Egineering Journal of the University of Qatar, Vol. 11, 1998, p. 193 - 208

SPREADSHEET CLASS SCHEDULING FOR THE COLLEGE OF ENGINEERING, UNIVERSITY OF QATAR

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ABSTRACT

The process of preparing class schedules is a lengthy and painstaking experience, especially when the requirements on the system approach saturation capacity. Instructors have to be assigned to places, with different capacities, for lectures, tutorials and laboratories, within the available time slots per day and working days per week, to satisfy the courses offered in a given semester. This paper analyzes the problem, discusses two approaches to solve it using manual trial and error and mathematical programming, and suggests a spreadsheet program to maintain the obtained solution. The author demonstrates that spreadsheets are a very efficient computational environment for maintaining up to date class schedules, producing useful reports, solving class conflicts, and planning for future extension of the college.

INTRODUCTION

The preparation of class schedules that suit both students and instructors and can fit into the available physical environment of the educational institution is very important to improve the efficiency of the education process.

Many class scheduling systems have been developed by universities or by software houses. For instance, the Purdue's University West Lafayette campus [1], has a scheduling system, the objective of which is to maximize the probability for all students to receive their first choice of courses. The system also produces schedules for final and evening examinations, and for graduate assistants teaching. The Class Scheduling System (CLASS) at the University of California, Berkley [2] assigns rooms to classes using a multi-pass sorting algorithm, produces several reports, and is integrated with other database systems. The resulting time tabling system requires a massive computation effort with over 170 internal programs!. Such systems are characterized by their complexity and relation to other databases on campus. They

are usually part of a more comprehensive administrative software, and run on large computers. Commercial class scheduling software are also available, but are expensive and sometimes difficult to use.

At the University of Qatar the schedule is typically prepared using a cumbersome manual trial and error procedure. However, if the class schedule could be put into an electronic environment that is easily available, simple to use, inexpensive and efficient, the procedure of maintaining the schedule and solving the class conflicts will be greatly facilitated. Spreadsheets provide a computational environment that is very suitable for class schedule preparation and maintenance, as well as making rapid changes when circumstances insist. The nature of spreadsheets is that they are composed of rows and columns which facilitates data entry and production of class schedule reports. Other spreadsheet features such as sorting and filtering data, immediate updating of reports, production of charts, and customizing reports are also very helpful.

THE CLASS SCHEDULING PROBLEM

The variables that comprise the problem are: the instructors, the places, the time slots, and the courses. The objective is to assign instructors to specific places and time slots to satisfy the teaching requirements dictated by the courses offered in a specific semester. The situation may be further complicated when credit hours systems are adopted, since the number of options is much larger. The assignment problem is constrained by the teaching load of instructors, the availability and capacity of places, i.e. lecture theaters, tutorial rooms, and technical laboratories. The whole system has to fit within the available daily instruction time for the working days of the week.

In general, the problem will have a solution if the instructors' teaching load in hours is greater than or equal to the total contact hours of the offered courses, and the latter being less than the maximum available teaching hours in the week within the physical constraints. The system has to be overdesigned to allow ease of allocation for future extension and emergencies.

In addition to the above main system constraints, other constraints may allow for consolidating contact hours for students and instructors, avoiding possible class overlaps for students taking courses from different years, minimizing the non-instruction time (reducing the time gaps between instruction hours), maintaining the same room for a particular lecture to avoid confusion, allow a day or two between

the lecture and its tutorial, and avoid the situation where instructors are assigned two consecutive lecture hours, when they do not wish this.

MANUAL APPROACH

The manual preparation of the class schedule, which is an error prone procedure, is also lengthy and painstaking. Assigning instructors to classes and checking availability of place and avoiding conflicting overlaps is made by trial and error, and may take several runs before reaching the final form. Also, a lot of the time is taken in preparing the detailed timetable reports and updating them after each editing. Some simple rules may be put to satisfy some of the constraints mentioned above and organize this manual process. Examples would be assigning the lectures in the morning, allowing a day or two between a lecture and its tutorial or laboratory, using the same location and time slot for a specific course, and starting with the larger classes first. The needed timetable reports such as the schedule for instructors, occupation of places, schedule for department and years are prepared on different sheets, that have to be revised each time a change is made. One of the examples of schedule updating tasks is to reflect the changes occurring from courses that were offered but not elected by students. Checks have to be made to insure that the number of registered students in a course does not exceed the capacity of the assigned place.

MATHEMATICAL PROGRAMMING APPROACH

The problem of assigning instructors to classes can be formulated as a resource allocation linear programming (LP) model. The LP model is a mathematical expression of the problem in the form of an objective function, subject to a set of constraints, where the function and the constraints are all linear functions of the system variables. The details of such model can be found in [3]. The system variables represent whether an instructor is occupying the time slot or not. A special type of LP, the 0-1 integer programming is more suitable for this particular application since the variables can assume either 0 or 1, indicating for instance the absence or existence of the instructor. The system constraints may reflect the teaching load for each instructor, the space limitation, instructor preference, and other special conditions that may be required by the administration.

A simple hypothetical example is used for the purpose of illustration. The education body has three instructors, four working days (the fifth working day is allocated to professional development of staff), and six time slots each day, four in

the morning and two in the afternoon. There are only six courses offered per semester. There is one space for lecture and a different space for tutorial available for each time slot. The teaching load is two lectures and two tutorials per instructor per week. It is also assumed that the first instructor does not prefer early morning classes, and the second prefers early classes, while the third has no special preferences. The last set of constraints will illustrate how to incorporate special conditions.

The system is feasible because the number of instructors multiplied by the teaching load (3x4) equals the number of offered course contact hours (6x2), and the number of teaching contact hours is less than the maximum possible hours which is 2 places x 6 time slots x 4 days = 48. The system degree of utilization is 12/48 x100 =25%.

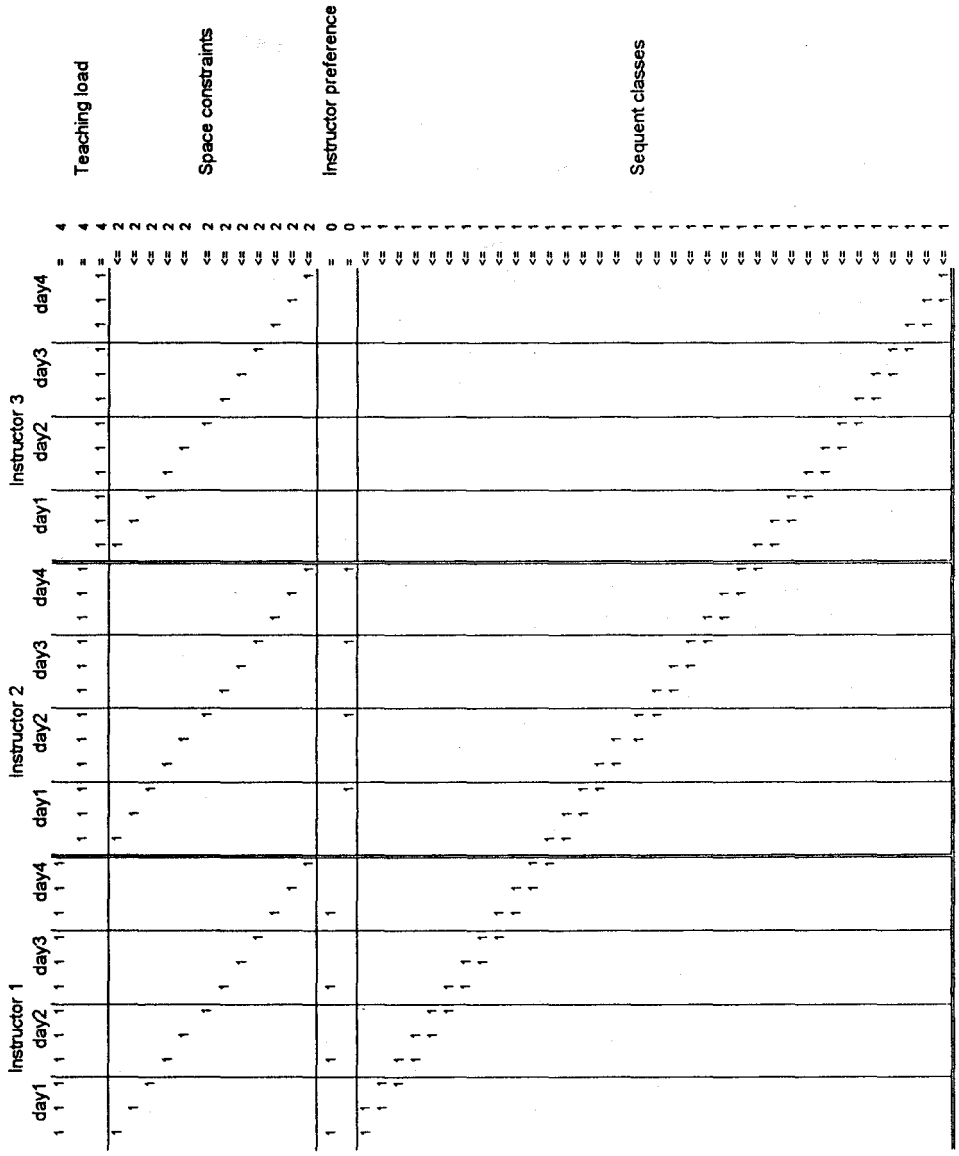
Using the definition of the system variables above, the number of variables is equal to the number of time slots per week, i.e. 3 instructors x 4 days x 6 time slots x 2 places = 144. The number of constraints will be 3 teaching load constraints + 24 space availability constraints (6 slots x 4 days) + 2 instructor preferences + 71 constraints to insure that instructors are not assigned two consecutive lectures or tutorials (6 slots x 4 days x 3 instructors -1). The total number of constraints is therefore 100, i.e. (3+24+2+71). It has to be noted that each instructor can occupy either a lecture or a tutorial in a given time slot.

It can be seen that even for this relatively simple problem, the number of system variables and constraints is relatively large for the chosen problem formulation. For demonstration purposes only, reductions will be made to the problem. These reductions are: each lecture or tutorial will take two consecutive time slots and the lecture space will be used for the tutorial and vice versa. The latter assumption will reduce the number of system variables and consecutive lecture constraints by half. Thus, the resulting system variables reduce to: 3 instructors x 4 days x 3 time slots = 36, and the constraints reduce to: 3 for teaching load + 12 for space constraints + 2 for instructor preference + 35 to still avoid consecutive lectures or tutorials (3 slots x 4 days x3 instructors -1) with a total of 52. The size is reduced from 144 x 100 to 36 x 52. Table (1) shows the reduced constraint matrix, where there are 3x4=12 variables for each instructor representing his availability in 3 slots per day, 4 days per week.

The following are examples of how the constraints are written:-

The teaching load constraint for Instructor 1 is expressed as:

Table 1. Constraint Matrix for LP Model



$$\sum_{i=1}^{i=12} x_i = 4 \tag{1}$$

where x_i is the variable number i, and the 4 is the number of teaching slots per week.

The space constraint for the first slot is expressed as:

$$x_1 + x_{13} + x_{25} \leq 2 \tag{2}$$

where x_1, x_{13}, and x_{25} represent the availability of the three instructors in the first slot, and the 2 indicates that there are only two lecture places.

The instructor's preference constraint for Instructor 1, who does not prefer early classes is expressed as:

$$x_1 + x_4 + x_7 + x_{10} = 0 \tag{3}$$

The consecutive lecture constraint for Instructor 2 for slots 1 and 2 on the first day of the week is expressed as:

$$x_{13} + x_{14} \leq 1 \tag{4}$$

Solving the LP problem, using any available LP package [4], produces the optimal solution shown in Table (2) where all the constraints are satisfied. An important feature of LP is the ability to solve huge problems, and that a global optimal solution can be always obtained given that the problem is feasible and properly formulated.

SPREADSHEET APPROACH

Spreadsheets are computational tools used frequently by accountants, scientists and engineers. They allow a wide range of calculations to be done efficiently. The details of the EXCEL spreadsheet program used for the application presented in this paper is given in [5]. The sheet designed to handle the class scheduling problem is capable of editing the suggested schedule and produce table reports through a user friendly interaction. The spreadsheet can be arranged to include the data required to present the suggested class schedule in the simplest possible form, where data entry and editing is made easy and where changes can be made quickly.

Table 2. Variable and Solution Matrices for LP Model

	day1			day2			day3			day4		
Instructor 1	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12
Instructor 2	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	x23	x24
Instructor 3	x25	x26	x27	x28	x29	x30	x31	x32	x33	x34	x35	x36

Instructor 1		1			1			1			1	
Instructor 2	1			1			1			1		
Instructor 3	1		1		1		1					

The ability to answer questions representing possible scenarios or solving emergency needs in the future can also be done very efficiently. The reports that can be extracted using the database functions may include the time table for each instructor, the occupation of each place for lecture, tutorial and laboratory, or the time table for a specific department or a specific year within the college program. The database can also answer questions like the time availability of certain large theaters for faculty and students get together, a possible slot for a faculty meeting, etc. Charts can be made to display the teaching load for faculty members, the saturation percentage of college spaces, the uses of certain place by a specific department, etc. Macros, which are small programs for repeating key strokes, can be written to automate report and chart generation and printing. The EXCEL program provides a 'Pivot Table' function that facilitates the preparation of customized reports with minimum effort from the user's side.

Case Study: College of Engineering, University of Qatar

The College of Engineering, University of Qatar has four departments, namely: Civil, Mechanical, Electrical, and Chemical. The data entered for each department are used to produce tables and charts related to each department. The data for all departments are combined together to produce tables and charts for the facilities shared by the College as a whole. Two different types of lecture theaters and labs are available; those for the general use by any department and for the first year, and those that are used only by the respective departments. The data used for demonstration are of a typical spring semester. Figure (1) shows the number of instructors and courses offered for each department, and Figure (2) shows percentage of students distribution in the college. Figure (3) shows teaching hours

for all faculty members. The relatively higher teaching loads are for instructors of first year general courses characterized by larger number of students which need several tutorial and laboratory groups. On the other hand, the relatively lower teaching loads are for instructors having heavy University administrative assignments. A rough estimate of the system degree of saturation can be calculated as about 40%, since the maximum available slot places is 10 slots x 5 days x 17 rooms = 850, and the manpower is 35 instructors x 10 hours average teaching load.

The basic schedule data entered comprise three blocks. The first block is the main one that contains the schedule data which is the day, slot, place and course number. The second block contains the course number, course title, the instructor's name, number of contact hours, the department, and number of registered students. The third block contains the place, its capacity, whether it is used for lecture or

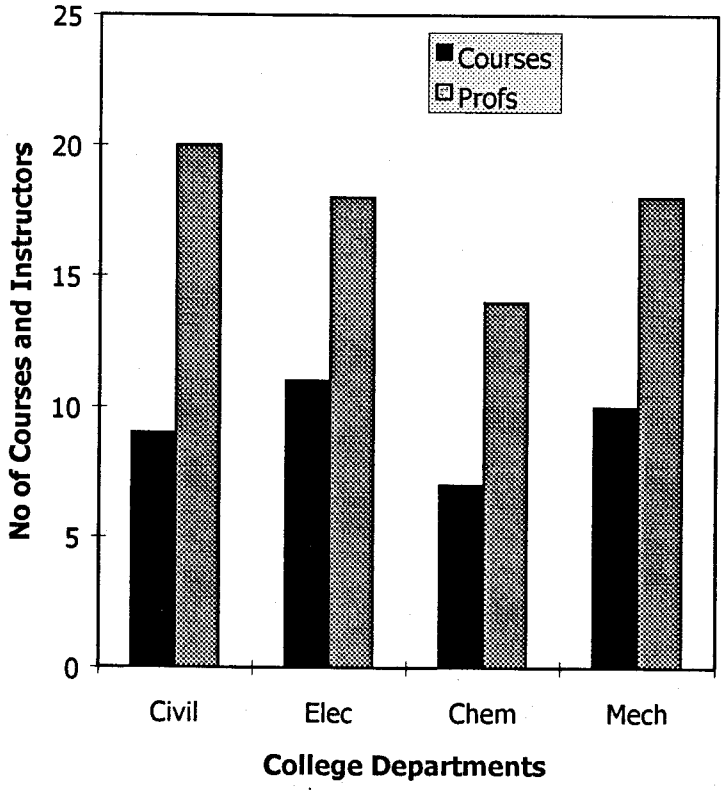


Fig. 1. Number of courses offered and instructors

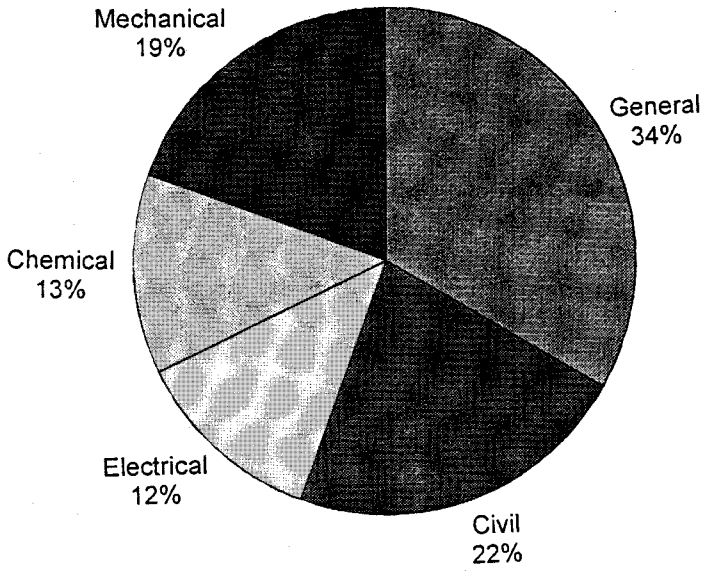


Fig. 2. Distribution of registered students

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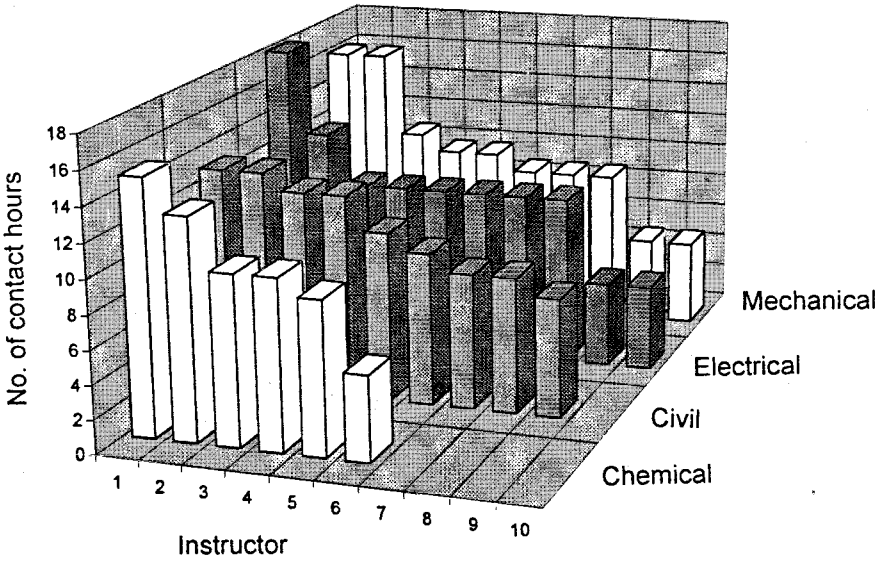

Fig. 3. Teaching hours for instructors

laboratory, and whether it is shared or belongs to certain department. The latter two blocks are added to the first to make a larger table containing all the information in the three blocks using the table lookup function. This data arrangement minimizes the data entry effort. Tables (3) though (5) show part of blocks one to three respectively.

The spreadsheet notebook composed of several sheets is arranged into seven worksheets, the first four are for the departments, the fifth is for courses offered to engineering students from the college of science and the English language units. The sixth worksheet is for the whole college of engineering combining the data in the previous sheets. The seventh worksheet is used to analyze conflicts for groups of registered students. Different timetable reports can be generated from the data in each worksheet depending on need. Each table report comprise three distinct sections; the rows, columns, and page sections. The first two are fixed while the third can be changed to allow the generation of series of tables, where choices are made using a spin control button. Figure (4) shows a typical table arrangement screen that demonstrates how data items can be dragged to the different section, i.e. the rows, columns and range sections. Table (6) presents a sample department course-instructor place report showing the occupation of a civil engineering room, where the rows section comprises the day of the week, the course number and instructor's name, the columns section comprises the slots of the day. The changing page section provides the choice of a specific room from a list of the rooms used by the department. Table (7) presents another department report showing instructor's time table where the rows section contains the day, the place and the course number, while the columns section contains the slots of the day. The changing page

Table 3. Part of Block 1

Day	Slot	Place	Crsnum
Sat	4	E239	CVE555
Sat	2	E209	CVE442
Sat	4	E209	CVE302
Sat	5	E239	CVE505
Sat	5	E231	ENG212
Sat	3	E209	CVE474
Sat	7	E239	CVE271
Sat	8	E239	CVE271

Table 4. Part of Block 2

Crstitle	Instructor	Conthrs	Dept	Regstd
Surveying (I)	Mohamed Hanafy	5	Civil	22
Structural Analysis (II)	Mohamed Al-Ansari	4	Civil	10
Civil Engineering Materials	Ayman Abdulsalam	4	Civil	15
Soil Mechanics	Waddah Akili	6	Civil	8
Water Resources (I)	Khalid Al-Hajri	5	Civil	25
Foundation Engineering	Waddah Akili	4	Civil	6
Water Resources (II)	Aly El-Bahrawy	4	Civil	12
Pavement Material and Design	Ezzidin Abuserdaneh	4	Civil	17
Selected Topics in Environmenal Engineering	Shamim Ahmed	4	Civil	26
Selected Topics in Transportation Engineering	Ezzidin Abuserdaneh	4	Civil	5
Construction	Ahmed Senouci	3	Civil	25

Table 5. Part of Block 3

Place	Capacity	Type	Usage
E232	40	Lec	Shared
Jazri	40	Lec	Shared
E231	40	Lec	Shared
E222	20	Lec	Electrical
E213	15	Lab	Electrical
E240	20	Lec	Civil
E169	20	Lec	Mechanical
E286	30	Lec	Chemical
E139A	8	Lec	Shared
E261	15	Lab	Chemical

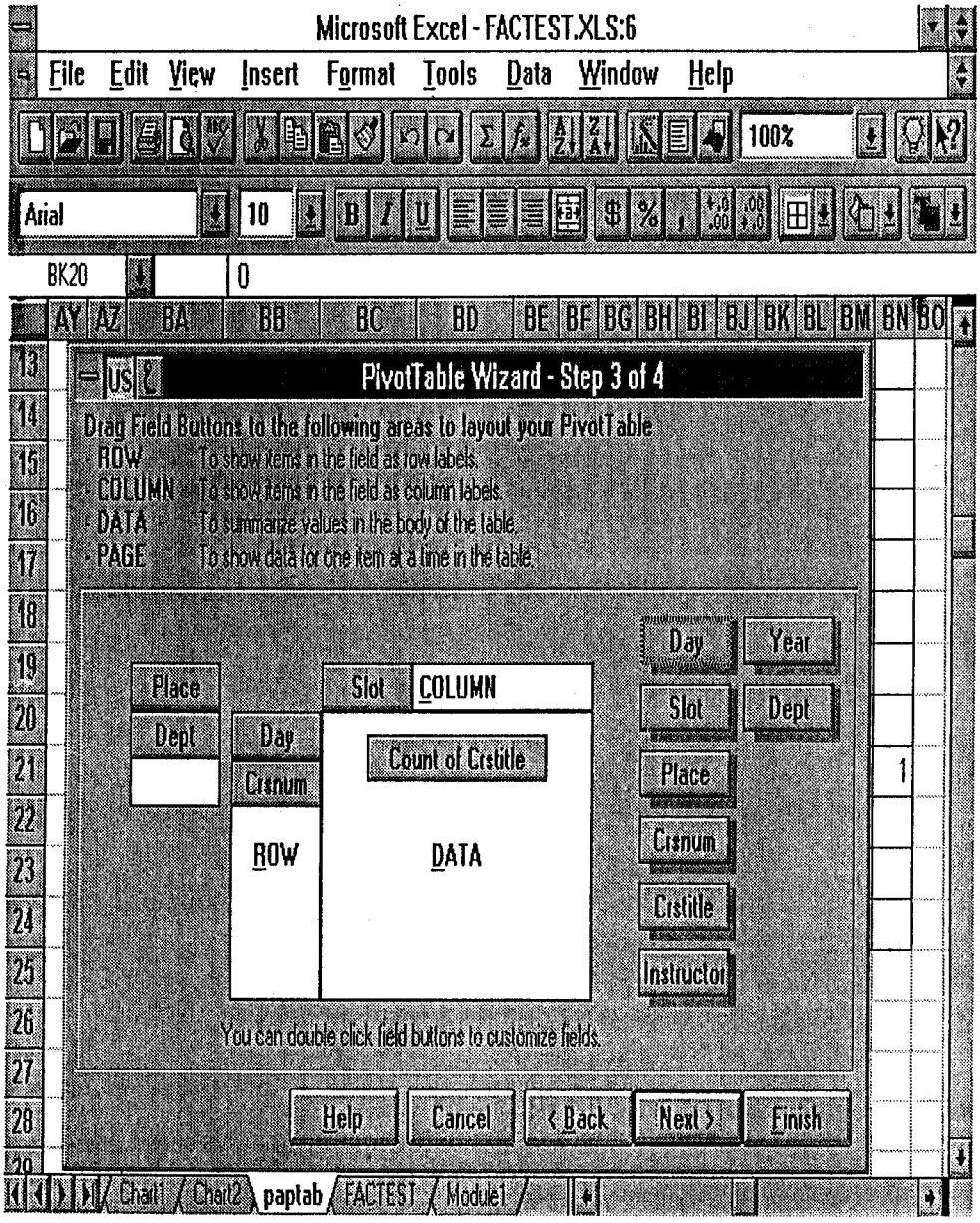

Fig. 4. Use of Pivot table to customize reports

Table 6. Course-Instructor Place Report

Place	E240

Count of Crstitle			Slot					
Day	Crsnum	Instructor	2	3	4	5	6	7
Sat	CVE481	Khalid Al-Hajri			1	1		
Sun	CVE412	Ayman Abdulsalam				1		
	ENG212	Aly El-Bahrawy			1			
Mon	CVE271	Mohamed Hanafy			1			
	CVE412	Ayman Abdulsalam			1			
	CVE434	Waddah Akili		1				
	CVE442	Aly El-Bahrawy				1		
	CVE481	Khalid Al-Hajri	1					
Tue	CVE341	Khalid Al-Hajri	1	1	1			
	CVE412	Ayman Abdulsalam					1	1
Wed	CVE271	Mohamed Hanafy			1			
	CVE302	Mohamed Al-Ansari				1	1	
	CVE481	Khalid Al-Hajri			1			

Table 7. Place-Course Instructor Report

Instructor	Ayman Abdulsalam

Count of Crstitle			Slot							
Day	Place	Crsnum	1	2	3	4	5	6	7	8
Sat	E209	CVE321					1			
	E239	CVE321	1	1	1					
Sun	E240	CVE412					1			
Mon	E209	CVE321					1			
	E240	CVE412				1				
Tue	E240	CVE412						1	1	
Wed	E239	CVE321						1	1	1

section contains a list of the department instructors to choose from. Table (8) presents a college report showing the occupation of a shared lecture room similar to that of Table (6) where the rows section comprises the day and course number. The latter table shows that the room is heavily occupied most of the week

especially in the morning mainly by the English unit and the mechanical engineering department. Table (9) presents another college report summarizing the occupation of all lecture, tutorial and laboratory rooms for all departments. It is worth mentioning that the layout of reports can be easily modified to suit the user using the Pivot Table Wizard menu provided by the EXCEL program.

Table 8. Course Place Report

Place	Jazri
Dept	(All)

Count of Crstitle		Slot									
Day	Crsnum	1	2	3	4	5	6	7	8	9	10
Sat	MCE412						1	1			
	MCE353						1				
	ENG111				1						
	EGL181B	1	1	1							
Sun	ELE302				1						
	ENG103A					1					
	EGL181B	1	1	1							
Mon	MCE443				1						
	MCE461	1	1	1							
	MCE472					1					
	EGL181C							1	1	1	
Tue	ELE555	1	1	1							
	ENG103A						1	1			
	ENG353						1				
	MCE461				1						
	EGL182B								1	1	1
Wed	ENG111				1						
	EGL181B	1	1	1							
	MTH182B						1				

Table 9. Departments Activities Place Report

Place	(All)

Count of Crstitle		Slot										
Day	Dept	1	2	3	4	5	B	6	7	8	9	10
Sat	Chemical	1	2		1	2	2	1	1	1		
	Civil	1	2	3	4	4		1	2	2	1	
	Electrical	1	2	3	4	1		2	2	3	1	
	English	8	8	8								
	Mechanical	1	1	1	2	2		4	3	1	1	
Sun	Chemical				2	4	1	1	1	1		
	Chemistry					1						
	Civil	1	2	2	6	3	1	2	2	1		
	Electrical	2	2	2	5	5		2	3	2		
	English	8	8	8								
	Mathematics								3	3		
	Mechanical	1	1	3	2	2		3	3	3		
Mon	Chemical	1	1	1	1	2	3	3	1	1		
	Chemistry				1							
	Civil	3	5	6	4	3		2	2	2		
	Electrical	2	4	3	5	3		2	2	2		
	English								3	3	3	
	Mathematics				1							
	Mechanical	2	2	3	3	5		3	2	2		
Tue	Chemical	2	3	3	3			1	1	1		
	Chemistry				1							
	Civil	2	3	5	3			2	1			
	Electrical	1	3	3	2			3	3	1	1	
	English									8	8	8
	Mathematics				3							
	Mechanical	2	4	4	3			2	1			
Wed	Chemical	1	1	1	3	1	1	5	2	2		
	Civil		2	3	4	5		5	4	4	1	1
	Electrical	2	2	2	7	2	1	1	1	1		
	English	8	8	8								
	Mathematics							2				
	Mechanical	1	2	2	3	3		3	3	3		

DISCUSSION AND CONCLUSIONS

This paper reviews the procedure for the new class schedule preparation at the University of Qatar, and demonstrates the use of an in-house LP model to find a mathematical solution to the problem, and a spreadsheet program to maintain the class schedule. The developed applications, and the resulting department and college reports, which are generated automatically, are valuable for the administration to make more efficient use of the available resources. By making the spreadsheet program available to all faculty members through a local area network, they can use it to find solutions to their specific schedule problems, and update the schedule to reflect the changes made. The spreadsheet schedule is simple, easy to use, inexpensive, and requires no previous programming experience. The spreadsheet schedule is also made available in Arabic using the bilingual version of the software. This facility allows other colleges of the University to make use of the developed class scheduling program. The program is now used to set up and maintain the class schedule for the College of Engineering, University of Qatar.

ACKNOWLEDGMENTS

I thank my colleagues Professors Andrew Wilson, and Richard Dawe for reading the manuscript and making many helpful suggestions.

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