current solution reaches a given lower bound.

The main control parameters of the procedure are the length of the tabu list k, the aspiration function A and the cardinality of the set V of neighbour solutions tested at each iteration.

2.1.3 SIMULATED ANNEALING

Simulated annealing is a probabilistic local search technique for finding solutions to optimization problems. It has been proposed by Kirkpatrick et al. (1983) and extensively studied by van Laarhoven and Aarts, Aarts and Korst (1987, 1989). Its name comes from the fact that it simulates the cooling of a collection of hot vibrating atoms. The process starts by creating a random initial solution. The main procedure consists of a loop that generates at random at each iteration a neighbour of the current solution. Like for tabu search, the definition of neighbour depends on the specific structure of the problem.

Let's call Δ the difference in the objective function between the new solution and the current one and suppose to deal with a minimization problem. If $\Delta < 0$ the new solution is accepted and becomes the current one. If $\Delta \geq 0$ the new solution is accepted with probability $e^{-\Delta/T}$, where T is a parameter, called the temperature.

The temperature T is initially set to an appropriately high value T_0. After a fixed number of iterations, the temperature is decreased by the cooling rate a, such that $T_n = a \times T_{n-1}$, where $0 \leq a \leq 1$.

The procedure stops when the temperature reaches a value very closed to 0 and no solution that increases the objective function is accepted anymore, i.e. the system is frozen. The solution obtained when the system is frozen is obviously a local minimum.

The control knobs of the procedure are the cooling rate a, the number of iterations at each temperature, and the starting temperature T_0.

A special architecture (both hardware and software) for performing fast programs based on simulated annealing is described in (Abramson, 1992).

2.1.4 GENETIC ALGORITHMS

Genetic algorithms are a solution technique for optimization problems (Davis, 1991; Michalewicz, 1994). Differently from tabu search and simulated annealing, they are not based on local search.

A genetic algorithm starts with a set of solutions randomly chosen $\{s^0{}_1,\ldots, s^0{}_n\}$, which is called the population at time 0.

The core procedure is a loop that creates the population $\{s_1^{t+1},\ldots, s_n^{t+1}\}$ at time t+1 starting from the population at time t. To this aim, the value of the objective function is computed for each solution s_i^t. Based on a weighted randomization, n elements of the population at time t are selected. Obviously, some solution may be selected more than once. The randomization is biased by the value of the objective function so as to assign a higher probability to be selected to the solutions that result in a better value of the objective function. In this way the best solutions get more copies, and the worse ones probably die off.

At this point each solution is selected for recombination with a given probability (P_R). The recombination is done by the crossover operator. That is, two selected solutions are mixed by swapping corresponding segments of their representations. One of the most common ways to do the crossover is by selecting a fixed number of positions in which the swapping takes place (fixed-point crossover).

For example, if two solutions are represented by the strings abcdef and uvwxyz and we choose two crossover points after the second and the fifth character, then the new solutions would be abwxyf and uvcdez.

In addition, mutation arbitrarily alters randomly some part of some solutions randomly selected, based on a given probability value (P_M).

The method terminates either when it generates a fixed number of populations, or when the best solution reaches a certain value of the objective function, or when the algorithm does not make any progress for a certain number of iterations.

The main control parameters of the method are the population size n, the probability of crossover P_R, and the probability of mutation P_M.

2.1.5 TILING ALGORITHMS

A tiling algorithm collects the classes to be scheduled into clusters known as tiles. Each of these tiles hold classes which can run simultaneously; these tiles are then assigned times using a separate search algorithm of some kind. This approach was used with some degree of success (Kingston, 2005), but only in situations such as that in a high school where several classes of students sit the same subject simultaneously. These groups of classes are clustered into the tiles for scheduling – this does not tend to happen in a university timetable where cohort groups sit far more varied courses.

2.1.6 AGENTS

Multi Agent Systems, such as that described by Kaplansky (Kaplansky, 2004), employ several software agents communicating with each other working towards different goals. Each agent can be set up to view the timetable from a different perspective and amends it until a stable timetable satisfying all agents is found.

2.1.7 LINEAR/INTEGER PROGRAMMING

The Linear and Integer Programming techniques, the first applied to timetabling, were developed from the broader area of mathematical programming. Mathematical programming is applicable to the class of problems characterised by a large number of variables that intersect within boundaries imposed by a set of restraining conditions (Thompson, 1967). The word "programming" means planning in this context and is related to the type of application (Feiring, 1986). This scheme of programming was developed during World War II in connection with finding optimal strategies for conducting the war effort and used afterwards in the fields of industry, commerce and government services (Bunday, 1984).

Linear Programming (LP) is that subset of mathematical programming concerned with the efficient allocation of limited resources to known activities with the objective of meeting a desired goal such as maximising profits or minimising costs (Feiring, 1986). Integer Programming (IP) deals with the solution of mathematical programming problems in which some or all of the variables can assume non-negative integer values only. Although LP methods are very valuable in formulating and solving problems related to the efficient use of limited resources they are not restricted to only these problems (Bunday, 1984). Linear programming problems are generally acknowledged to be efficiently solved by just three methods, namely the graphical method, the simplex method, and the transportation method (Palmers and Innes, 1976; Makower and Williamson, 1985).

The construction of a linear programming model involves three successive problem-solving steps. The first step identifies the unknown or independent decision variables. Step two requires the identification of the constraints and the formulation of these constraints as linear equations. Finally, in step three, the objective function is identified and written as a linear function of the decision variables.

2.1.8 DIRECT HEURISTICS

Direct heuristics usually fill up the complete timetable with one lecture (or one group of lectures) at a time as far as no-conflicts arise. At that point they start making some swapping so as to accommodate other lectures.

A typical example of this method is the system SCHOLA described in (Junginger, 1986). The system is based on the following three strategies:

A. Assign the most urgent lecture to the most favourable period for that lecture.
B. When a period can be used only for one lecture, assign the period to that lecture.
C. Move an already-scheduled lecture to a free period so as to leave the period for the lecture that we are currently trying to schedule.

A lecture is "urgent" when it is tightly constrained; that is, when the teacher (and the class) has little availability and many lectures to give. A period is "favourable" when few other lectures can be scheduled at that period based on the availability of the other teachers and classes.

The system SCHOLA schedules the lectures alternating Strategies A and B as much as possible. When no more lecture can be scheduled in this way, it starts using Strategy C.

Strategy A is the core of the system, and it is employed almost in all systems, with different way of defining urgency and favourableness. The use of Strategy B might prevent Strategy A to enter in dead-ends. Strategy C provides a limited form of backtracking to recover from the "mistakes" of Strategy A.

The algorithm in (Papoulias, 1980) can also be considered a direct heuristics. It stresses on the requirement that lectures must be spread across days. The favourableness of a period for a lecture is therefore based also on the fact that another lecture of the same teacher to the same class has not been already assigned to a consecutive day.

2.1.9 NETWORK FLOW TECHNIQUES

Ostermann and de Werra (1983) reduce the timetabling problem to a sequence of network flow problems. The general network model can be formulated as follows:

$$\begin{aligned} min \quad & \sum_{j=1}^{m} c_j x_j, \\ s.t. \quad & Ax = b, \\ & l \leq x \leq u \end{aligned}$$

where A_{nxm} is the vertex edge incidence matrix, b_{nx1} is the vector of supplies, and u_{1xm}; l_{1xm} are vectors of capacities and lower bounds.

Ostermann and de Werra create a network for each period so that the flow in the network identifies the lectures given in that period. De Werra (1985) proposes a similar method creating a network for each class. We now briefly describe the latter one.

For a given class $c_{i,}$ do the following steps: (i) introduce a vertex for each period k and each teacher t_j; (ii) connect k with t_j if teacher t_j is available at period k and he/she has not been assigned to another class for period k in a previous network; (iii) introduce a source vertex s with edges (s, k) for all periods k and a sink vertex t with edges (t_j ; t) for all teachers t_j; (iv) set both the capacities u(t_j ; t) and the lower bounds l(t_j; t) to r_{ij} ; (v) for all other edges u = 1 and l = 0.
The solution of the network, which is always integer due to the total unimodularity property (Papadimitriou and Steiglitz, 1982, pp. 316-318), gives a schedule for all the lectures for the given class.

The construction of the network is repeated for all classes and eventually, if a solution is found for all networks, it leads to a complete timetable. Obviously, since there is no backtracking on the classes already scheduled, we have no guarantee that the solution is found whenever it exists.

A network flow approach has been recently used by Ikeda et al. (1995) for the implementation of the SECTA system.

In the case of university course timetabling, we look at the network employed by Dinkel et al. It contains three levels, plus a source and a sink vertex. The first level is the Department Level which includes a vertex for each department, such that all of these vertices are connected to the source. The second level is the Faculty/Staff Level which includes a vertex for each possible combination of teacher and course taught by the teacher; these vertices are connected to the vertices representing the departments to which the teachers belong. The third level is the Room Size/Time Level, which contains a vertex for each combination of room and time. Each vertex of this level is connected to a vertex of the second level only if the size of the room represented by the vertex is compatible with the number of students of the course represented by the other vertex. An edge between levels 2 and 3 represents a possible lecture.

The capacities and the lower bounds of edges representing the lectures are 0 and 1 respectively, and due to unimodularity, this ensures that the optimal solution to the problem will possess all integer values.

The coefficients of the objective function are assigned based on availabilities of teachers and rooms, and preferences of the teachers.

The network model can be solved in polynomial time; however it does not prevent the solution from assigning a single teacher to multiple lectures at the same time. The procedure therefore solves the problem and, if it finds a feasible solution, the process is over, otherwise a human intervention changes some of the weights manually so as to get rid of the reason of infeasibility. The procedure is executed several times until a feasible solution is obtained.

2.1.10 LOGIC PROGRAMMING APPROACH

Kang and White (1992) propose the logic programming approach to the school timetable problem. In particular, they use PROLOG as the implementation language for their timetabling program. The main advantage of this approach is the ability to express in a declarative way, the constraints involved in the problem.

The full backtracking capability of the PROLOG machine is overridden by a heuristics that allows only for a limited attempt to reschedule assignments that create conflicts. In particular, when a lecture becomes unschedulable, the procedure finds an "equivalent" lecture already scheduled and reassigns it to a different period. If no equivalent lecture can be moved to a different period, leaving a feasible period for the currently-processed lecture, it is put into a list of lectures which will be manually scheduled later.

2.1.11 CONSTRAINT-BASED APPROACH

The work in (Yoshikawa et al., 1996) proposes the use of a general-purpose Constraint Relaxation Problem solver, called COASTOOL. In a constraint relaxation problem, a given penalty is assigned to each constraint and the objective is to find an assignment of the problem variables that minimizes the total penalty.

The constraint language allows the user to express several types of constraints. For example, it is possible to express the unavailabilities of a given teacher. The following constraint states that the set lectures of the teacher Smith, identified by the set SmithLessons, cannot take place during the set of period representing the unavailabilities of Smith, identified by the set SmithAbsence.

```
(define-constraint PartTimerSmith
:object ((:set lesson SmithLessons))
:variables ((v lesson))
:condition (not (is-a v SmithAbsence))
:penalty 10)
```

The solution method combines a greedy algorithm for finding an initial solution and a hill-climbing procedure for the optimization phase (Minton et al., 1992). The employment of a smart greedy algorithm, called Really-Fully-Lookahead algorithm, for the initialization phase, and a strongly biased optimization algorithm, for the optimization phase, allows the method to find a high-quality solution in a reasonable amount of time.

2.1.12 COMBINATION OF METHODS

The algorithm in (Cooper and Kingston, 1993) combines several heuristics. As a core strategy, it uses a form of bipartite graph matching, that they call meta-matching.

The algorithm identifies groups of lectures that must be scheduled all at different times, which are called meeting-sets. Thereafter, it iteratively performs a matching between lectures belonging to a meeting set, on one side, and the so-called prototimes on the other; the prototimes are variable time slots that are later assigned to actual periods in a successive phase.

The algorithm is improved by choosing among the possible assignments those that assign as many lectures as possible to the prototimes already used for previously scheduled meeting-sets. This enhancement helps in finding a feasible timetable in presence of many large meeting-sets.

As already mentioned, the cited paper solves an extension of the basic problem which requires to deal with different interchangeable resources, such as teachers and rooms. Actual resources are assigned to lectures by a specific procedure. Such procedure, depending on the number of resources involved may use a brute-force algorithm or a covering technique called beam search.

2.1.13 RULE-BASED APPROACH

A solution technique based on expert systems is given in (Meisels et al., 1991; Solotorevsky et al., 1994).

Solotorevsky et al. define a rule-based language, called RAPS, for specifying general resource allocation problems, and they use it, among the others, for a course timetabling problem. In particular, they consider lectures as activities and periods as resources to be assigned to the activities.

RAPS has five types of rules, namely assignment rules, constraint rules, local change rules, context rules, and priority rules.

Assignment rules assign lectures to periods, one at a time, and therefore, they are the core of the system. These rules, like all the others, are supplied by the user, and thus the heuristics used is not predefined but is chosen by the user.

Constraint rules specify the constraints that the solution must satisfy. They are checked each time a new lecture is assigned to a period (i.e. a new activity is assigned to a resource). Constraint rules are split into positive and negative ones, that is, constraints that must be satisfied and constraints that must fail. Constraint rules allow to identify conflicts as soon as they arise.

Local change rules specify the action to perform when there is a lecture that the assignment rules are not able to tackle. The purpose of local change rule is to undo a previous assignment in order to create the opportunity to assign the current one.

Context rules select the active context. In fact, the system allows for multiple contexts: In different contexts the various lectures and periods may have different priority. The priority of the objects determines which object, among those of a given type, is processed first.

Priority rules determine the priorities of the lectures and the periods, in each context. The priorities are calculated each time a context is entered.

The system may work in two possible modes: greedy and non-greedy. In the greedy mode, when the assignment rules fail to make an assignment, the system selects a different lecture. Conversely, in the non-greedy mode, when a fail occurs, the control is passed to the local change rules.

Dhar and Ranganathan (1990) propose the use of an expert system, called PROTEUS, for the allocation of teachers to courses, and compare it to integer programming techniques.

2.1.14 CONSTRAINT LOGIC PROGRAMMING APPROACH

A constraint logic programming (CLP) system (Jaffar and Lassez, 1987) is a tool for modeling a specific search problem, which provides the ability to declare variables and their domains, and to place constraints.

In order to search for a solution, a CLP system generates values for the variables, propagating values through the constraints in order to prune parts of the solution space where inconsistencies are discovered. The basic method is therefore, a backtrack search where the constraints allow the system to look ahead to the consequences of decisions and spot failure earlier.

For dealing with optimization problems, the CLP systems provide a solution technique based on a form of depth first branch-and-bound search.

Azevedo and Barahona (1994) deal with the timetabling problem using a CLP language called DOMLOG. DOMLOG extends CHIP (Van Hentenryck, 1991), a popular CLP language, with features such as user-defined heuristics and a flexible lookahead constraint solving.

In particular, DOMLOG allows for the possibility to specify a finite domain for the variables. In addition, the user can specify the heuristics for the selection of the value of a domain to assign first to a given variable.

Several other authors recently employed constraint logic programming for course timetabling with a good success. Frangouli et al. (1995) and Gueret et al. (1995) solve their course timetabling problem relying on the finite domain libraries of the logic programming language ECL^{i}PS^{e} (ECRC, 1995) and CHIP, respectively. Henz and WÜrtz (1995) rely on the Oz system (Smolka, 1995), which is a multi-paradigm concurrent constraint language.

3 CHAPTER THREE: METHODOLOGY

3.1 THE RATIONAL UNIFIED PROCESS (RUP)

The Rational Unified Process (RUP) methodology for software development was used in the development of this system. The Unified Process has emerged as a popular and effective software development process. In particular, the Rational Unified Process, as modified at Rational Software, is widely practiced and adopted by industry. RUP is a complete software-development process framework, developed by Rational Corporation. It's an iterative development methodology based upon six industry-proven best practices. Processes derived from RUP vary from being lightweight i.e. addressing the needs of small projects, to more comprehensive processes addressing the needs of large, possibly distributed project teams.

The critical idea in the Rational Unified Process is *Iterative Development*. Iterative Development is successively enlarging and refining a system through multiple iterations, using feedback and adaptation. Each iteration will include requirements, analysis, design, and implementation. Iterations are *timeboxed*.
RUP adopts the Unified Software Development Process (USDP) Key ideas of being use-case driven; architecture-centric; and Iterative and incremental.

Software Engineers now agree that an iterative model is required to facilitate changes to earlier decision-making documents. This model allows each phase to be visited any number of times, so that corrections and improvements can be made. USDP aims to deliver working, free-standing, useful 'chunks' of software, one at a time, e.g., each use case may represent one increment of delivered software.

3.1.1 ITERATIONS

Each phase has iterations, each having the purpose of producing a demonstrable piece of software. The duration of iteration may vary from two weeks or less up to six months.

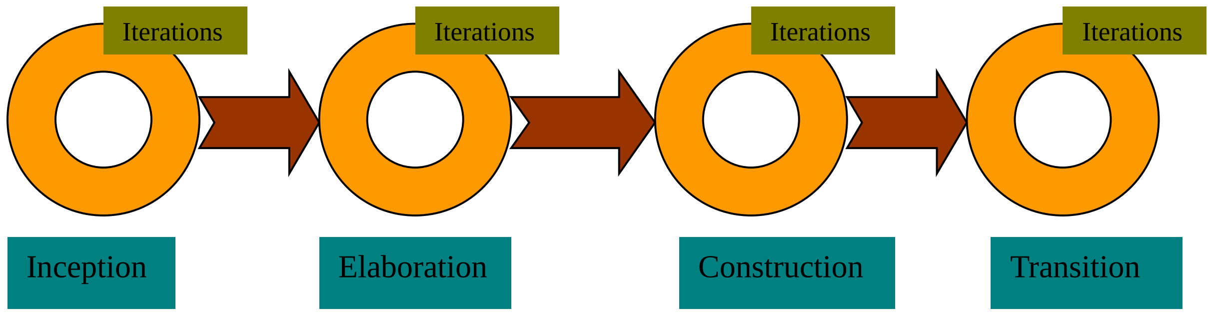


Figure 1: The iterations and the phases.

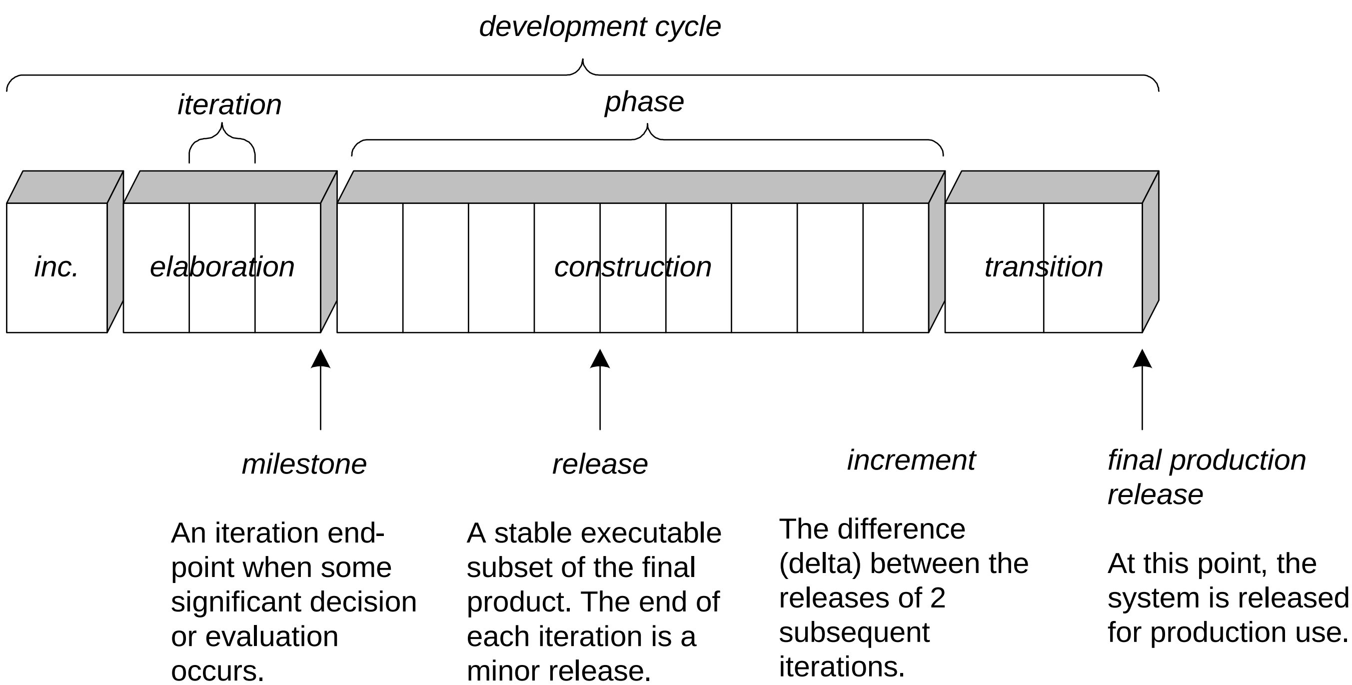


Figure 2: Iterations in RUP.

3.1.2 INCREMENTAL

The idea behind an incremental model is that once something is produced by a process, it can be used as a basis for the next process. For example, when a part of the software system has been designed, the developers can begin the implementation for that software unit. This is true in spite of the fact that the rest of the software system has not yet been designed.

3.1.3 WHY RUP?

The philosophy of process-oriented methods is that the requirements of a project are completely frozen before the design and development process commences. As this approach is not always feasible, there is also a need for flexible, adaptable and agile methods, which allow the developers to make late changes in specifications.

The Unified Process reduces risk since it allows you to develop the most critical and risky aspects of the project before addressing the less risky. If the risky aspects of the project fail, the project was only a small failure since it failed so early. Often you will also develop a prototype or skeleton of the user interface. User interface changes can be caught early, and modified quickly before it affects very much of the rest of the system.

The UP was created to be an *agile* software development methodology. In other words, if requirements, expectations, technologies, personnel, etc. change, the project should be able to adapt with minimal waste of effort.

3.1.4 UP BEST PRACTICES

- Get high risk and high value first.
- Constant user feedback and engagement.
- Early cohesive core architecture.
- Test early, often, and realistically.

- Apply use cases where needed.
- Do some visual modeling with UML.
- Manage requirements.
- Manage change requests and configuration.

3.1.5 ADVANTAGES OF RUP

- The RUP puts an emphasis on addressing very early high risks areas.
- It does not assume a fixed set of firm requirements at the inception of the project, but allows to refine the requirements as the project evolves.
- It does not put either a strong focus on documents.
- The main focus remains the software product itself, and its quality.

4 CHAPTER FOUR: SYSTEM ANALYSIS

4.1 JAVA

Java is widely adopted and there is a vast range of both commercial and open source libraries available for the platform, making it possible to include support for virtually any system, including native applications via JNI or JNA. When it comes to RIAs, Java's main weakness is its multimedia support. Java 6 Update N improves some features that have hindered the use of Java for RIAs including startup time and download size, and Sun Inc. has even included new multimedia support in this release.

4.1.1 DETAILS ABOUT JAVA

Java is a programming language originally developed by Sun Microsystems and released in 1995 as a core component of Sun's Java platform. The language derives much of its syntax from C and C++ but has a simpler object model and fewer low-level facilities. Java applications are typically compiled to byte code which can run on any Java Virtual Machine (JVM) regardless of computer architecture.

4.1.2 PLATFORM INDEPENDENCE

One characteristic, platform independence, means that programs written in the Java language must run similarly on any supported hardware/operating system platform. One should be able to write a program once, compile it once, and run it anywhere.

4.2 XML

The Extensible Markup Language (XML) is a general-purpose specification for creating custom markup languages. It is classified as an extensible language because it allows its users to define their own elements. Its primary purpose is to facilitate the sharing of structured data across different information systems, particularly via the Internet, and it is used both to encode documents and to serialize data.

It started as a simplified subset of the Standard Generalized Markup Language (SGML), and is designed to be relatively human-legible. By adding semantic constraints, application languages can be implemented in XML. These include XHTML, RSS, MathML, GraphML, and Scalable Vector Graphics, MusicXML, and thousands of others. Moreover, XML is sometimes used as the specification language for such application languages.

XML is recommended by the World Wide Web Consortium. It is a fee-free open standard. The W3C recommendation specifies both the lexical grammar and the requirements for parsing.

4.2.1 ADVANTAGES OF XML

- It is text-based.
- It can represent common computer science data structures: records, lists and trees.
- The strict syntax and parsing requirements make the necessary parsing algorithms extremely simple, efficient, and consistent.
- XML is heavily used as a format for document storage and processing, both online and offline.
- The hierarchical structure is suitable for most (but not all) types of documents.
- It is platform-independent, thus relatively immune to changes in technology.

4.3 DATA STRUCTURE & FLOW DIAGRAM

XML File contains the following sections as shown in the figure 3 below:

1. Teacher List
2. Subject List
3. Room List
4. Timeslot List
5. Students List
6. Days Options
7. Constraints, Rules

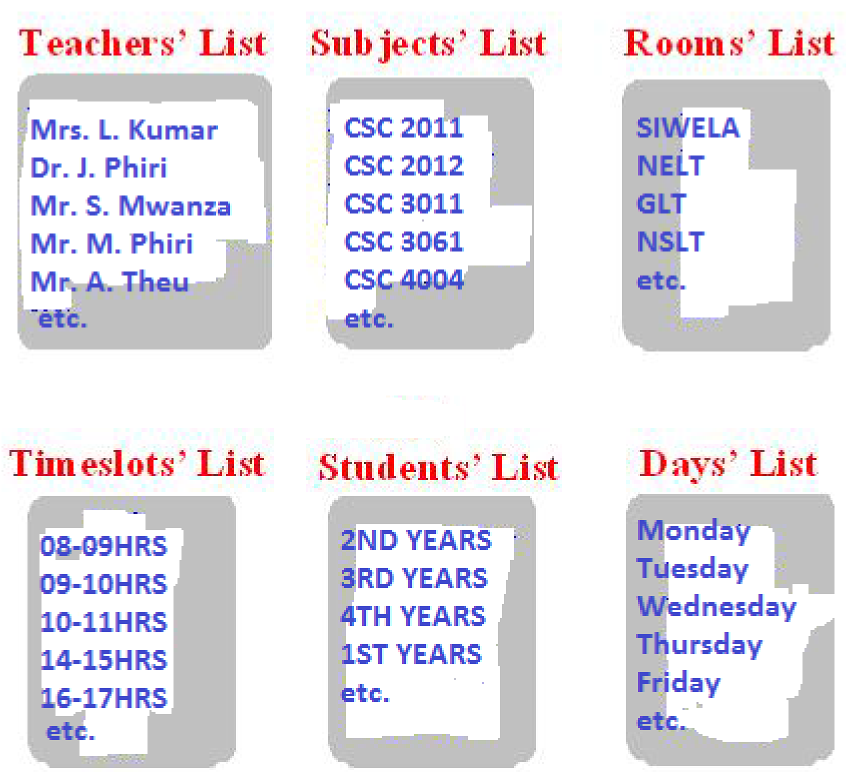


Figure 3: Data Structure.

4.4 FLOW OF DATA WITHIN THE PROJECT

Figure 4 below shows the flow of data from the user to the timetable generator algorithm and back to the user.

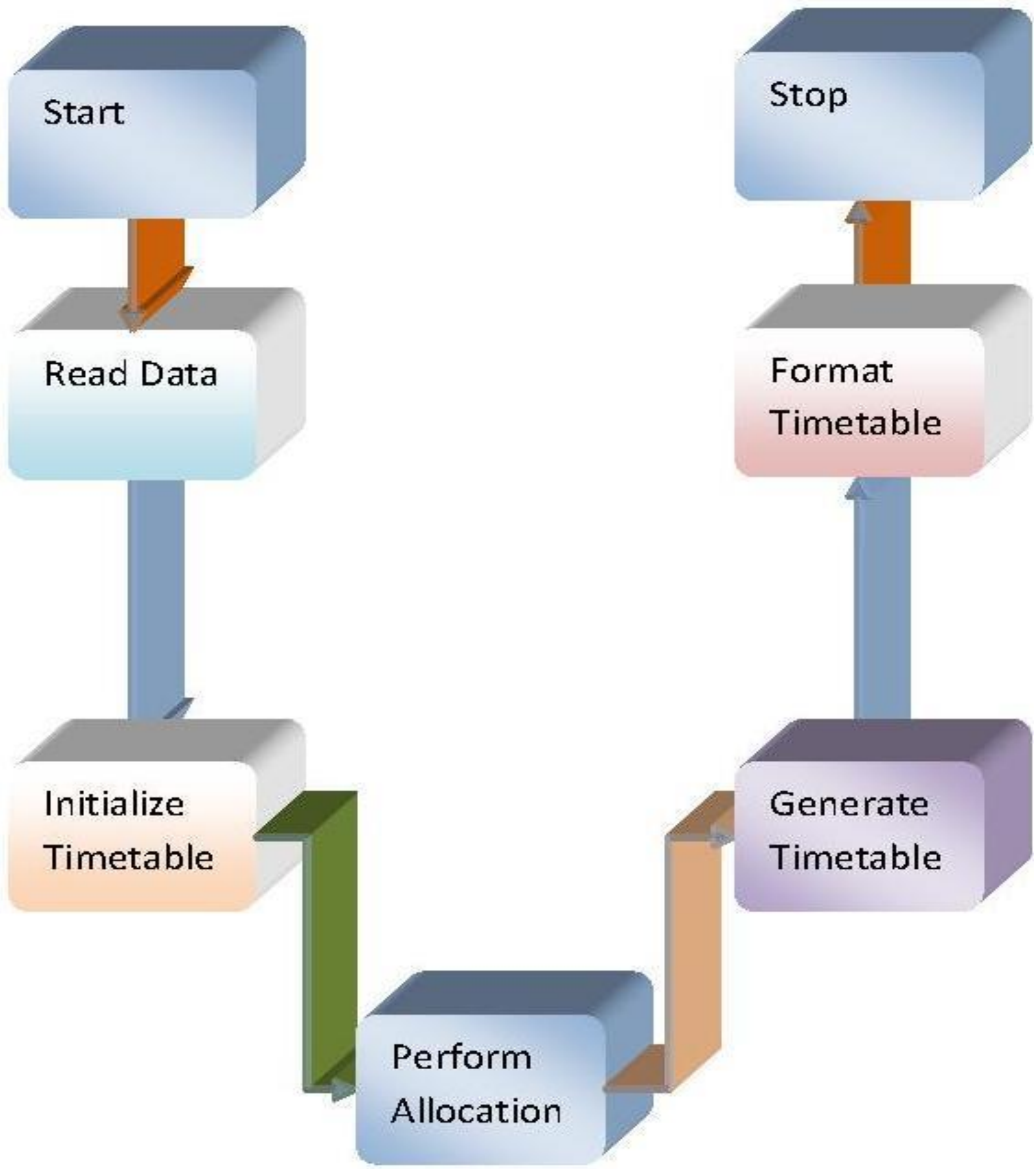


Figure 4: Flow of Data within project.

4.5 FUNCTIONAL REQUIREMENTS

4.5.1 USE CASE DIAGRAM

Figure 5 below shows the use case diagram for the timetable generation system.

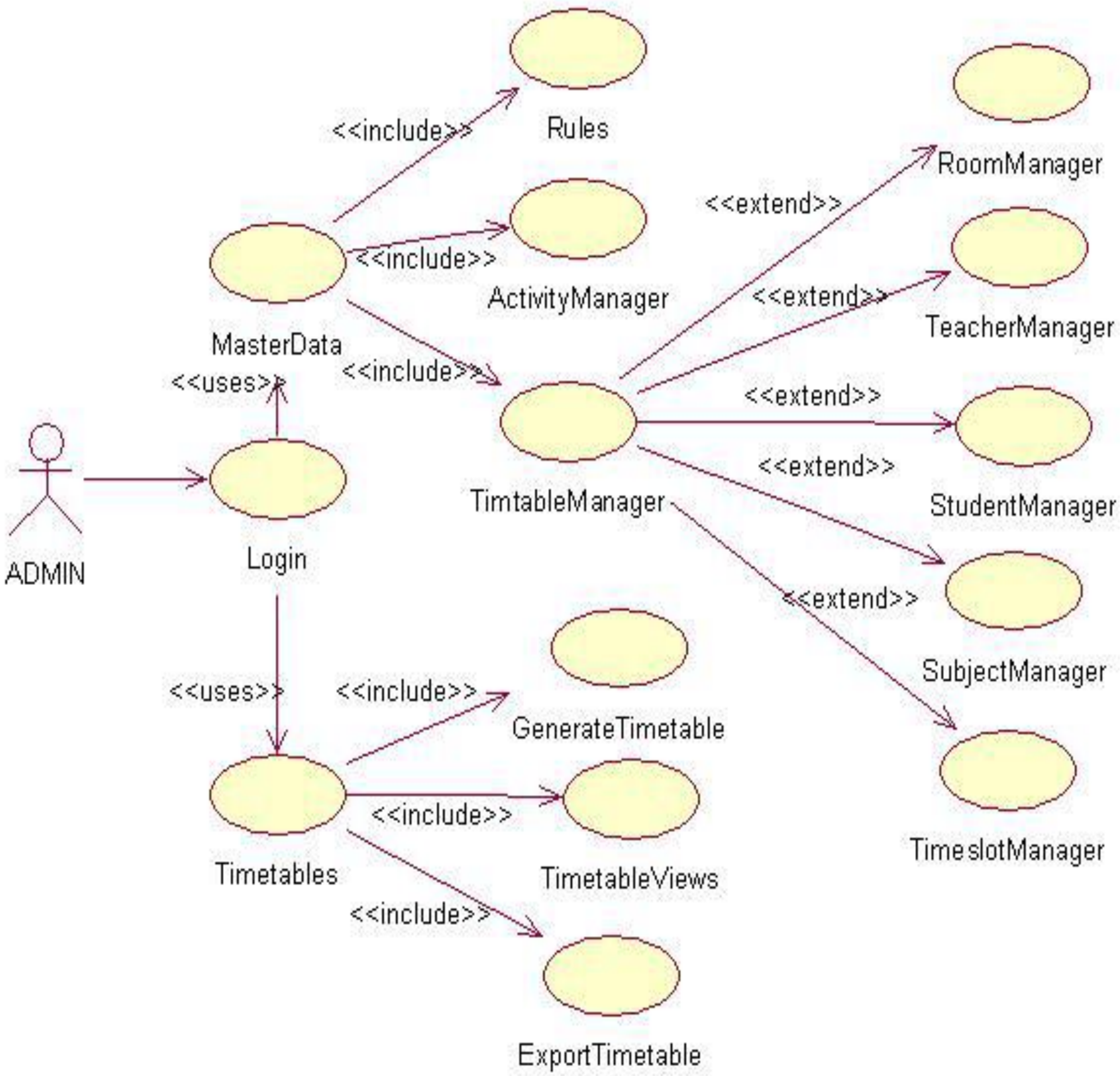


Figure 5: Use Case Diagram.

A use case is made up of a set of scenarios (such as: Login, Data Management, Rules settings etc.). Each scenario is a sequence of steps that encompass an interaction between a user and a system.

4.6 NON-FUNCTIONAL REQUIREMENTS

Non-functional requirements describe the constraints on the services and/or functions offered by the system and constraints on the development process and standards. These requirements are grouped into three main types: Product requirements which specify product behavior, Organizational requirements which are derived from policies and procedures in the customer's and developer's organization, and External requirements which are derived from factors external to the system and its development process.

4.6.1 PRODUCT REQUIREMENTS

The TTGS System must have the following attributes:

4.6.1.1 USABILITY REQUIREMENTS

The system must have an easy to use and understandable user interface. This will ensure that the user, for which this system is intended, will be able to achieve a level of proficiency with the system with minimum effort in a very short period of time.

4.6.1.2 EFFICIENCY REQUIREMENTS

Response time, memory utilization, processing time and other performance factors should be optimal in the system. In the event that only the most minimum of system resources are available, the system should be able to function optimally and it should not make wasteful use of system resources.

4.6.1.3 RELIABILITY REQUIREMENTS

The system's functions and services should be available to its users most of the times. The rate of failure and/or the probability of it not being available should both be very low. Failures in the system should not occur too often, at least a longer time space between them.

4.6.1.4 DEPENDABILITY REQUIREMENTS

In the event of the system failing due to any reason, it should not cause any physical or economic damage to the customers, end users or the developers.

4.6.1.5 ROBUSTNESS REQUIREMENTS

The time taken for the system to restart after a system failure should be very short. The percentage of user and system events that cause failures should be very minimal. The probability of data being corrupted due to a failure should be very minimal as well.

4.6.1.6 MAINTAINABILITY REQUIREMENTS

Since software specifications change all the time as business needs change for organizations, the TTGS system has been designed in such a way that it easily evolves meeting the customers' changing demands. The system should be easy to maintain so as to cut on the maintenance costs.

4.6.1.7 FLEXIBILITY

The system should be modifiable depending on the changing needs of the user. Such modifications should not entail extensive reconstructing or recreation of software. It should also be portable to different computer systems.

4.6.1.8 SECURITY

This is a very important aspect of the design and should cover areas of hardware reliability, fall back procedures, physical security of data and provision for detection of fraud and abuse. System design involves logical design first and then physical construction of the system. The logical design describes the structure and characteristics of features, like the outputs, inputs, files, database and procedures. The physical construction, which follows the logical design, produces actual program software, files and a working system.

4.6.1.9 PORTABILITY

The system should be installed or re-installed somewhere else with little or no modification. The system shall be cross platform and be compatible with a number of common architectures and should also be able to run on a variety of operating systems.

4.6.1.10 CONSISTENCY

The system shall maintain a constant look and appearance and exhibit high levels of consistency among its various modules and components.

4.6.2 ORGANIZATIONAL REQUIREMENTS

4.6.2.1 IMPLEMENTATION REQUIREMENTS

The system has been developed following the RUP methodology thus increments of software or code were added iteratively at each stage. An XML Knowledge Base has been used as the storage structure for the system. The front end (GUI) has been written in the Java programming language using eclipse as an Integrated Development Environment (IDE).

4.6.2.2 STANDARDS REQUIREMENTS

The initial system is done in English, that is, all text, labels and system documentation. However, alternative local language support for dictionary lookup may be added later if need be.

4.6.2.3 DELIVERY REQUIREMENTS

The system will be delivered to its intended users only after thorough testing, verification and validation of the individual system components. Also all necessary documentation needed by the user will be delivered.

4.6.3 HARDWARE REQUIREMENTS

In summary form:

CPU : 1GHz Minimum.

Memory : 512MB Minimum.

Capacity : 5GB Hard Drive Space.

Others : Mouse, Keyboard, VGA Digital Monitor.

4.6.4 EXTERNAL REQUIREMENTS

4.6.4.1 INTEROPERABILITY

The system has been designed to easily integrate with other systems once deployed. It should be able to function properly on any system without giving an idea to the user as to what could be happening in the background.

4.6.4.2 ETHNICAL REQUIREMENTS

Only authorized users will be able to view certain details of the information supplied by the users and all information supplied will be treated with the highest confidence. Information displayed will only have necessary detail for the general public.

5 CHAPTER FIVE: SYSTEM DESIGN

5.1 PROPOSED SYSTEM

The Timetabling Algorithm is the main component of this project which produces the HTML based timetable sheet as the output. The project takes various inputs from the user such as Teacher List, Course List, Student Set List, Room List, Day List and Timeslot as well as various rules, facts and constraints using web based forms, which are stored in XML based knowledge base. This knowledge base serves as input to the Timetable Generator Algorithm residing on the server machine.

The system is organized into a three-tier architecture. The knowledgebase lies in the middle, between the timetabling algorithm and the GUI front end. After the representation of the KB was standardized, the timetabling algorithm was designed. The design of the timetabling algorithm took most of the project total time.

The diagram below (Figure 6) shows the proposed System – The Timetable Generation System

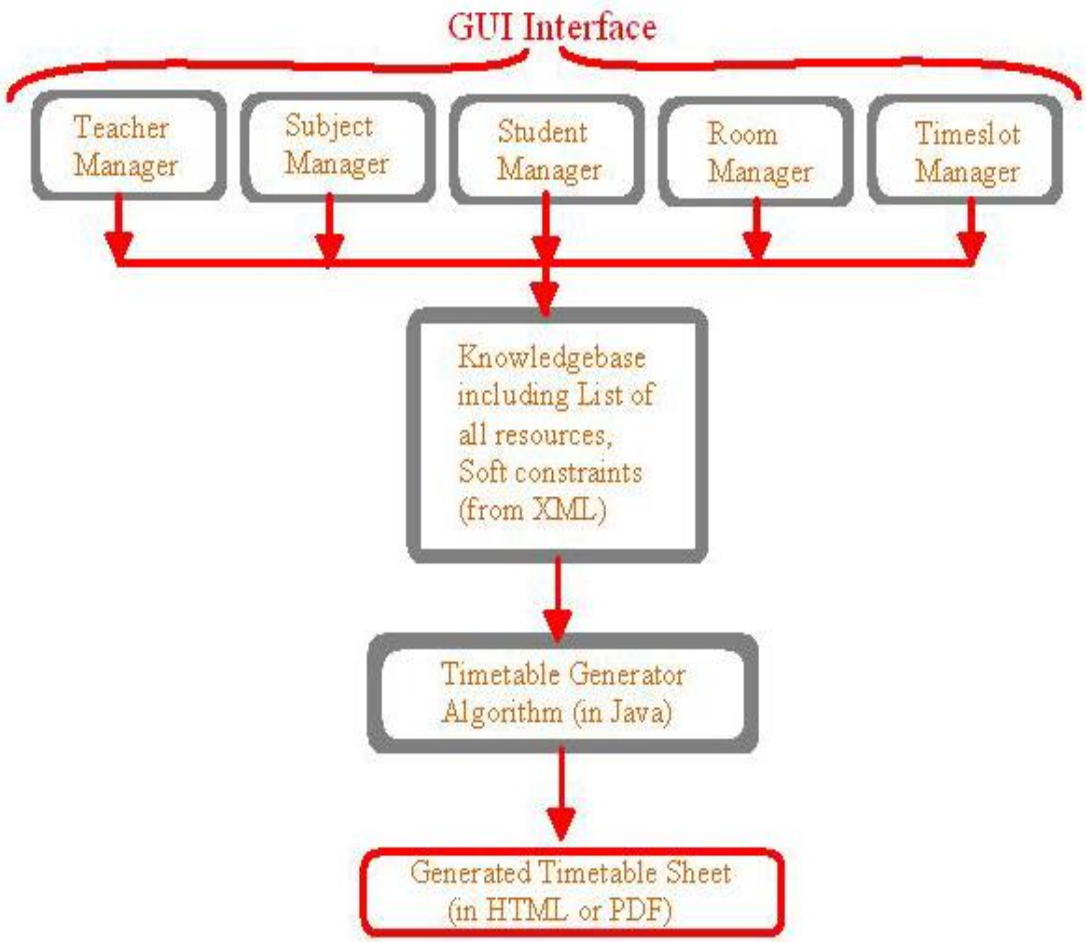


Figure 6: Proposed System.

5.2 TTGS FEATURES

- Simple... Easy-to-understand & simple-to-operate with intuitive user interface, guides and samples.
- Fast... Generates timetable in minutes, saving your time, efforts and money.
- Rules configuration and verification.
- Different views of timetable depending upon who is viewing timetable.

With Timetable Generation System, timetable generation process involves just a few simple steps:

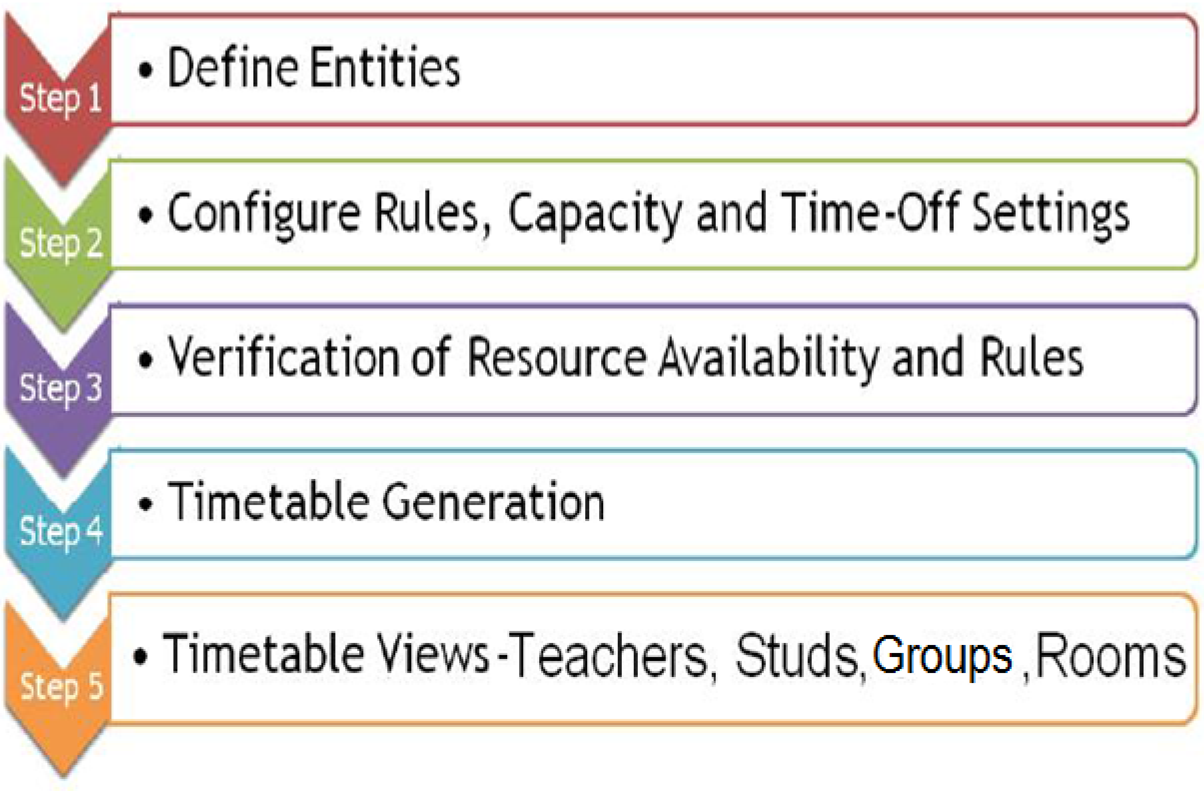


Figure 7: Timetable Generation Process.

The diagram below (Figure 8) shows the General View of the Timetable Generation System.

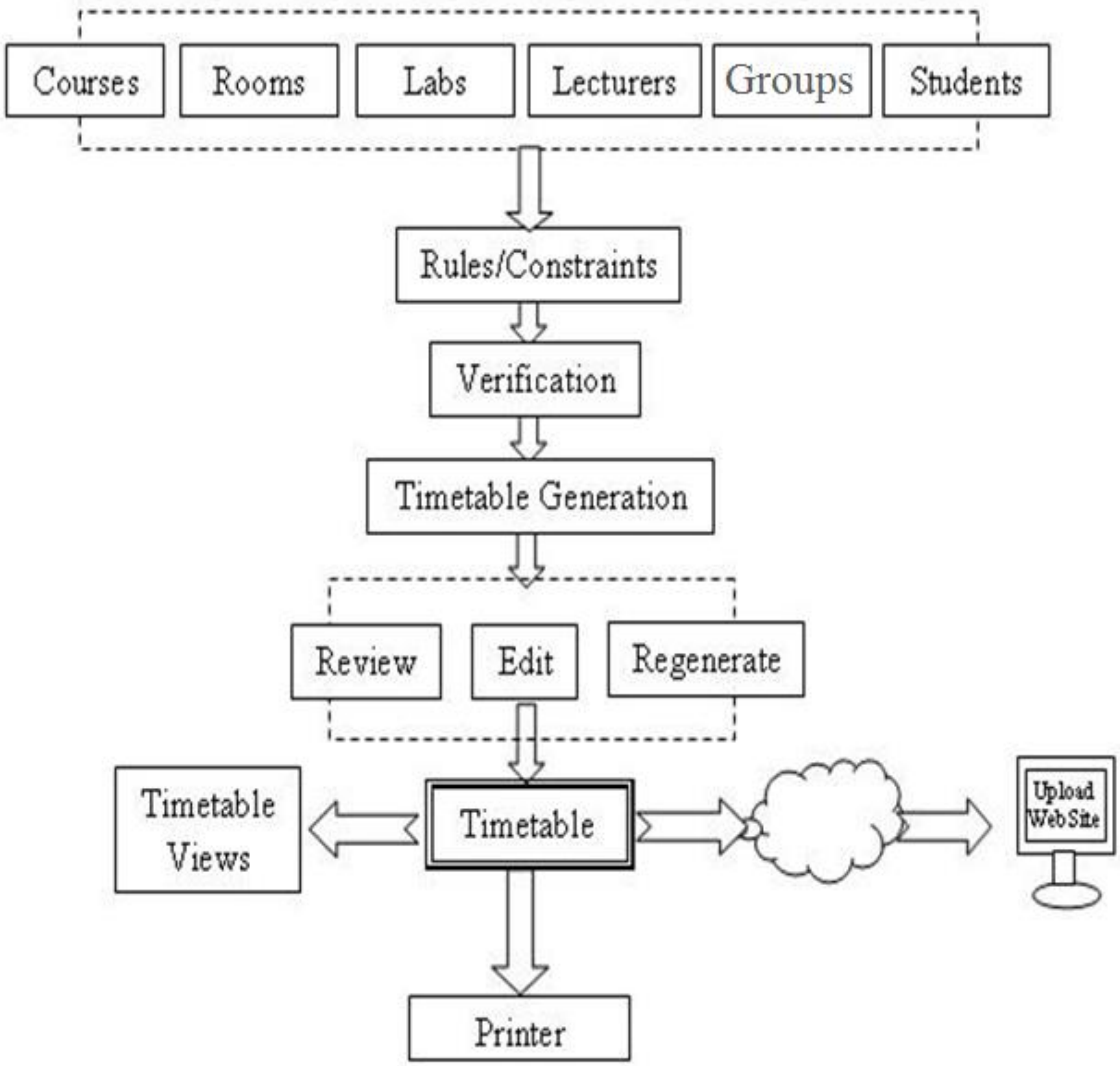


Figure 8: General View of TTGS.

5.3 CLASS DIAGRAM

Packages: Packages allow us to break up a large number of objects into related groupings. In many object oriented languages (such as Java), packages are used to provide scope and division to classes and interfaces.

Classes: The core element of the class diagram is the class. In an object oriented system, classes are used to represent entities within the system; entities that often relate to real world objects.

The following diagram (Figure 9) shows the package DataSourceKB which contains classes to handle the Back End (Knowledge Base).

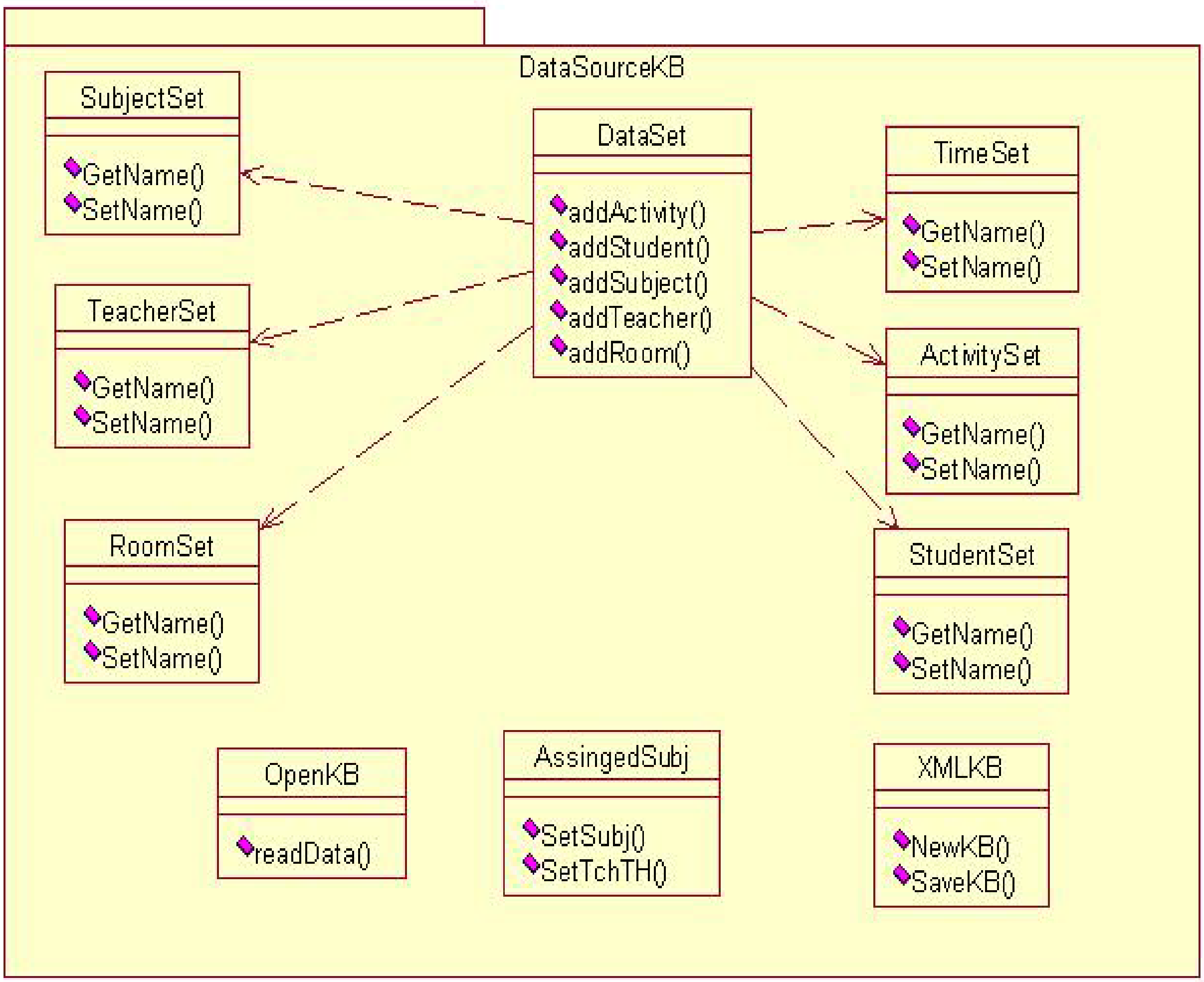


Figure 9: Class Diagram 1.

The following diagram (Figure 10) shows the package TTGS which contains sub packages and classes to create the Front End.

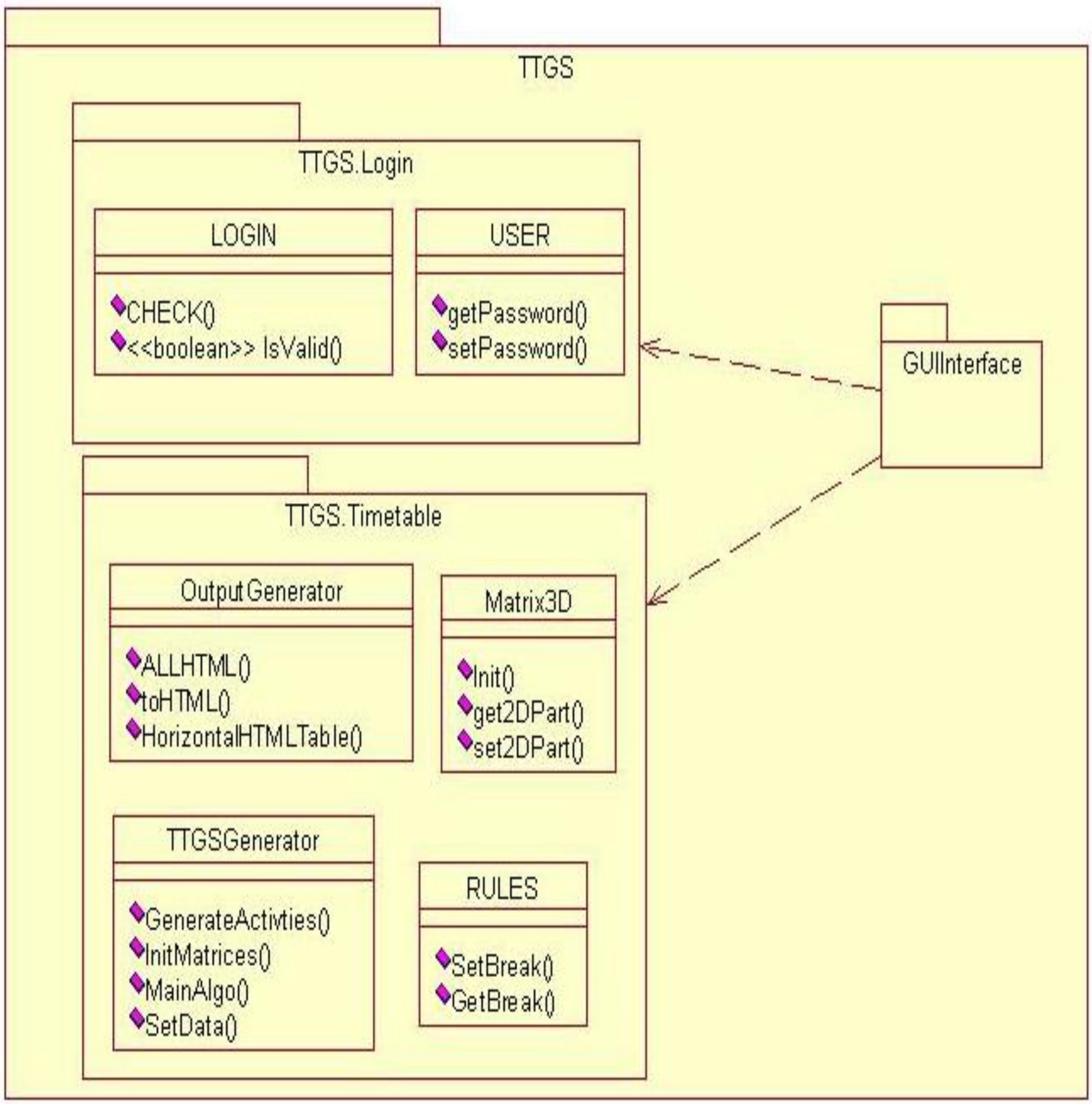


Figure 10: Class Diagram 2

5.4 LOGIN TABLE

The LOGIN table was designed and created using Microsoft Access Database Management System (DBMS) as shown in Table 1 and 2 below.

LOGINNAME	PASSWORD	NAME	TYPE	Click to Add
admin	*****	Administrator	Admin	
compadmin	*********	Computer Dep	Admin	
itadmin	*******	IT Dept.	Admin	

Table 1: Datasheet View of the Login Table.

Field Name	Data Type
LOGINNAME	Short Text
PASSWORD	Short Text
NAME	Short Text
TYPE	Short Text

Table 2: Design View of the Login Table.

6 CHAPTER SIX: IMPLEMENTATION

6.1 XML KNOWLEDGEBASE

As XML was preferred as the back-end, I had to design it first using XML Notepad 2007 and then retrieve it using Java into the system application.

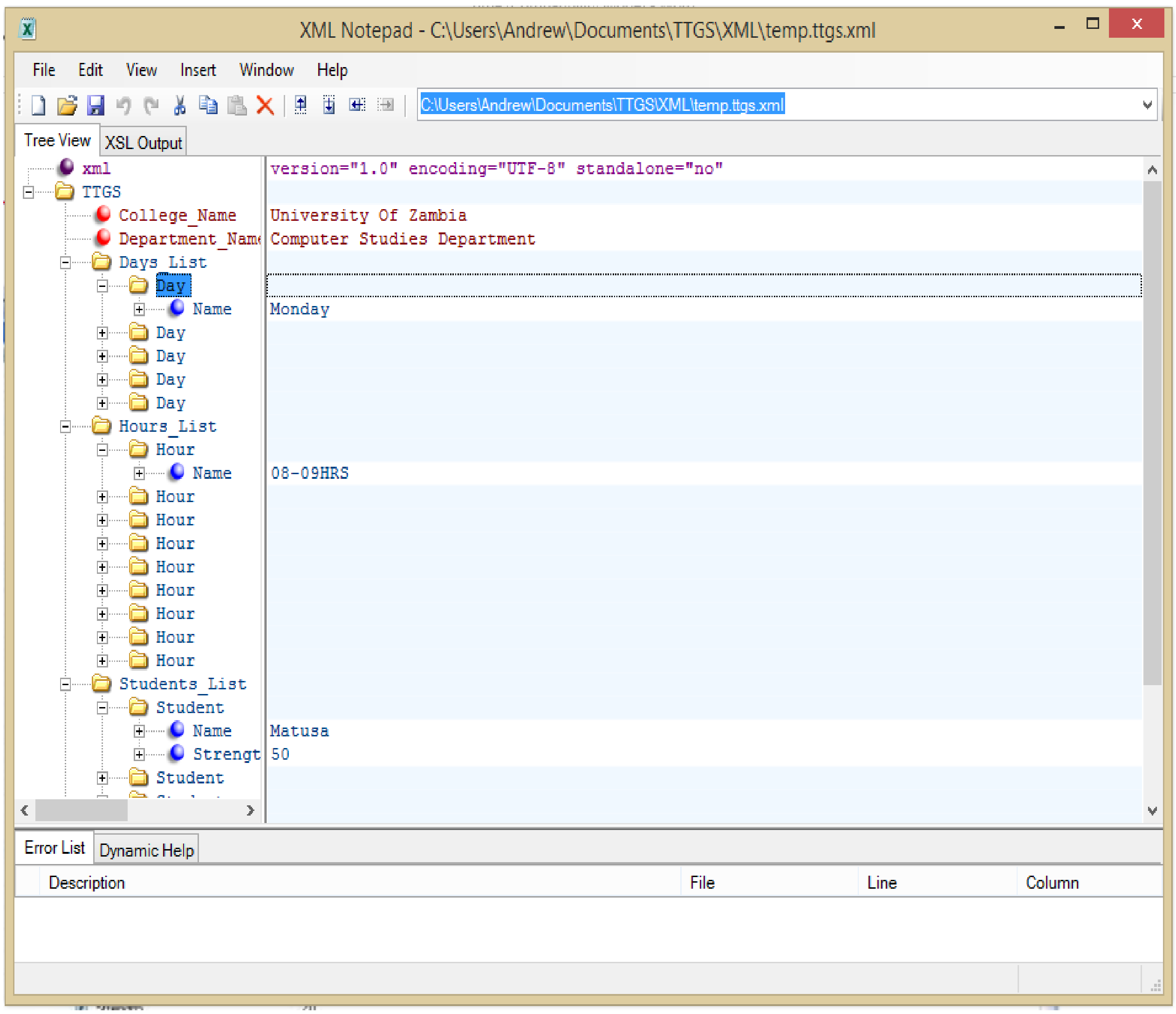


Figure 11: temp.ttgs.xml - XML Knowledgebase.

6.2 USER INTERFACE CODE

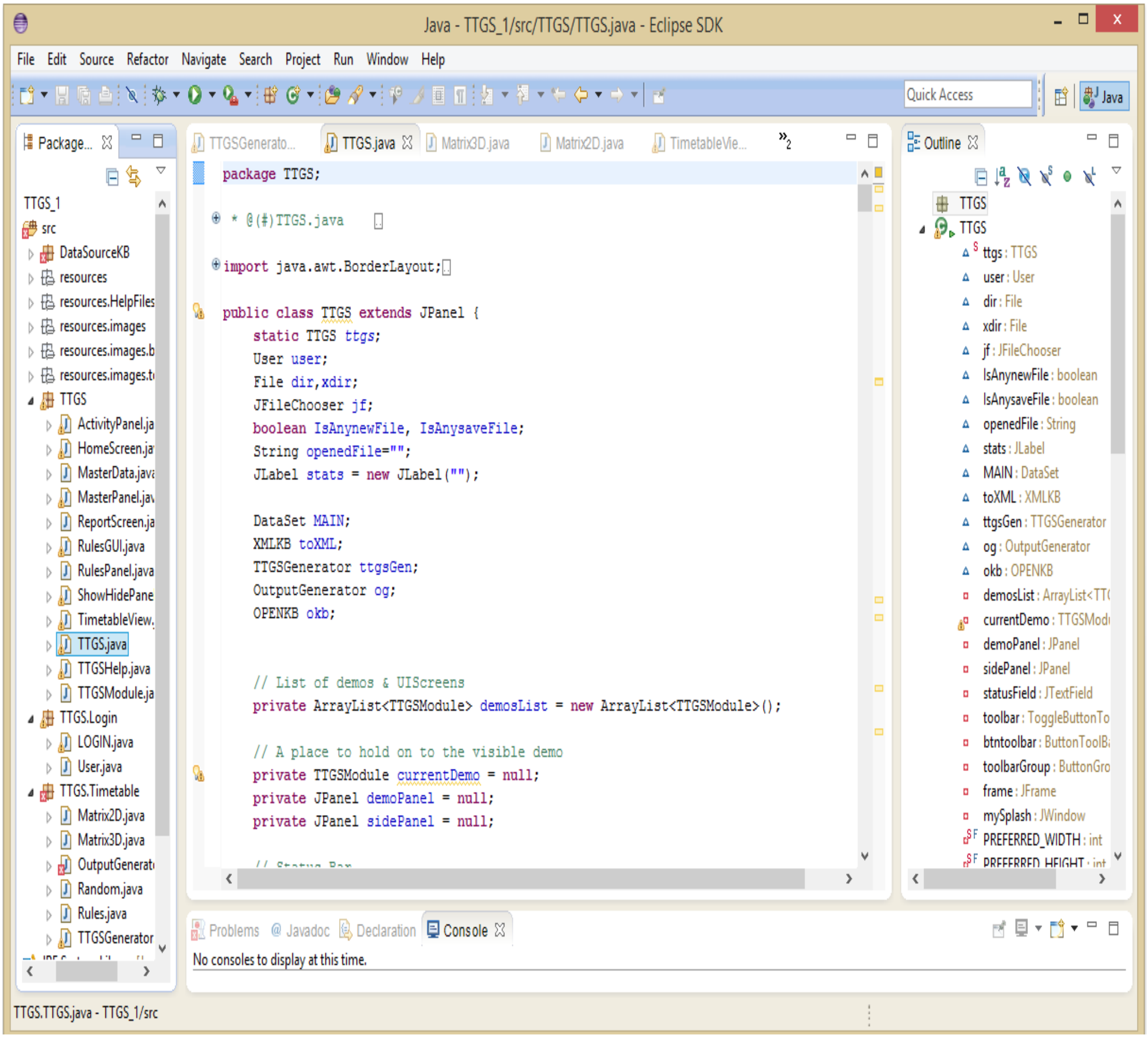


Figure 12: TTGS Main Class.

The diagram above (Figure 12) shows the main class TTGS, which can be seen as an entry class.

The following diagram (Figure 13) shows the Matrix3D class, which can be viewed as a Template Class. A Template class can take many forms, i.e. we can instantiate this class by any data type (e.g., String, Integer, Boolean).

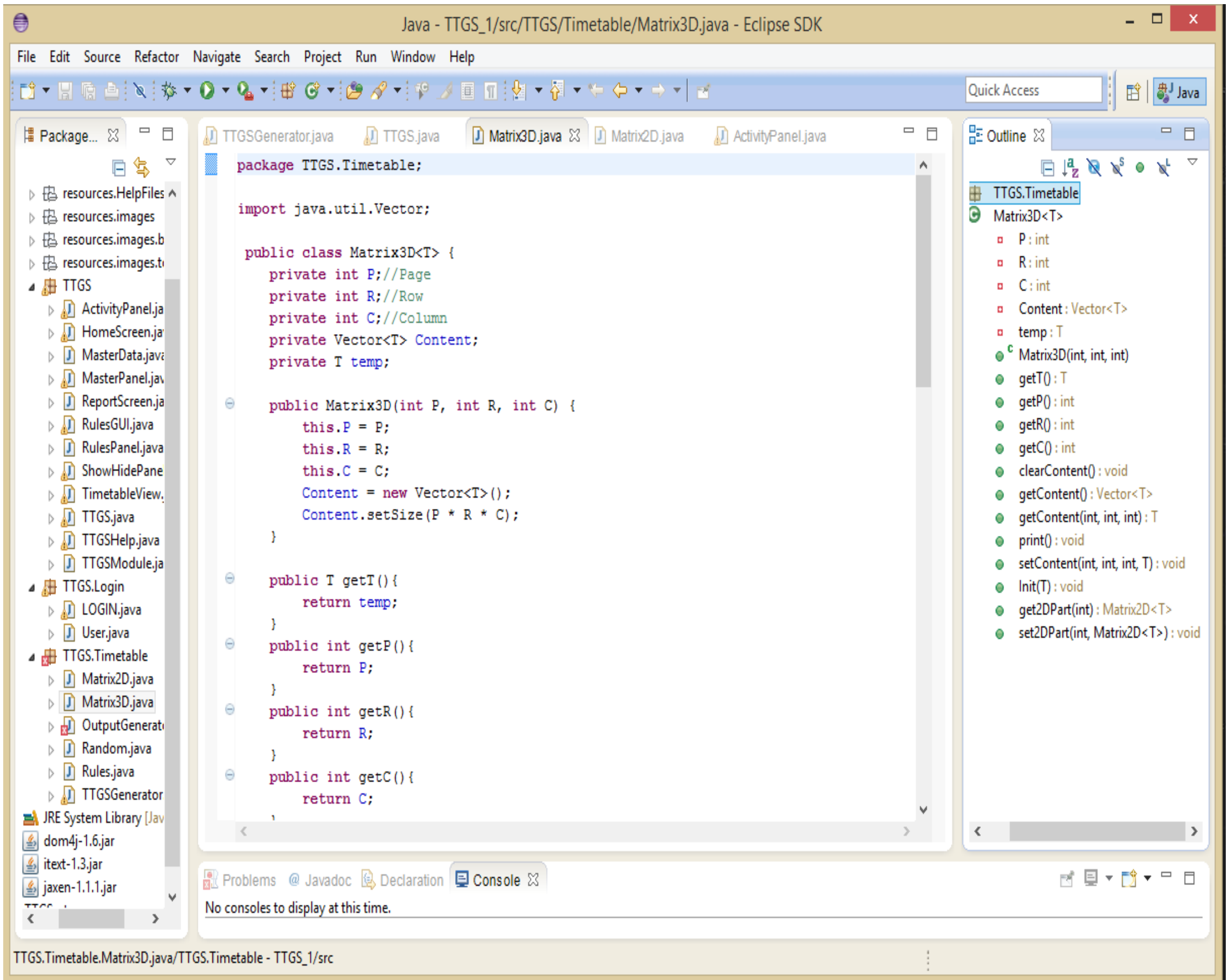


Figure 13: Matrix3D Class.

6.3 OUTPUT GENERATOR CODE

The following diagram (Figure 14) shows how the generated timetable can be represented in HTML.

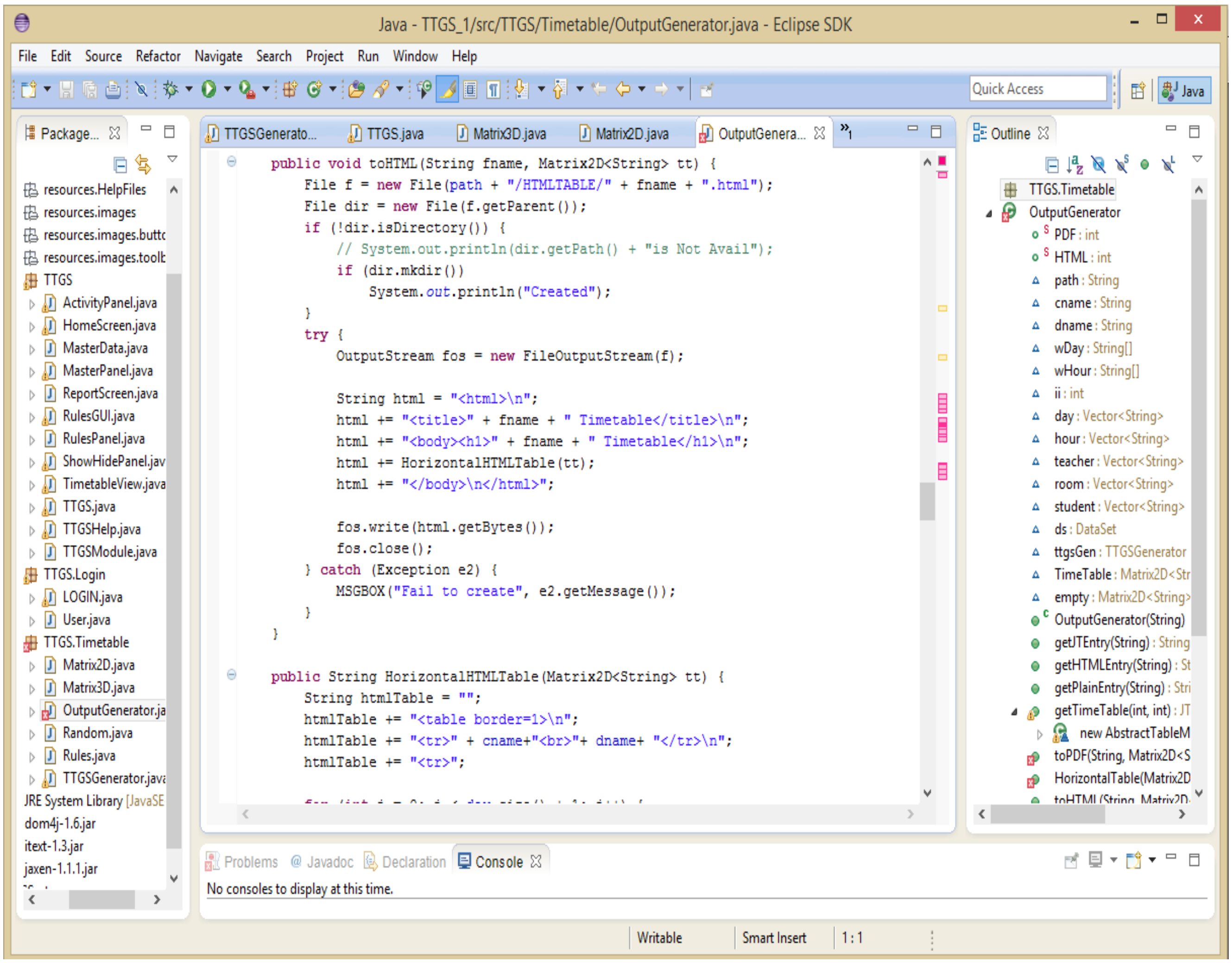


Figure 14: Output Generator - Export to HTML file.

6.4 TIMETABLE GENERATOR CODE

The following diagram (Figure 15) shows the Main algorithm. This is the heart of the project. It works in the following way:

- Initiates storage matrices.
- Performs allocation by checking TSR (Teacher, Student, Room) resources.
- If any resource is absent (not available), it exits, else it places the activity at current timeslot and day.

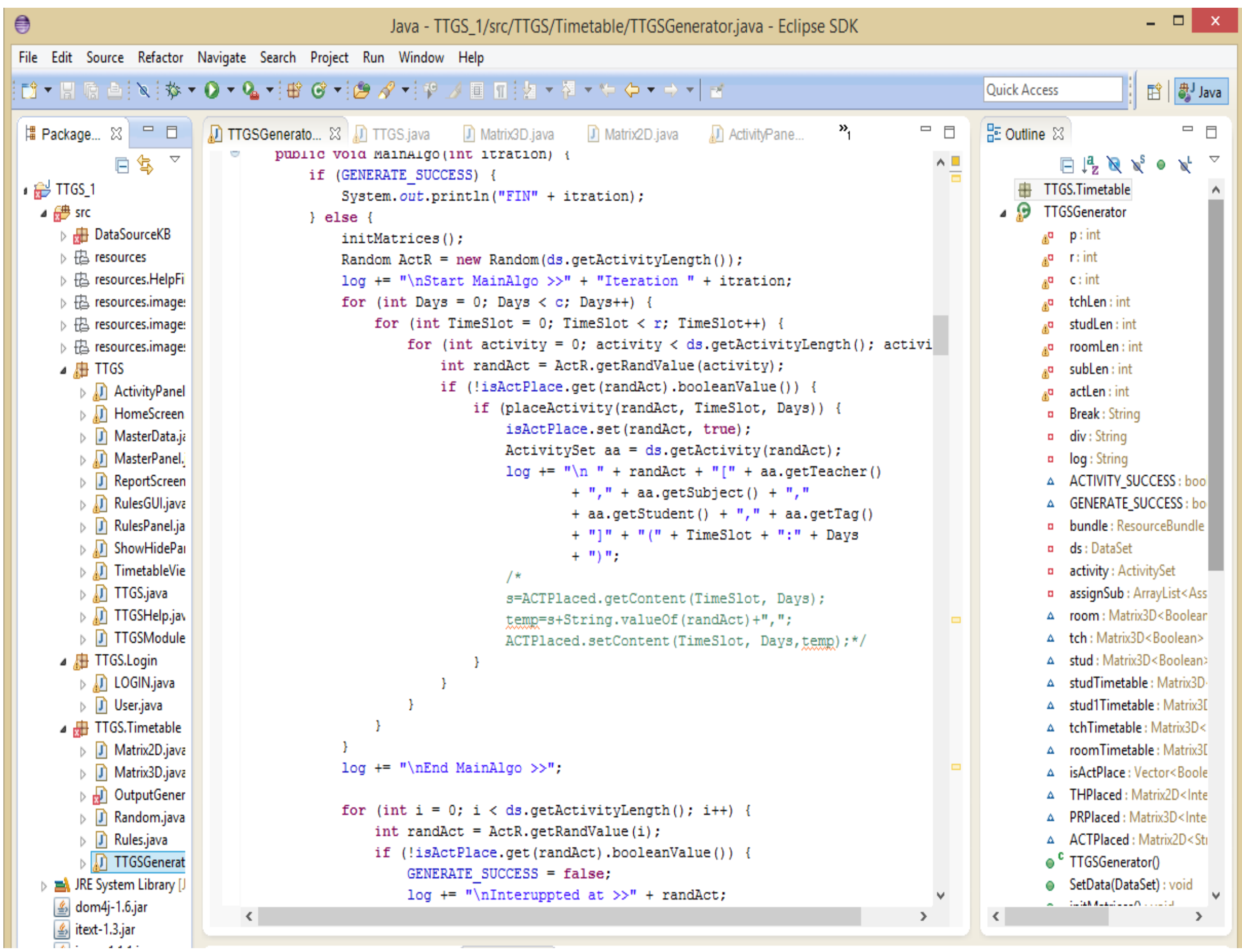


Figure 15: TTGS Main Algorithm Code.

The following diagram (Figure 16) shows how activities should be generated.

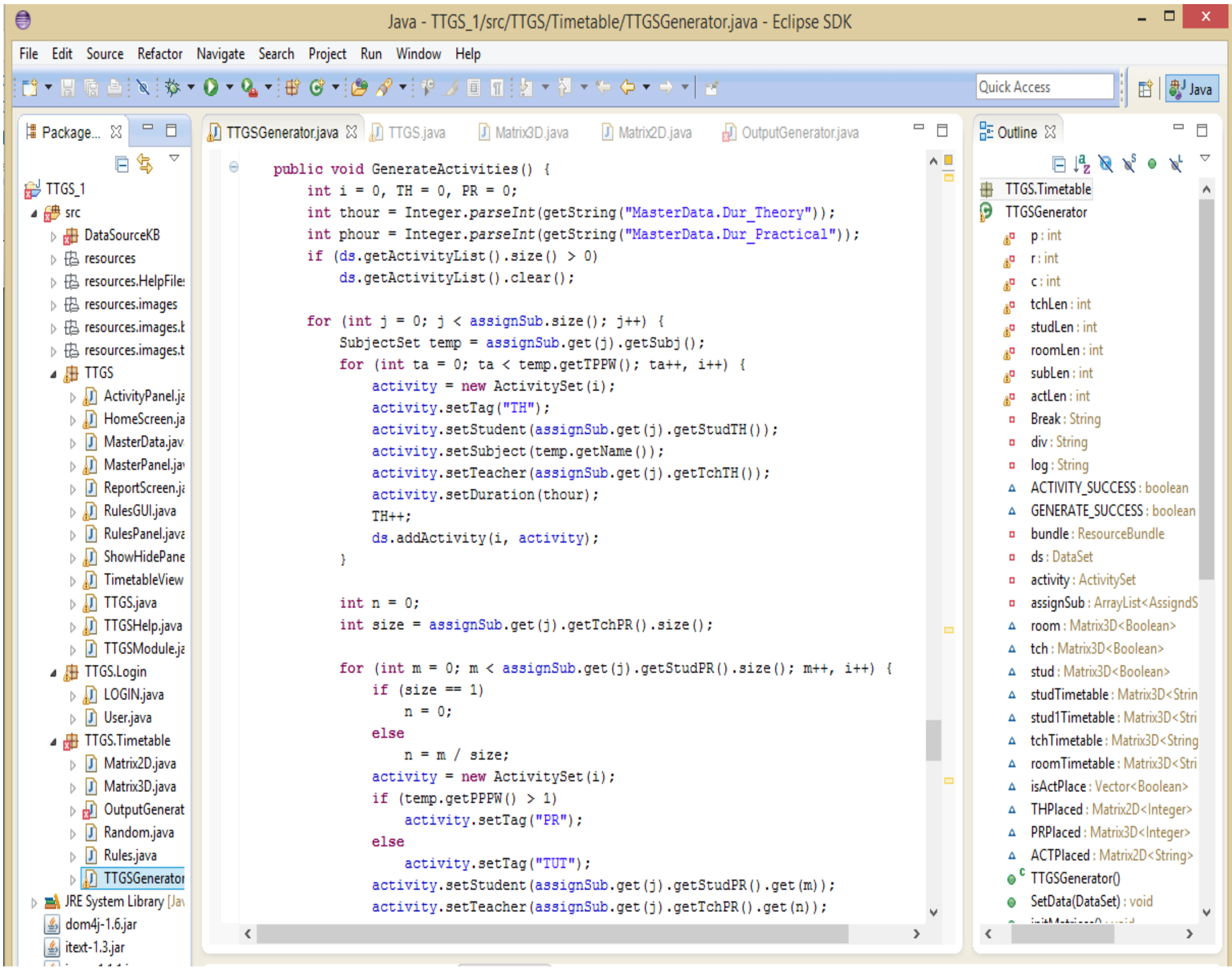


Figure 16: TTGS Activity Generation.

The following diagram (Figure 17) shows how the particular activity can be placed at (Day, Timeslot). It is called in the Main Algorithm.

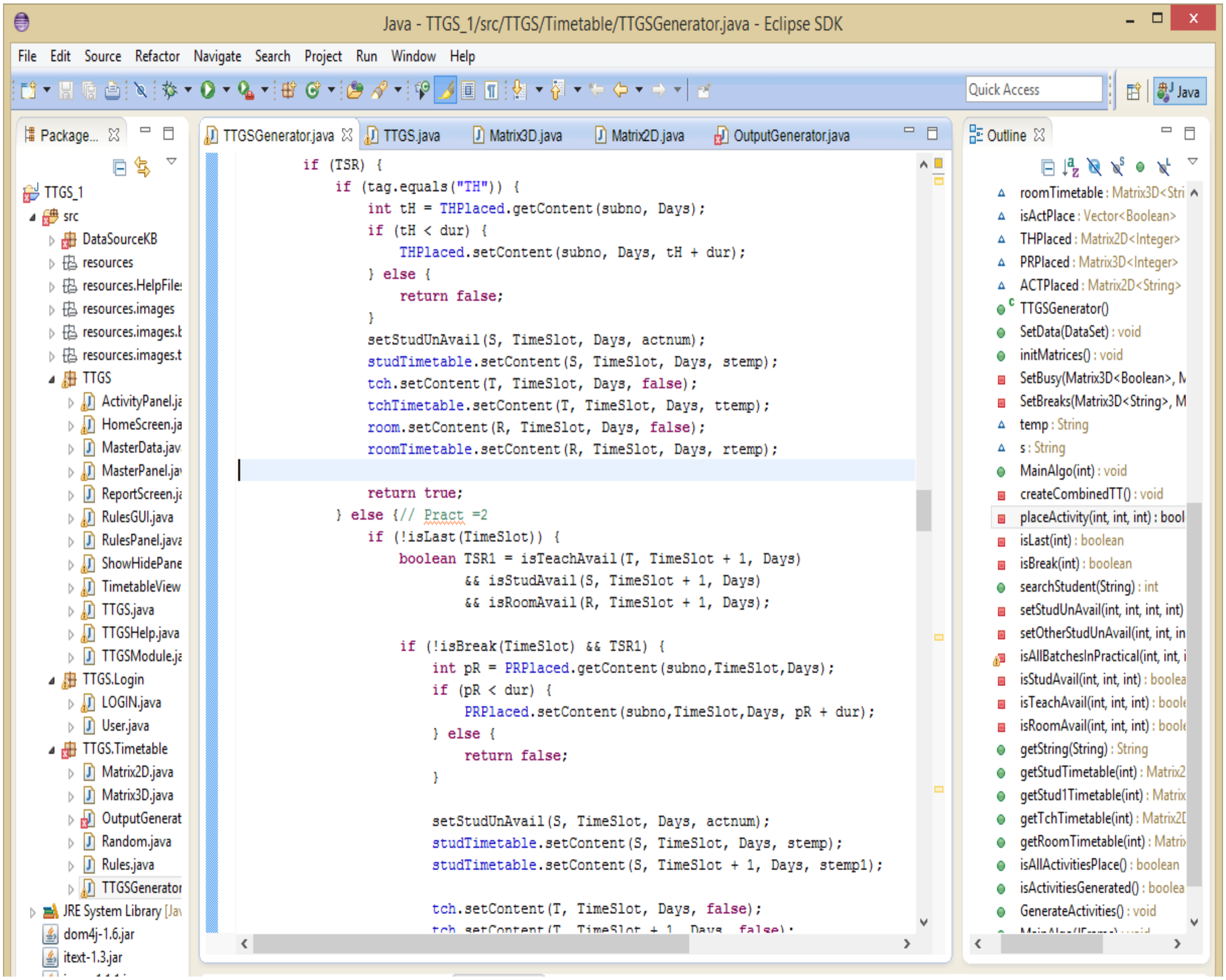


Figure 17: TTGS Placement of activity.

7 CHAPTER SEVEN: TESTING AND RESULTS

7.1 TESTING STRATEGIES

The TTGS System was subjected to different kinds of testing strategies in order to identify its limitations and determine its full capabilities. To demonstrate that the system met the requirements, a separate test was done for every requirement in the user and system requirements document. Thus validation testing was performed. To discover faults or defects in the system where the behavior of the system is incorrect, undesirable or does not conform to its specification, defect testing was also performed. The different components of the system were each put on extensive unit testing to ensure that the system was robust. Below is a list of the various test strategies that were performed and a brief explanation for each.

7.1.1 UNIT TESTING

The system's individual components were tested independently to ensure that they operate correctly. The database, being one of the critical components of the system, was subjected to thorough testing. Data integrity was maintained through enforcement of some constraints on the attributes. Test cases were developed to ensure that all valid queries sent to the database returned the correct information.
Testing the Graphical User Interface
Test cases used for unit testing included:

- Test for all valid user events
- Test for invalid user events such as malformed text inputs like invalid words, or words containing invalid characters.
- Test for correctness of the results. Ensure that results displayed are for the requested inputs

7.1.2 INTEGRATION TESTING

The system consists of many independent modules. These modules were tested independently every time a change occurred in one of them. The modules were then integrated with the rest of the system subsystems and tested as a whole to ensure that they worked together and met the specified requirements.

7.1.3 SYSTEM TESTING

The individual subsystems were then merged to form a fully-fledged system. To ensure functionality and completeness of the system, the entire system was then tested as a whole keeping particular attention to how subsystems were coordinating and making changes to all irregularities and system errors.

7.2 EXTERNAL INTERFACES

7.2.1 USER INTERFACE DESCRIPTION AND CHARACTERISTICS

The user interface is the main component of the three-tier architecture model and is the only way through which users can use and interact with the system. Therefore, the design of the interface was in such a way that users should not struggle to use the system. To ensure that the system is usable, a user-centered design approach was followed. The following features added usability:

- Windows: These enabled more information to be displayed and some data to be entered through the user's screen.
- Icons: These are images (or shortcuts) that represent applications, objects and various operations and commands to be performed on the system.
- Menus: These offer users a structured way of choosing from the available set of optional services the system provides.
- Pointing Devices: Pointing devices like the mouse control the cursor as a point of entry to the windows, menus, and icons on the screen.

Designed with the principles of Multimedia and Human Computer Interaction (HCI), the following were some of the goals that had to be met by the interfaces:

- Attractive to use and simple
- Consistent with most operations (Consistency)
- Easy to learn (Learnability)

- Easy to use (Usability)
- Have a good utility
- Reduce on error rate
- Familiar with users of the system

7.3 SCREEN SHOT OF TTGS

The Screen Shots of the system were taken as shown in the following diagrams (Figure 18 to Figure 31). As the Graphical User Interface (GUI) is main entry point to any software application, I tried by all means necessary to make the Timetabling System as highly interactive as possible so as to make it ideal and simple for both naive and sophisticated users. The TTGS front-end has been designed in Java (Swingset), hence the reason why I was able to make the interfaces with so much ease.

7.3.1 HOME SCREEN

This is the first interface that a user sees and interacts with upon launching TTGS. It is a simple interface that is so easy to navigate and understand at one instance. In order to access the various services offered by the system, the user simply has to log in using a correct username and password. The diagram on figure 18 shows the home screen which is the entry point to the TTGS Application.

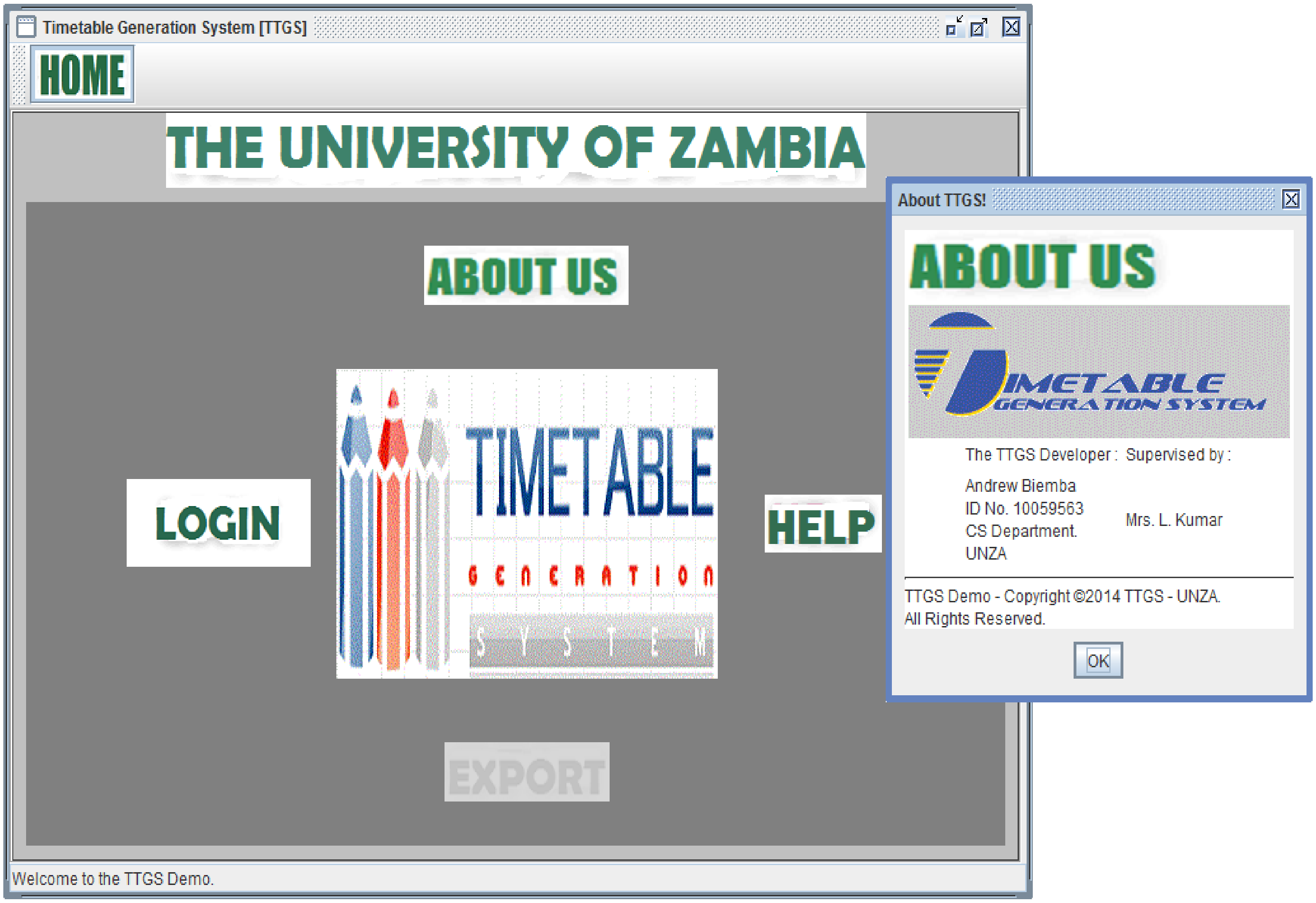


Figure 18: Home Screen.

The following diagram (Figure 19) shows the Login Screen which allows authorized access to the TTGS Application.

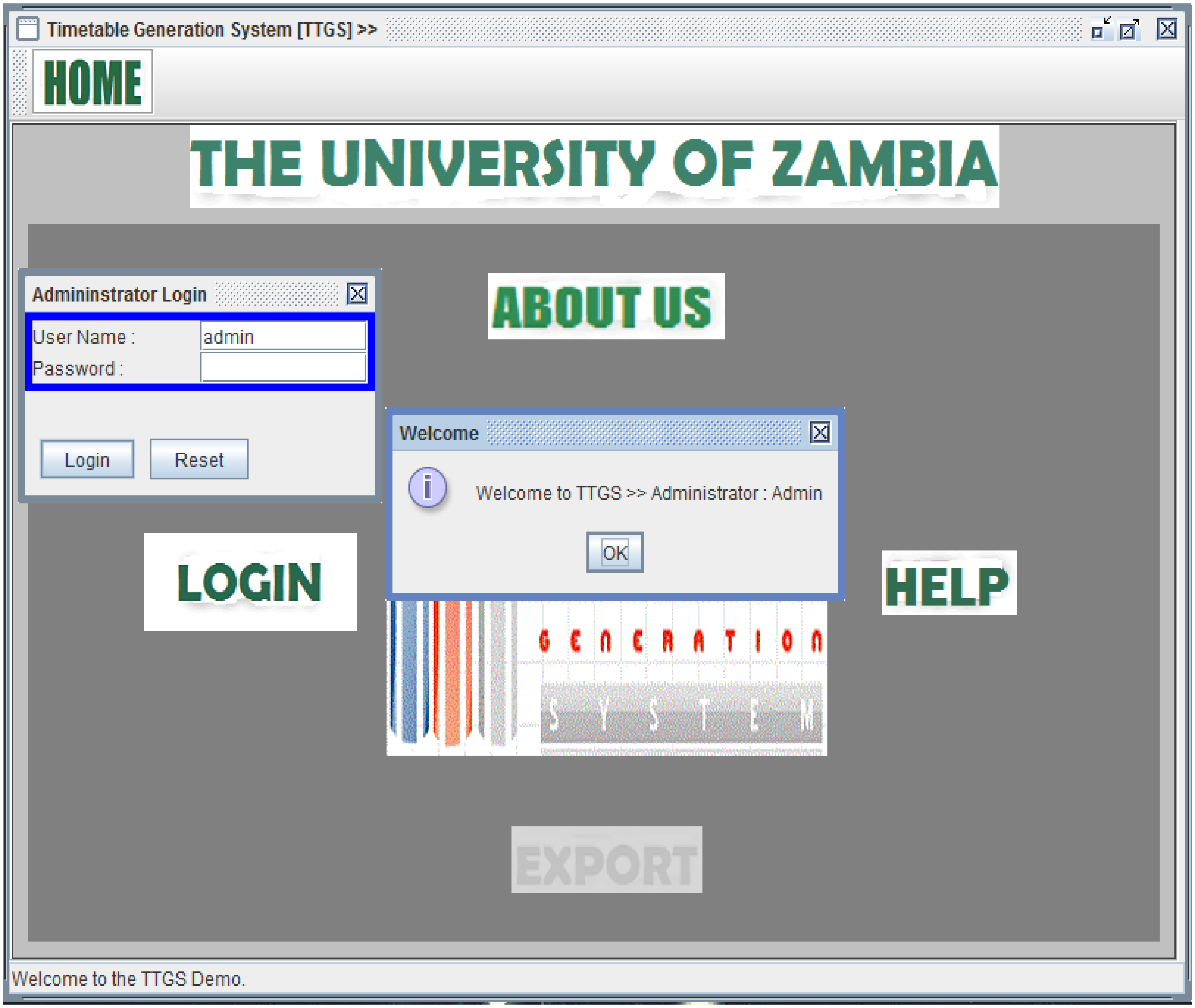


Figure 19: Login Screen.

7.3.2 TTGS SYSTEM SCREEN

This is the screen or interface that is presented to the user after the user successfully logs in. This screen contains a menu bar that provides key functionalities or sections of the system. This is shown in the diagram (figure 20) below.

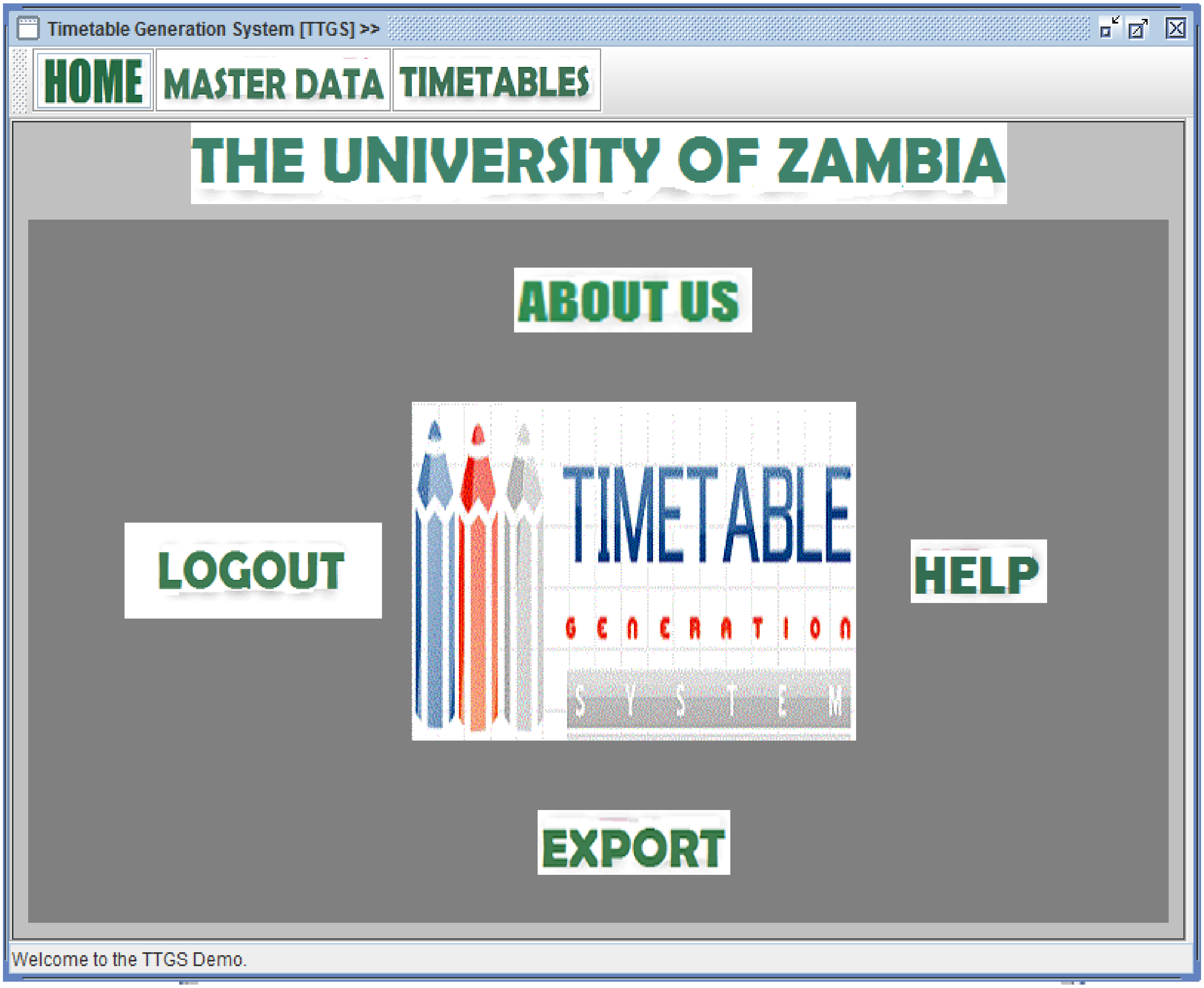


Figure 20: TTGS System Screen showing the main menu.

The diagram below (Figure 21) shows the Lecturer Manager Screen which provides the facility to enter all data entities. The other Manager Screens similar to this one are the Course, Student, Room and Timeslot Manager Screens.

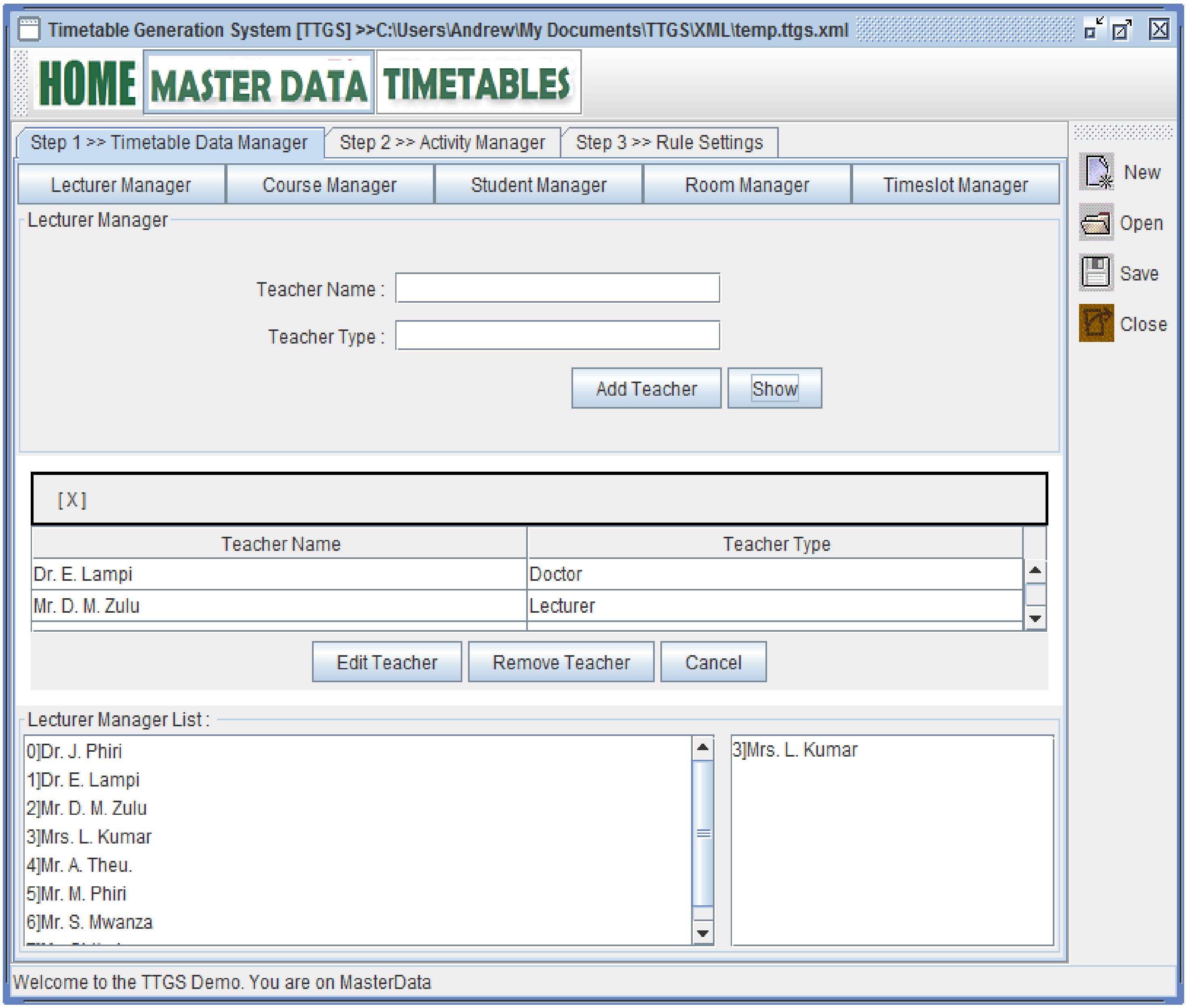


Figure 21: Lecturer Manager Screen.

The following diagram (Figure 22) shows the Timeslot Manager Screen which provides a way to set the working days & timings.

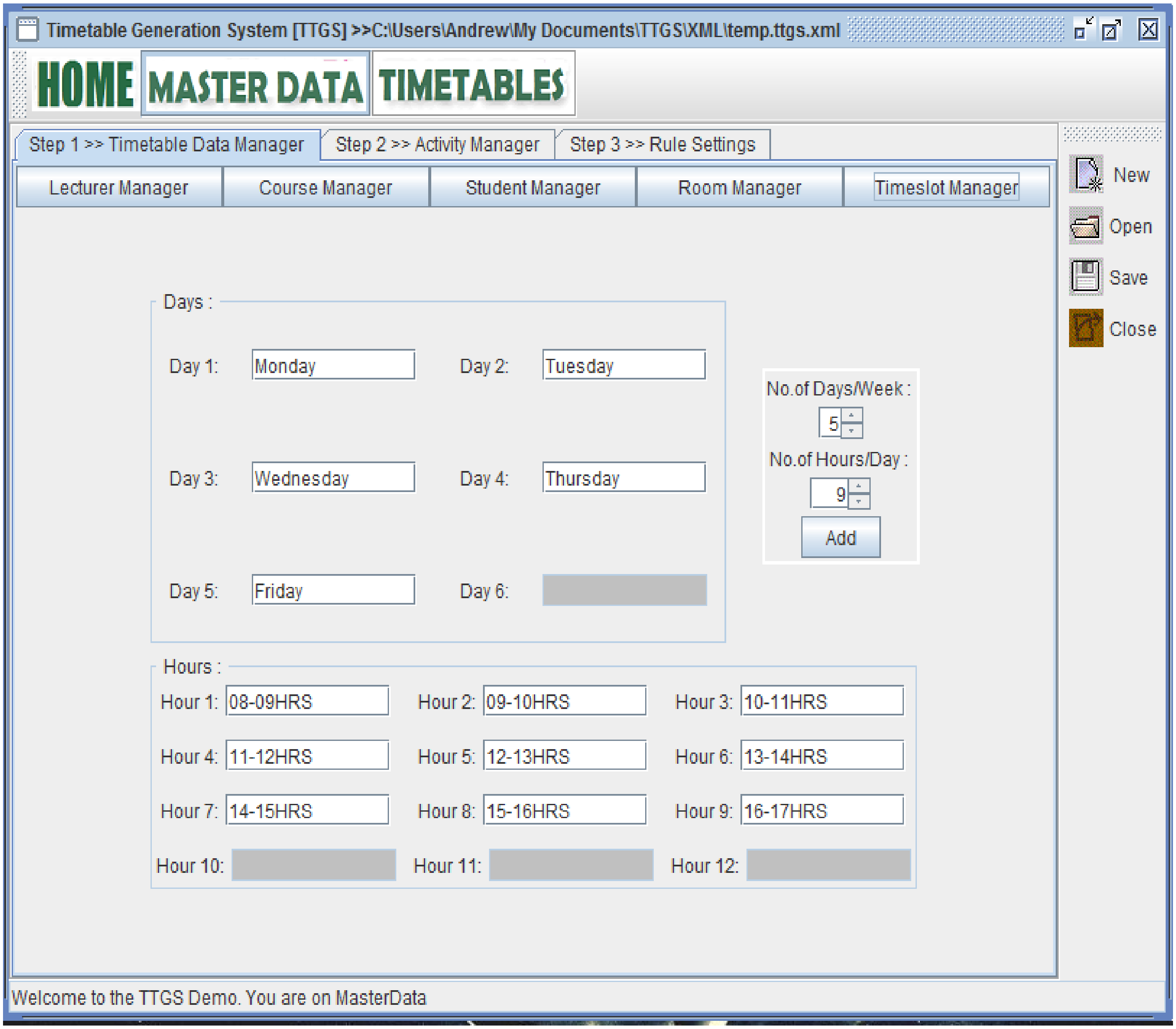


Figure 22: Timeslot Manager Screen.

The diagram below (Figure 23) shows the Subject-Student (Course-Student) Assignment Screen which facilitates the administrator to assign a set of subjects or courses to Students.

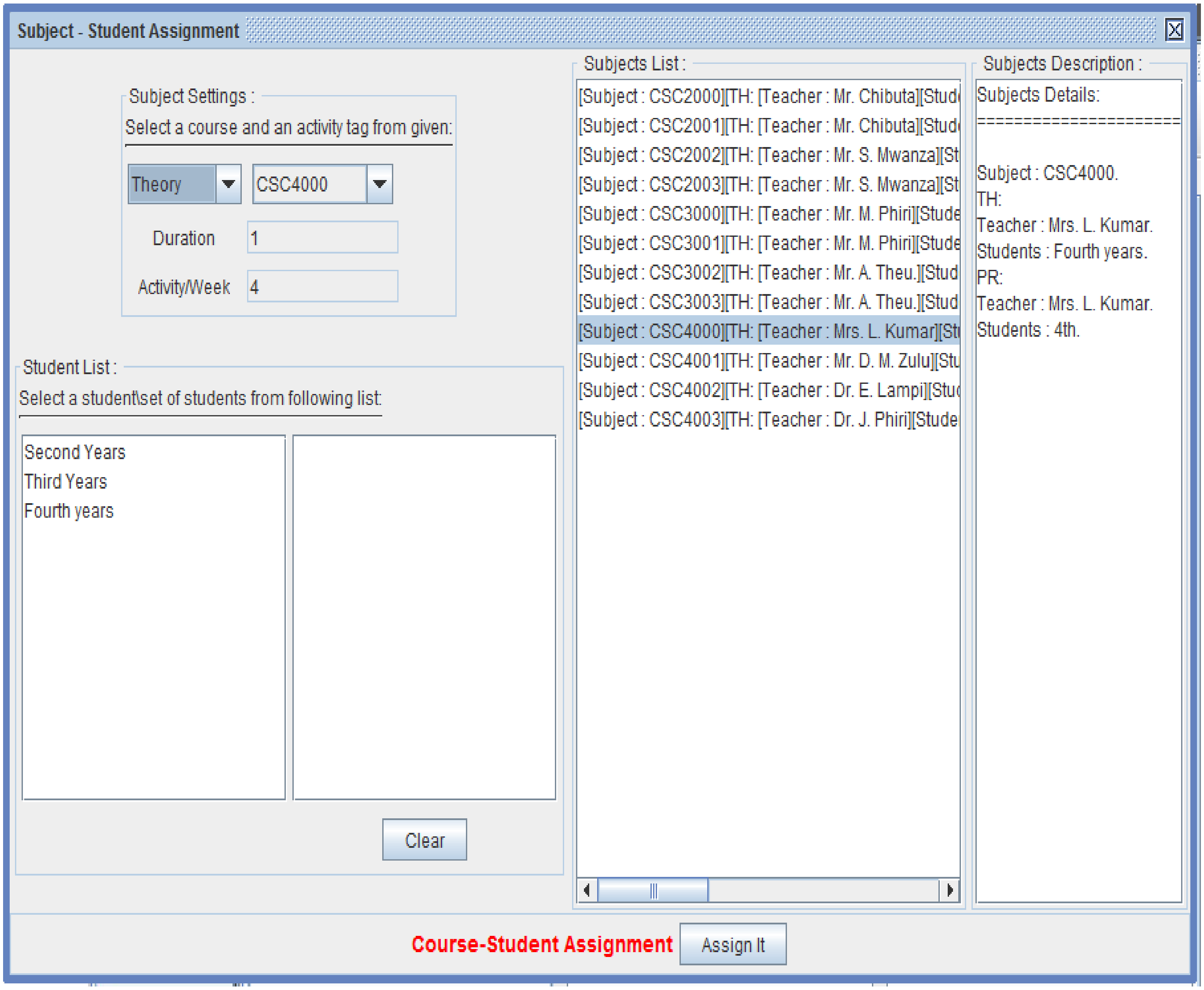


Figure 23: Subject-Student Assignment

The diagram below (Figure 24) shows the Subject-Teacher (Course-Lecturer) Assignment Screen which allows the user to assign one or more subjects (courses) to a teacher or lecturer.

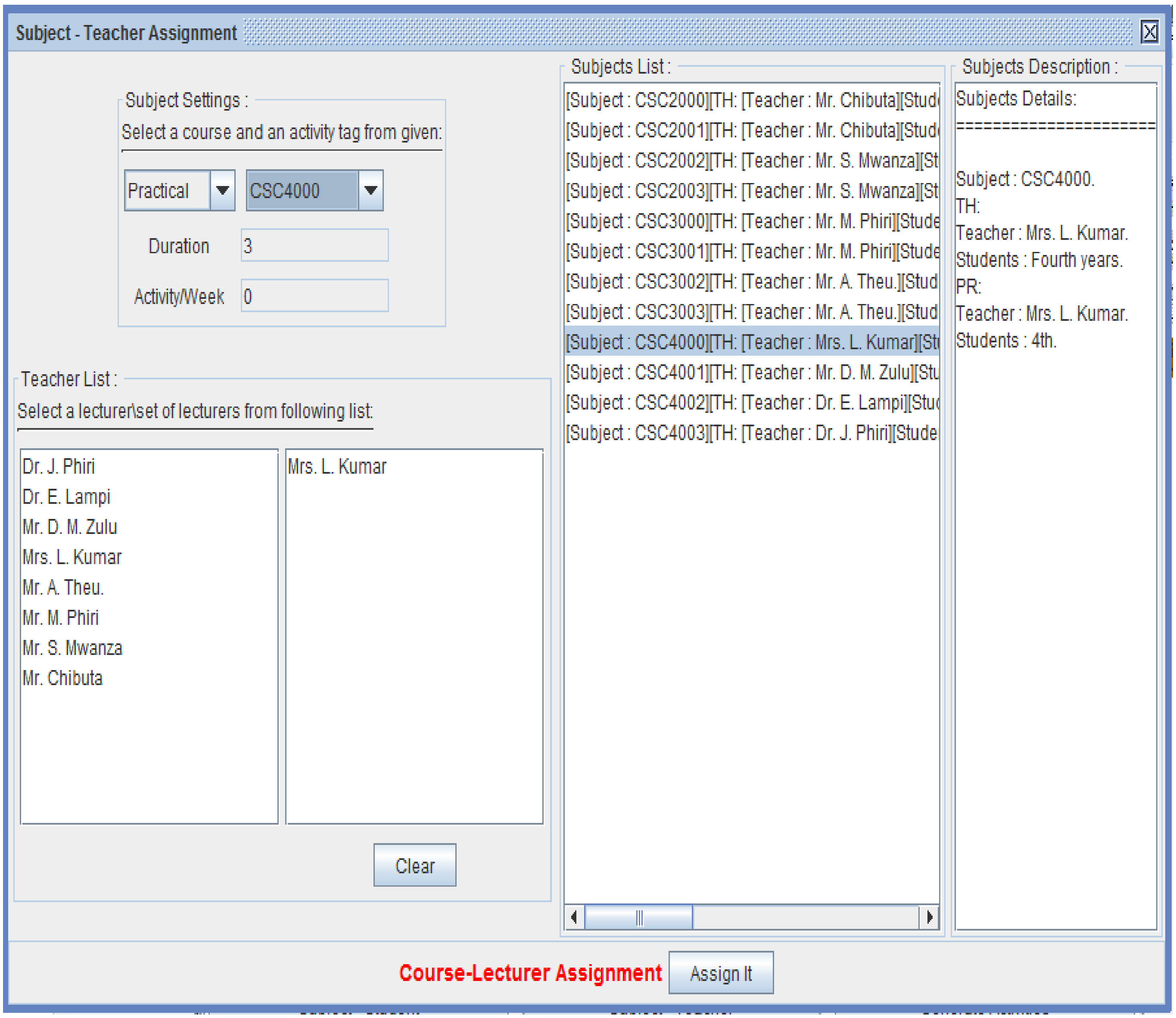


Figure 24: Course - Lecturer Assignment.

The following diagram (Figure 25) shows the Activity Manager Screen which allows the user to generate activities based on Teacher-Student-Subject Assignment.

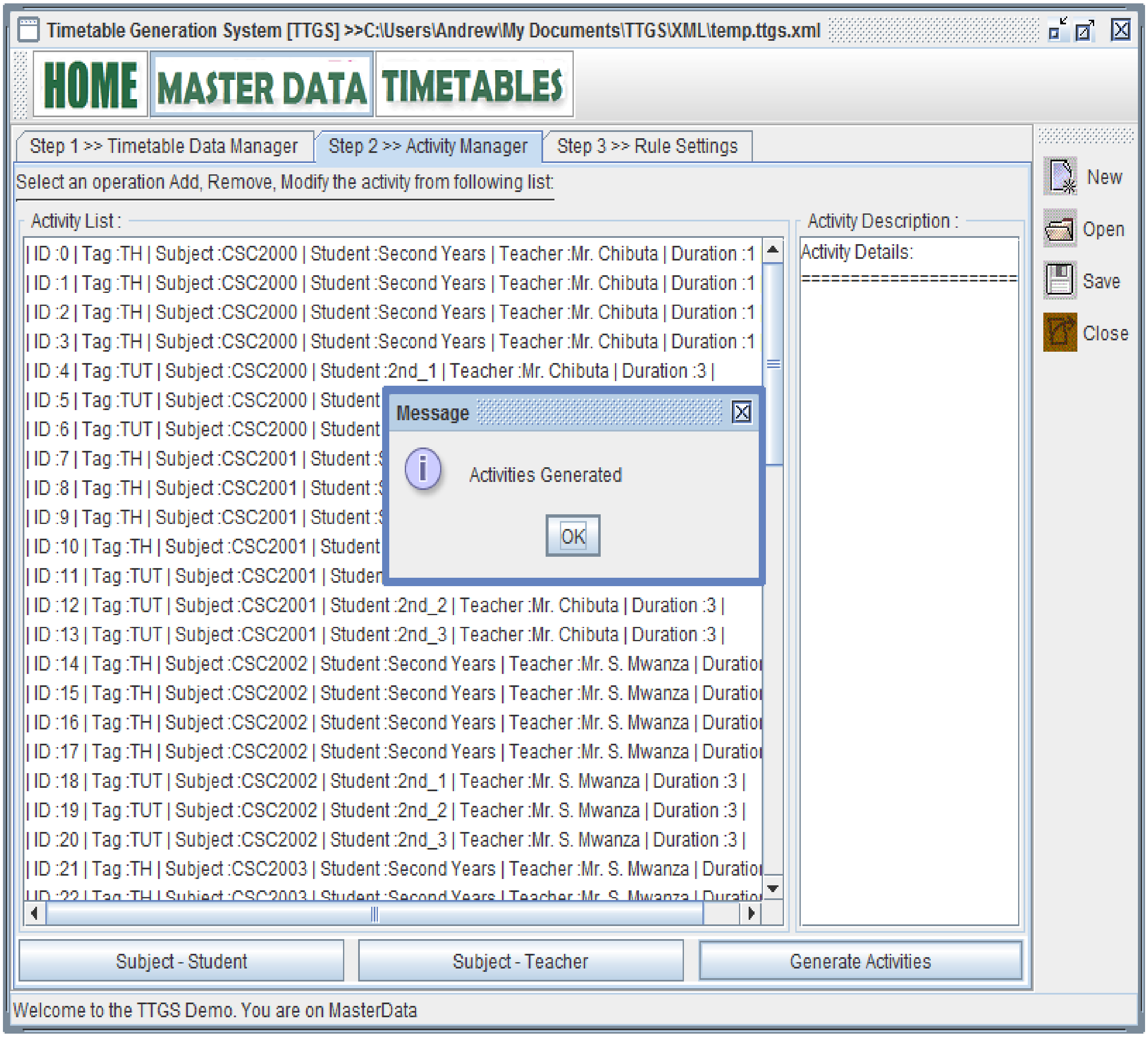


Figure 25: Activity Manager Screen.

The following diagram (Figure 26) shows the Rules Manager Screen which allows the user to set the soft constraints such as Break Time, Teacher Availability, Student Availability, etc.

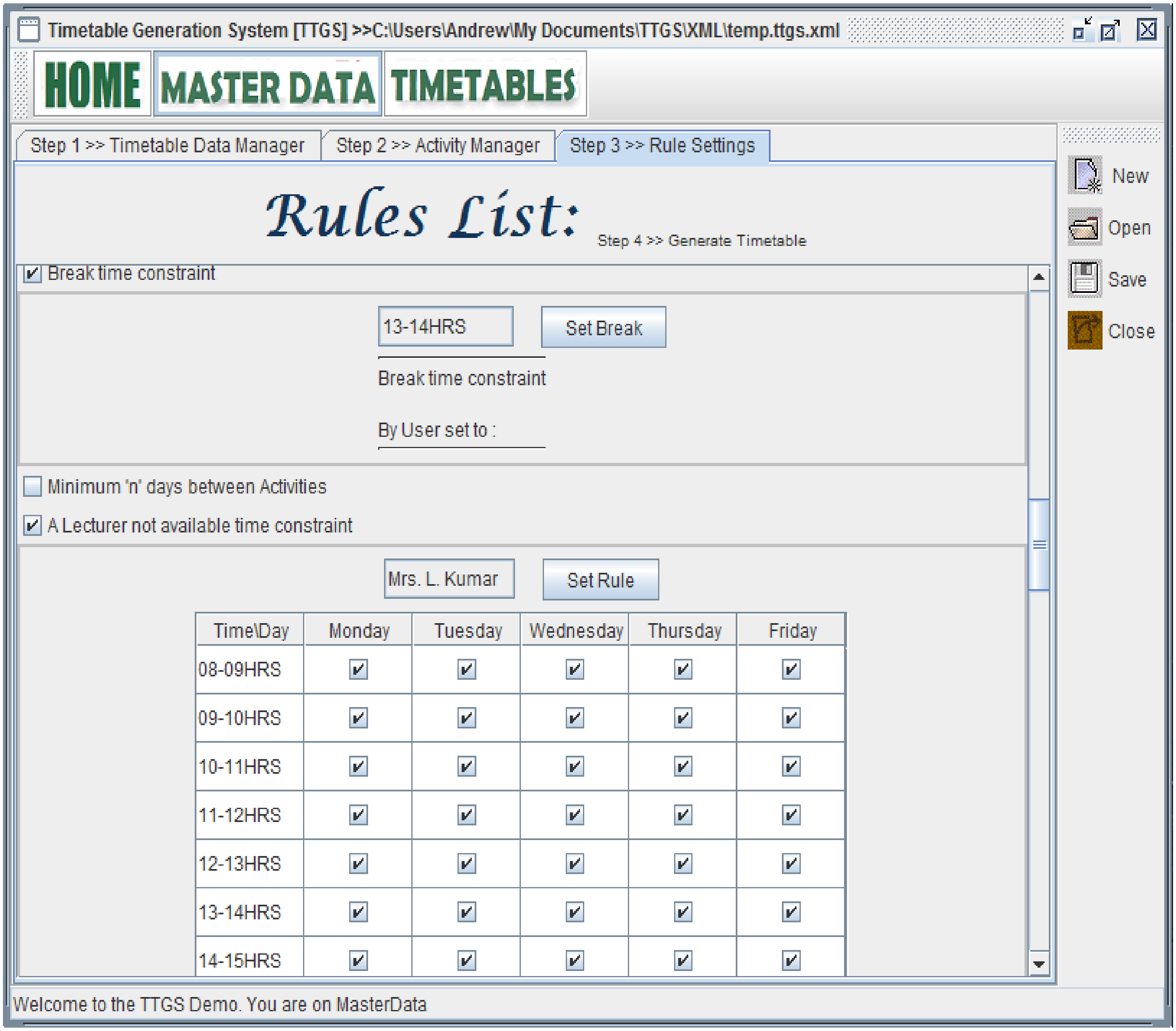


Figure 26: Rules Manager Screen.

The diagram below (Figure 27) shows the Timetable Generation Screen which allows the user to generate the timetable. If the timetable is successfully generated, a message is displayed that indicates that the timetable has been generated successfully. If the user desires a different output, then they just have to regenerate it.

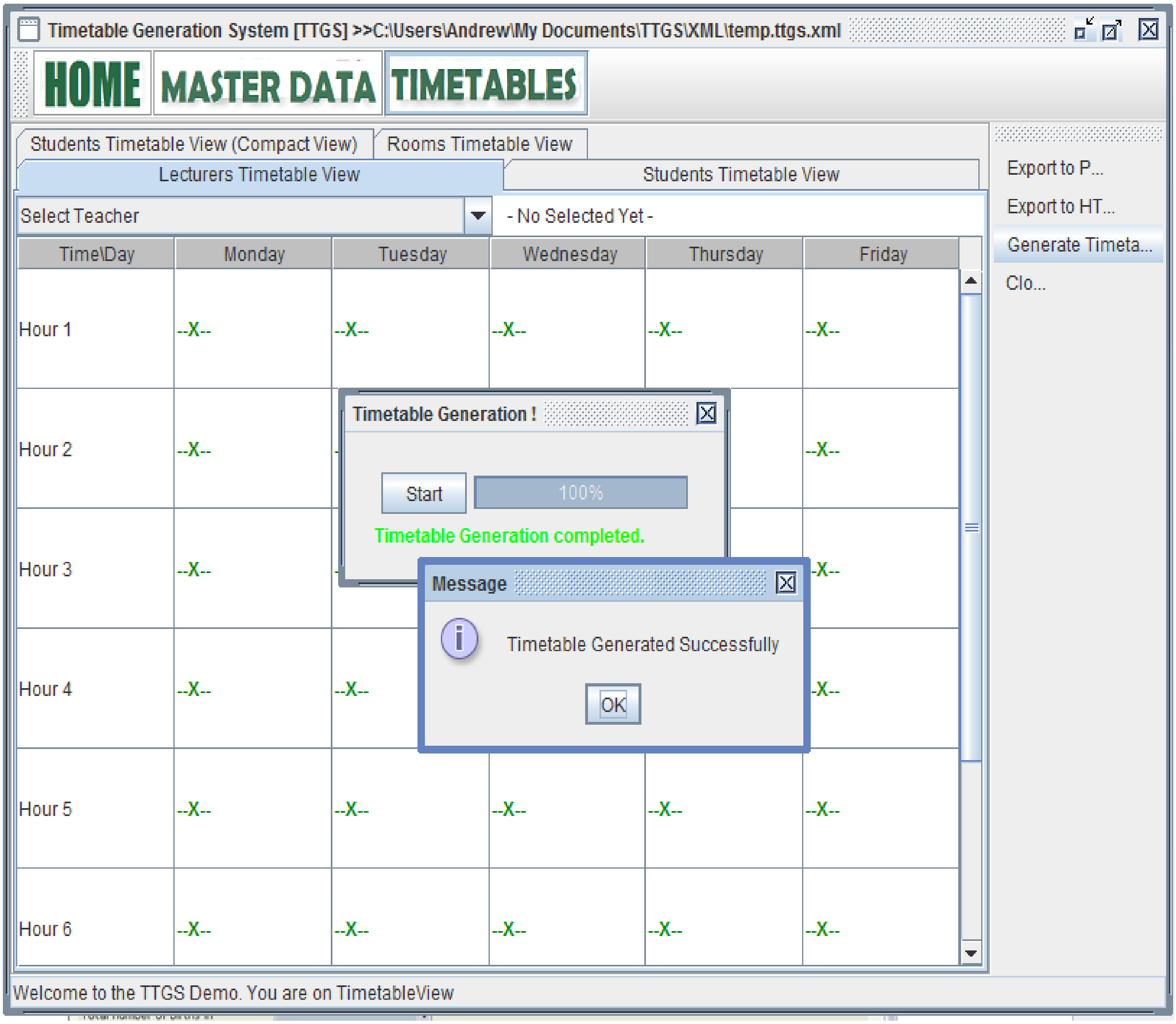


Figure 27: Timetable Generation.

7.3.3 TIMETABLE VIEW SCREEN

The diagram (Figure 28) below shows various Timetable Views after successful timetable generation.

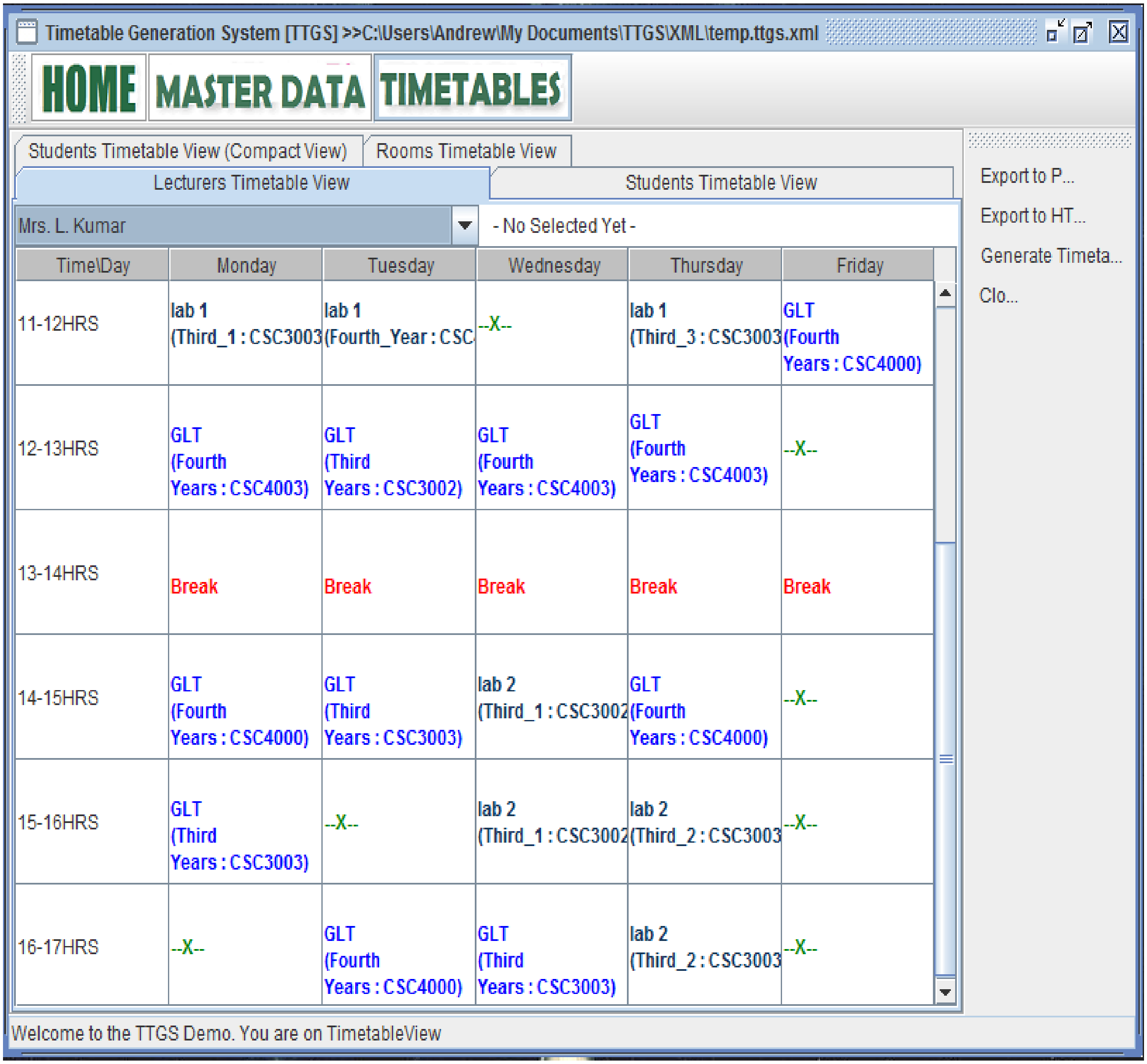


Figure 28: Teacher Timetable View.

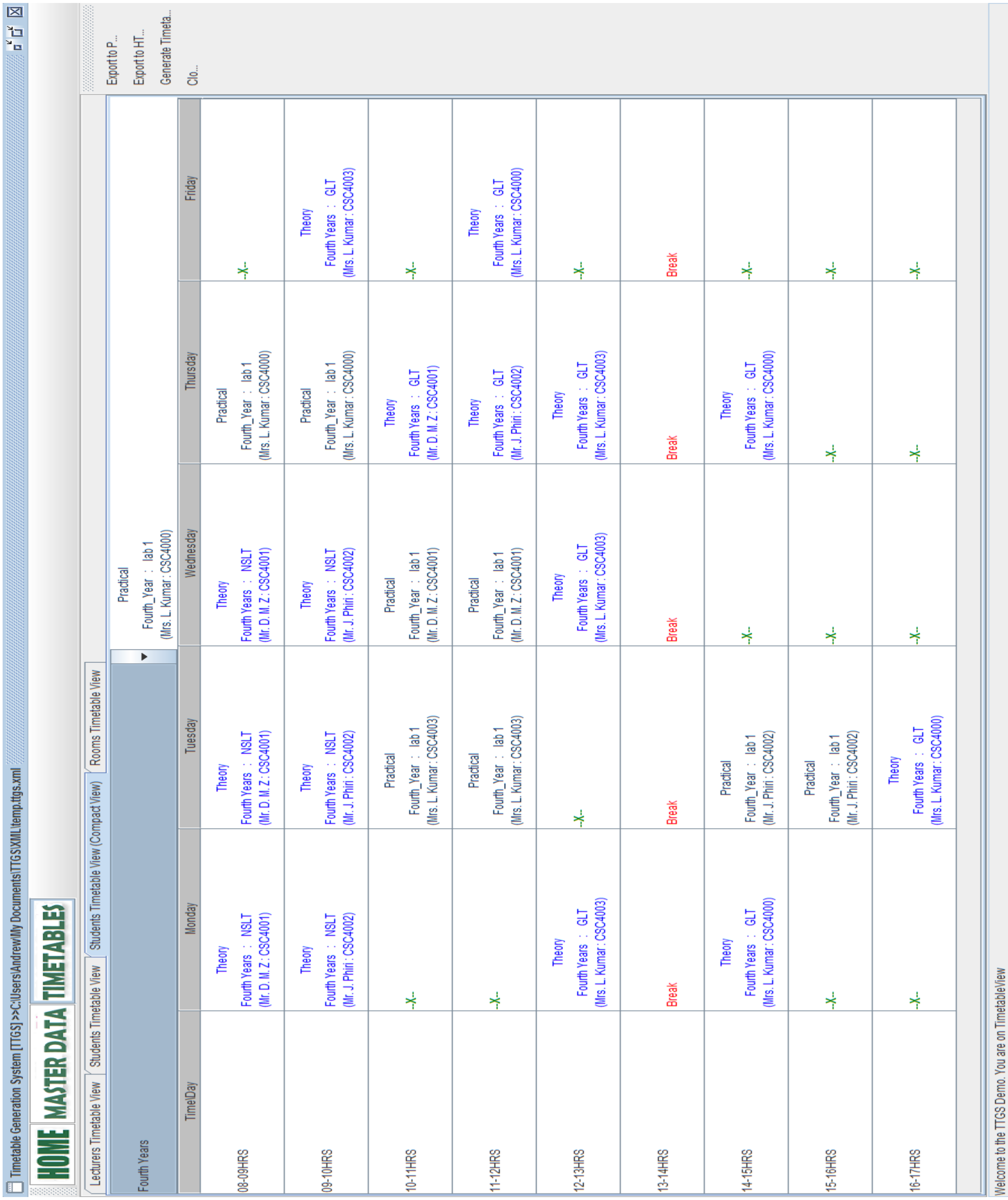
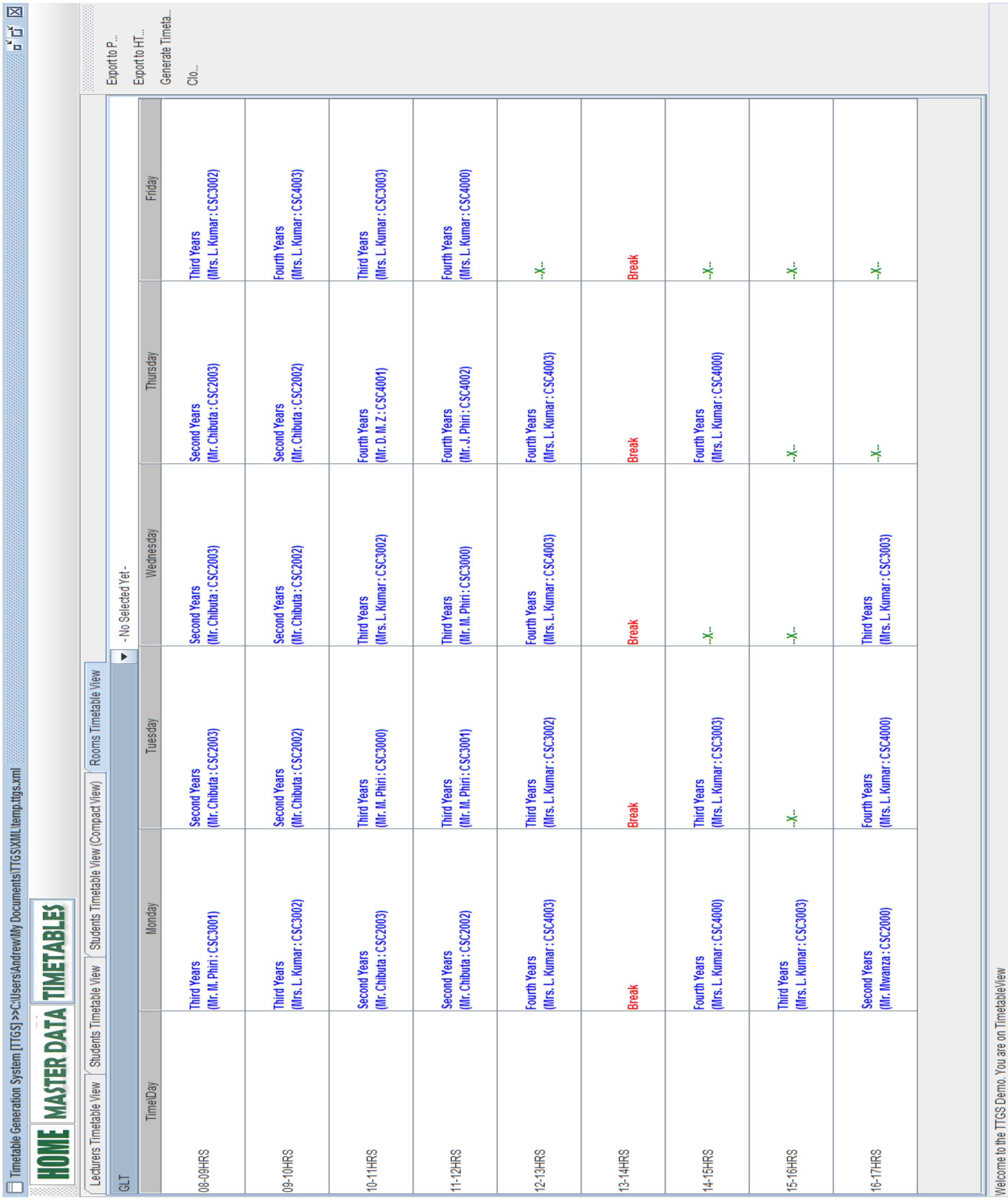


Figure 29: Student Timetable View.



Time\Day	Monday	Tuesday	Wednesday	Thursday	Friday
08-09HRS	Third Years (Mr. M. Phiri : CSC3001)	Second Years (Mr. Chibuta : CSC2003)	Second Years (Mr. Chibuta : CSC2003)	Second Years (Mr. Chibuta : CSC2003)	Third Years (Mrs. L. Kumar : CSC3002)
09-10HRS	Third Years (Mrs. L. Kumar : CSC3002)	Second Years (Mr. Chibuta : CSC2002)	Second Years (Mr. Chibuta : CSC2002)	Second Years (Mr. Chibuta : CSC2002)	Fourth Years (Mrs. L. Kumar : CSC4003)
10-11HRS	Second Years (Mr. Chibuta : CSC2003)	Third Years (Mr. M. Phiri : CSC3000)	Third Years (Mrs. L. Kumar : CSC3002)	Fourth Years (Mr. D. M. Z : CSC4001)	Third Years (Mrs. L. Kumar : CSC3003)
11-12HRS	Second Years (Mr. Chibuta : CSC2002)	Third Years (Mr. M. Phiri : CSC3001)	Third Years (Mr. M. Phiri : CSC3000)	Fourth Years (Mr. J. Phiri : CSC4002)	Fourth Years (Mrs. L. Kumar : CSC4000)
12-13HRS	Fourth Years (Mrs. L. Kumar : CSC4003)	Third Years (Mrs. L. Kumar : CSC3002)	Fourth Years (Mrs. L. Kumar : CSC4003)	Fourth Years (Mrs. L. Kumar : CSC4003)	-X-
13-14HRS	Break	Break	Break	Break	Break
14-15HRS	Fourth Years (Mrs. L. Kumar : CSC4000)	Third Years (Mrs. L. Kumar : CSC3003)	-X-	Fourth Years (Mrs. L. Kumar : CSC4000)	-X-
15-16HRS	Third Years (Mrs. L. Kumar : CSC3003)	-X-	-X-	-X-	-X-
16-17HRS	Second Years (Mr. Mwanza : CSC2000)	Fourth Years (Mrs. L. Kumar : CSC4000)	Third Years (Mrs. L. Kumar : CSC3003)	-X-	-X-

Figure 30: Room Timetable View.

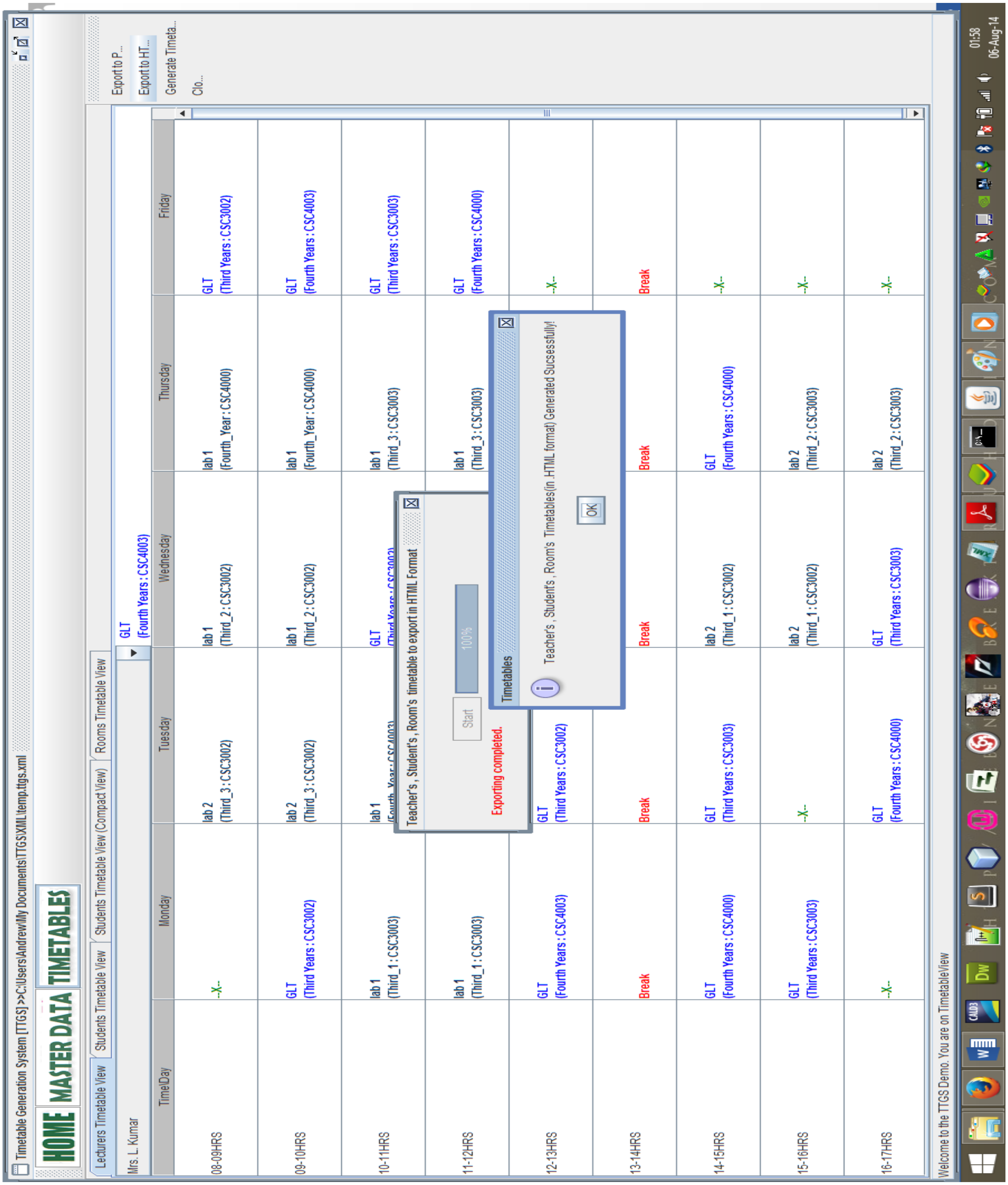


Figure 31: Timetables Export to HTML.

7.4 TEST CASES

7.4.1 TEST CASE 1: LOGIN SCREEN

Objective : - To check whether user name & password are valid or invalid.

Test Data : - User Name = ”admin” and Password =”admin”.

Sr No.	Steps	Data	Excepted Data	Actual result	Status
1	Enter username, password and click on the Login button.	admin admin	Should display a welcome message and take the user to the main screen.	✓	Pass
2	Enter correct User name and blank password and click on the Login button.	admin	Should display an error message ‘Must Enter Password.’	✓	Pass
3	Enter blank username and correct password and click on the submit button.	admin	Should display an error message ‘Must Enter User Name.’	✓	Pass
4	Enter blank user name and blank password and click on the submit button.	admin	Should display an error message ‘Must Enter User Name & Password.’	✓	Pass
5	Enter wrong user name and password.	andrew biemba	Should display an error message ‘Sorry try again!’	✓	Pass

Table 3: Test Case for the Login Screen.

7.4.2 TEST CASE 2: COMPUTER STUDIES DEPARTMENT.

The table below shows the work load of the Computer Studies Department.

Sr. No	Name Of Staff	Courses	Year/ Group	Theory (Hrs)	Practical/Lab (Hrs)	Total (Hrs)
1	Dr. J. Phiri	CSC 4722 CSC 4130	Fourth Years Fourth Years	3 3	3*1 3*1	6 6
2	Dr. E. Lampi	CSC 4130 CSC 3120	Fourth Years Third Years	3 3	3*1 3*1	6 6
3	Mrs. L. Kumar	CSC 3600 CSC 3612	Third Years Third Years	3 3	3*1 3*1	6 6
4	Mr. D. M. Zulu	CSC 4921 CSC 3402	Fourth Years Third Years	3 3	3*1 3*1	6 6
5	Mr. M. Phiri	CSC 4630 CSC 3712	Fourth Years Third Years	3 3	3*1 3*1	6 6
6	Mr. A. Theu	CSC 4745 CSC 4505	Fourth Years Fourth Years	3 3	3*1 3*1	6 6
7	Mr. S. Chibuta	CSC 2202 CSC 3712	Second Years Third Years	3 3	3*1 3*1	6 6
8	Mr. S. Mwanza	CSC 2000 CSC 2702	Second Years Second Years	3 3	3*1 3*1	6 6

Table 4: Computer Studies Dept. work load.

8 CHAPTER EIGHT: CONCLUSION

8.1 CHALLENGES

It has not been an easy road and certainly a number of challenges here and there were encountered. I came across many difficulties and problems while implementing this software but my tremendous desire to complete the project made me overcome them.

The issue of time management posed a great challenge on the completion of the project. The project, to start with, was started later into the academic year and not at the beginning. To ensure timely completion of the project, it was a mammoth task to adequately define and identify sequences of all activities to be carried out. Estimating activity resources and their duration was hectic. Schedule development and controlling it throughout the project lifespan was difficult too. Despite all this, the project was successfully implemented.

8.2 CONCLUSION

This project has evolved from just a mere idea into a life changing Time Table Generation System that will definitely have an instant impact on academic institutions. Users (college or university administrators) will generate timetables automatically instead of the laborious manual way of having to brain storm on how to avoid course or room clashes by student groups. The system will generate time tables in a quicker and more convenient way, thereby saving a lot of time and effort in the process.

During the system analysis and design stages, objects were identified from the functional requirements, contextual and block designs were constructed and with the aid of special software development tools such as Visual Paradigms, use case diagrams, sequence diagrams, activity diagrams and class diagrams were created which ultimately led to the implementation of the full-fledged software system.

The project met the aims and objectives and thus the software system is capable of performing the core operations it was primarily developed for. It includes all the fundamental functionalities stated in the proposal. Therefore, it was a major success and my hope is that this software will be used in colleges, universities and other academic institutions as an Open Source Project.

Finally, it is hoped that the knowledge acquired in this undertaking shall be put to good use and also be applied in solving real life problems in the industry and hence ultimately make the world a better place to live in.

It is expected that this system will receive overwhelming response from the general public due to its user friendliness and hence will simplify the lives of the masses and make time table creation a joy indeed.

8.3 FUTURE WORK

- To extend the system so as to accommodate all lecture sessions across the university.
- To generate timetables for all classes which use shared resources.
- To also include exam scheduling in the system.
- To provide additional features such as:
  - Student Attendance.
  - Assignment Distribution over the intranet.
  - Direct Export to college site.

8.4 RECOMMENDATIONS

A lot of issues have been identified and learnt throughout the development of the TTGS project. To this effect, I put forth the following recommendations:

- The department should convince the corporate world, probably through the project's coordinator, to give and/or allow students to do some of their projects.
- The department should ensure that projects are started on time, at the beginning of the academic year, to facilitate early or timely and smooth completion of projects.

- The department of computer studies should introduce courses that focus on Web Technology to help students apply the techniques in their final year projects.

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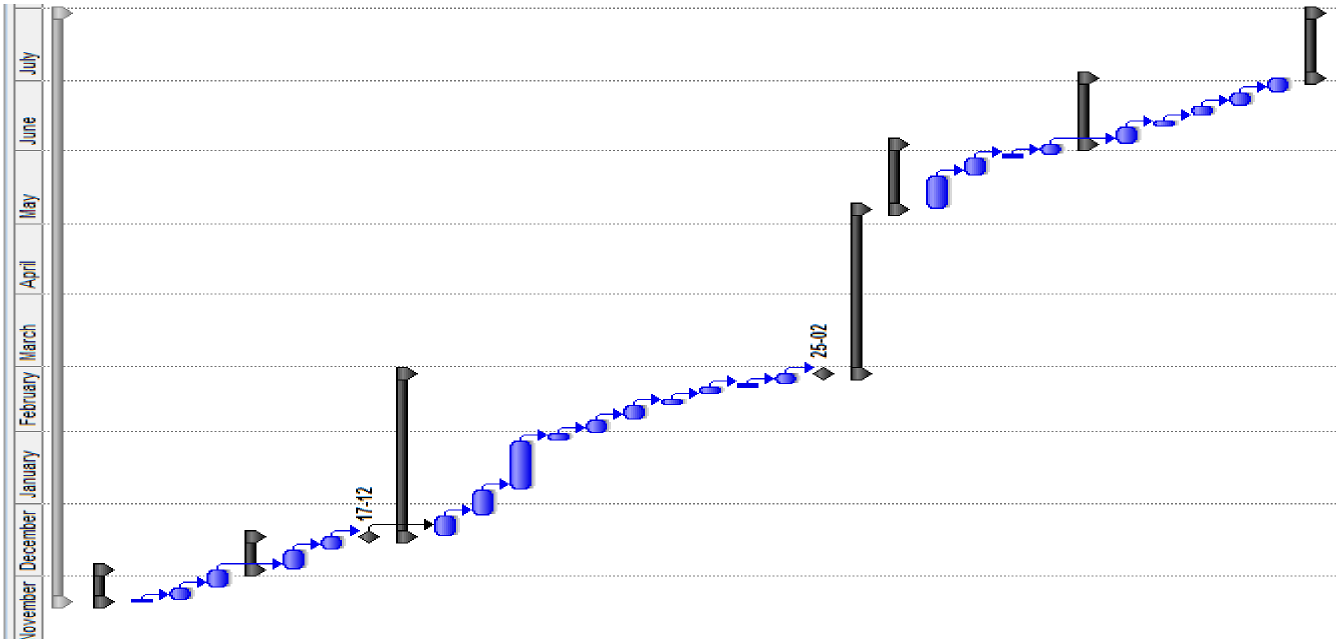
10 APPENDIX

10.1 APPENDIX A: MAIN ALGORITHM

```
public void MainAlgo(int itration) {

    if (GENERATE_SUCCESS) {

      System.out.println("FIN" + itration);

    } else {

      initMatrices();

      Random ActR = new Random(ds.getActivityLength());

      for (int Days = 0; Days < c; Days++) {

       for (int TimeSlot = 0; TimeSlot < r; TimeSlot++) {

        for (int activity = 0; activity < ds.getActivityLength(); activity++) {

         int randAct = ActR.getRandValue(activity);

         if (!isActPlace.get(randAct).booleanValue())

          if (placeActivity(randAct, TimeSlot, Days))

              isActPlace.set(randAct, true);

        }

       }
```

```
        }

for (int i = 0; i < ds.getActivityLength(); i++) {

          int randAct = ActR.getRandValue(i);

          if(!isActPlace.get(randAct).booleanValue()) {

            GENERATE_SUCCESS = false;

            break;

          } else {

            GENERATE_SUCCESS = true;

            createCombinedTT();

          }

        }

      }

    }
```

10.2 APPENDIX B: GANTT CHART



	Task Name	Duration	Start	Finish	Predecessors
0	Timetable Generation System	180 days	Wed 20-11-13	Tue 29-07-14	
1	1 Initiation	10 days	Wed 20-11-13	Tue 03-12-13	
2	1.1 Meeting With Supervisor.	1 day	Wed 20-11-13	Wed 20-11-13	
3	1.2 Choose Project Title.	3 days	Thu 21-11-13	Mon 25-11-13	2
4	1.3 Project Plan.	6 days	Tue 26-11-13	Tue 03-12-13	3
5	2 Planning	10 days	Wed 04-12-13	Tue 17-12-13	
6	2.1 Develop Scope Plan.	6 days	Wed 04-12-13	Wed 11-12-13	4
7	2.2 Review Scope Plan.	4 days	Thu 12-12-13	Tue 17-12-13	6
8	2.3 Approve Scope Plan.	0 days	Tue 17-12-13	Tue 17-12-13	7
9	3 Analysis Tasks	50 days	Wed 18-12-13	Tue 25-02-14	
10	3.1 Information Gathering	7 days	Wed 18-12-13	Thu 26-12-13	8
11	3.2 Technology Familiarization	7 days	Fri 27-12-13	Mon 06-01-14	10
12	3.3 Study & Analyze Information Gathered.	15 days	Tue 07-01-14	Mon 27-01-14	11
13	3.4 Define draft requirements.	3 days	Tue 28-01-14	Thu 30-01-14	12
14	3.5 Create entity relationship diagram for database.	4 days	Fri 31-01-14	Wed 05-02-14	13
15	3.6 Create sample interface.	4 days	Thu 06-02-14	Tue 11-02-14	14
16	3.7 Create sample report.	3 days	Wed 12-02-14	Fri 14-02-14	15
17	3.8 Develop simple prototype of database.	3 days	Mon 17-02-14	Wed 19-02-14	16
18	3.9 Review prototype with supervisor.	1 day	Thu 20-02-14	Thu 20-02-14	17
19	3.10 Make adjustments based on supervisor feedback.	3 days	Fri 21-02-14	Tue 25-02-14	18
20	3.11 Initial prototype approved by supervisor.	0 days	Tue 25-02-14	Tue 25-02-14	19
21	4 Design Tasks	50 days	Wed 26-02-14	Tue 06-05-14	
37	5 Implementation Tasks	20 days	Wed 07-05-14	Tue 03-06-14	
38	5.1 Front-end Implementation	10 days	Wed 07-05-14	Tue 20-05-14	36
39	5.2 Integrating Front-end With Database	6 days	Wed 21-05-14	Wed 28-05-14	38
40	5.3 System Installation.	1 day	Thu 29-05-14	Thu 29-05-14	39
41	5.4 Enter project data.	3 days	Fri 30-05-14	Tue 03-06-14	40
42	6 Testing	20 days	Wed 04-06-14	Tue 01-07-14	
43	6.1 Test database.	5 days	Wed 04-06-14	Tue 10-06-14	41
44	6.2 Analyze Defects.	3 days	Wed 11-06-14	Fri 13-06-14	43
45	6.3 Make adjustments, as needed.	4 days	Mon 16-06-14	Thu 19-06-14	44
46	6.4 Conduct user testing.	4 days	Fri 20-06-14	Wed 25-06-14	45
47	6.5 Make adjustments based on user testing.	4 days	Thu 26-06-14	Tue 01-07-14	46
48	7 Closing	20 days	Wed 02-07-14	Tue 29-07-14	

10.3 APPENDIX C: HOW TO RUN THE PROGRAM

10.3.1 PROCEDURE:

1. Ensure that you have JDK installed on your machine and that you have set the correct path to the java compiler (javac) in the environmental variables of your system.
2. Copy the folder or directory named “TTGS” which contains the java files and other supporting files and libraries onto your computer system.
3. Open the command prompt or terminal.
4. Change the directory to the “TTGS” directory.
5. Compile all the files in this directory (you can use the command “javac *.java” to compile all the files in the directory at once).
6. Compile the Driver (Main) Class separately (use the command “javac TTGS.java”).
7. Run or execute the TTGS.java file (use the command “java TTGS”).

Alternatively, you will require to install Eclipse IDE onto your machine. With Eclipse IDE running on your machine, you simply have to copy the contents of the TTGS folder to the IDE or just import the folder as a new project. Then select the folder in the eclipse window and click on the execute button or icon to run the program.