DEVELOPING A MULTIHYBRID SYSTEM TO SIMULATE A UNIVERSITY CAMPUS

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ABSTRACT
The main focus of this work lies in developing a simulation system that can represent several different points of view in the world defined by a university campus. The primary focus is on the utilization of spaces as well as the capacity utilization and the ability to test different measures to improve both. But these measures should have no negative impact on the quality of the university teaching from the students' point of view.

Keywords: utilization analysis, space management

1. INTRODUCTION
This work focuses on developing a simulation system that can be used to study and evaluate different points of views in the world of a university campus. The strategies for the assignment of spaces to lectures as well as the capacity utilization of rooms and the ability to test different measures to improve both are included in the main usability. But at the same time these measures should have no negative impact on the quality of the university teaching from the students' point of view.

Opposite to several other approaches used to solve the problem of limited space resources at a university that quite often focus on the timetabling problem (S. Abdennadher, M. Marte 2000),(Beyrouthy C., Burke E.K., McCollum B., McMullan P., Landa-Silva D., Parkes A. 2006) this approach focuses mainly on the facility management point of view (D. Wiegand 2005). The problem of generating a timetable for lectures and courses is not the center of interest for this simulation tool. It uses the existing timetable as a basis to evaluate the current situation according to room utilization and room capacity utilization. It also identifies potential solutions that may result in a room assignment that frees space that seemed to be occupied. Possible modifications that can be generated automatically to the given schedule are time shifts within intervals that can be set by the user and the splitting of a lecture into two parallel events. Further changes to the timetable can only be done with user interactivity. One major condition to be considered that proved to be a major constraint was to not decrease the quality of teaching. That means that the impact of possible modifications to the time schedule on the students has to be reflected in the simulation result.

Instead of trying to generate a timetable to increase the utility of rooms the emphasis of this work lays in the analysis of the space management and the assignment of rooms to lectures is modeled in great detail. Using discrete event simulation in the field of facility management is still a relatively new concept (D. Wiegand, P. Mebes, V. Pichler, 2006). The simulation of the room assignment over time including aspects of the facility management was modeled using a discrete event simulation approach, enabling the user to experiment with changes to the space management rules, including the major aspects of facility management. The integration of other critical aspects required further additions to the model: For the assessment of the quality of the space management and the resulting room assignment students are integrated in the system. These students have a timetable according to their field of study and personal attributes. They behave individually, as they decide which lectures to attend according to their own as well as the lectures characteristics. These students are designed to act as they would in real life, attending lectures, courses and exams and testing the feasibility of the calculated room assignment. It also accounts for the factor of walking times between lectures where a room change is necessary into consideration. All this strongly suggested using an agent based approach. The simulation tool used for implementing the discrete events model is generally suited to also implement an agent based approach (S. Tauböck, F. Breitenecker 2005). But the combination of both approaches as well as the high number of students simulated quickly enforced a split into two different models that interact via a simulation database.

2. BOOKING PROCESS

The first step was to develop a database driven, event based simulation model to simulate the university campus and all events taking place.

A campus is considered to consist of several buildings that may be quite wide spread. Buildings contain rooms that are used for lectures and courses that may be attended by students. This already describes the main components that need to be modeled: Buildings are basically defined by their position and the distance between them. They contain rooms that represent the spaces that can be booked for events. These rooms have a number of attributes that make them usable for certain kinds of events as well as a position within the building. The attributes cover the capacity that depends on the seating as well as the equipment the room provides.

To identify measures that have positive impact on the utilization of spaces the process of assigning spaces to events has to be implemented meticulously but configurable to allow the testing and experimenting with alternative strategies. To represent the booking process a booking manager with variable behavior is modeled. The parameters for this behavior include a selection of different rules that need to be applied for the selection of a room for a certain course, allowances that can be made according to room size or equipment and changes in the behavior that should arise with time or during a particular situation. These parameters define a basically rather rigid set of rules that may ease in the case of a shortage of available space.

The MoreSpace simulation model uses three different data sets as a basis or a simulation run: the list of all events that need a room to be assigned, all information regarding the lecture halls and their status and the information about the number of students attending a course.

The MoreSpace simulation uses this data for calculating a suggestion for the assignment of rooms to these events according to the selected booking management rules. The booking rules define which type of event will be considered of higher priority and therefore will be handled by the booking manager first. It also determines the basic demands a certain event type may have on the setup of the room. The assignment of rooms to events takes place during the whole simulation time – for a University the major part of the room assignment will take place before the semester starts. The simulation tool offers the possibility to use the strategy of pooling opposed to the usual first come first serve policy. That in itself proves to have quite an impact as it allows coordinating the room assignment in a much more efficient way: At the time of actually assigning the rooms the complete situation the overall demand on space is already known.

The simulation of the booking process leads to successful and not successful booking attempts, as not always a solution can be found where all demands can be fulfilled. Other results are i.e. the utilization of rooms as well as the capacity utilization.

3. STUDENT BEHAVIOR

For the assessment of a tested strategy not only the utilization of spaces but also the impact on the quality of teaching from the students' point of view has to be considered. This is done by actually simulating the students as well. The student behavior can be reduced to two abilities that are of interest for this model: to attend lectures and to move through the campus.

The number of students attending a certain course is an important but generally unknown number. It directly influences the selection of the room as it defines the demand of capacity. But until the course actually starts the number remains unknown. It can be estimated based on the experience of the prior years but this is an ability that only lies with the lecturer. The simulation model needs data and formulas to calculate the expected number of students.

Reviewing the data that could be provided including the number of students enrolled and the number of exams taken for each course did show a certain trend but also indicated another facet to this problem that had to be taken into account: not all lectures are attended by exactly the same students, even within one field of study and semester. In reality a pool of students exists who are enrolled for this certain study and semester and if a lecture takes place some of them will attend it, but not necessarily all of them.

The group that attends one lecture usually is not exactly the same as the group that attends the next one. Fluctuations can be due to personal reasons of the single students or the overlap of two lectures or some unknown reason. Generally students from other fields of study max join the group attending due to their interest in this subject.

To deal with these fluctuations an agent based approach was developed. Students are considered as single individuals with their own behavior that is influenced by their chosen field of study and their progress. Students also have their individual factor of diligence and a certain willingness to move between rooms. These factors define the basic make up of the single students: they affect the decision to remain in the current lecture or to leave early to be in time for the next lecture in the case of overlapping events. It also might result in not attending a lecture if the way between to spaces is too long. The factors also specify the number of courses a certain student will attend during the semester.

Concerning courses several facts are known:

- They can be distinguished in mandatory and non mandatory courses

- Courses in bachelor studies have a higher attendance rate that courses during later semesters
- The number of students attending usually goes down during the semester

Based on the attributes of lectures and courses and the behavioral factors of the students the selections of events they may attend are set. Whether a student actually attends a lecture during the semester is determined shortly before it takes place based on the current 'mood' of the student - this mood is composed of the individual factors, the attributes of the event in question, the current situation of the system and certain randomness.

Moving between lectures proved to be a not-negligible factor for the contemplation of the campus as a whole. On the one hand the time it takes a student to move between two spaces can be considerable as the campus can be quite wide spread and this influences the decision making of students. On the other hand it showed that during times of high utilization of spaces the time for these movements increased considerably as the corridors in the buildings are full of people as shown in Figure 1.

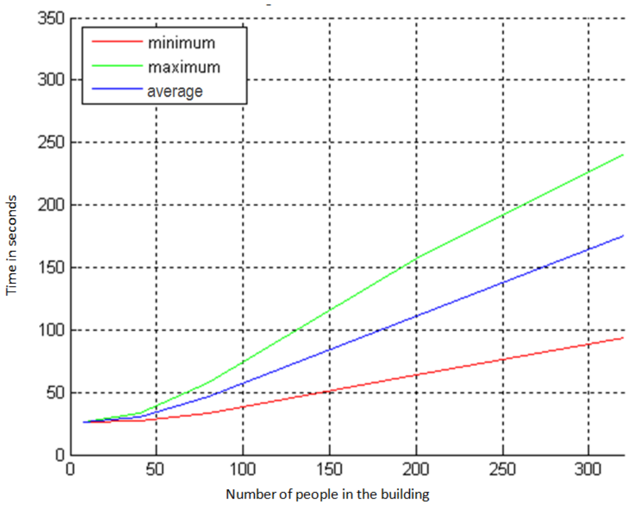

Figure 1: Walking time from room HS1 to room HS2

4. IMPLEMENTATION

Due to the fact that very different requirements must be met by the different parts of the simulation system different modeling approaches are used. The booking process is realized using an event based modeling approach, where each course or lecture is assigned a certain space. The first prototype was implemented in Enterprise Dynamics (Bruckner M., Tauböck S., Wiegand D., Emrich S., Zerlauth S. 2010), to further enhance performance and flexibility the model was further enhanced in details concerning the facility management and then re-implemented in JAVA.

The student simulation uses an agent based approach – in the prototype this was partly integrated in the Enterprise Dynamics simulation model, resulting in a model where agents were integrated into an event based system. Only the movement of students between rooms was calculated in a JAVA model that was connected to the Enterprise Dynamics model moving students between these two models at every entry or leaving of a room (Bruckner et al 2010). In the next step these two models were separated. The process of assigning spaces could be regarded as completely independent from the student simulation. Therefore the simulation models are kept separate; the result of the booking simulation becomes one of the inputs for the student simulation.

The student simulation itself can be run in two different modes: the calculation of travelling times between rooms can be done during the simulation run, enforcing a very exact calculation and therefore resulting in a very high computational effort. It can also run based on prior results regarding the travelling times, allowing much faster calculation in cases where no changes to the travelling times are expected.

5. CONTROLLING THE COMPONENTS

The simulation system is divided into the simulation of the booking process, the student simulation and the simulation of travelling times. All simulation models are controlled by a database that contains the underlying data structure. To enhance reusability of the model the main design is kept as generic as possible.

The goal was to create a system that can be applied to other universities and similar facilities without much further development. Buildings and rooms have attributes that can be adjusted to fit any particular campus or room structure. Courses and lectures can be used arbitrarily to represent any event that takes a certain length of time and needs a certain kind of room. Students and their attributes may represent any person attending an event. The parameterization to create such a system is done via a graphical user interface that is used to define scenarios and experiments. Scenarios contain the basic getup of the simulated system including the definition of the building and room structure, events that will take place and the rules for the assignment of events to spaces. Experiments can be used to change parameters and run experiments within the predefined scenario.

The database acts as the connecting element between the individual models. It contains the input data for the booking simulation as well as its results. These data is provided to the student simulation. The graphical user interface, the scenario manager, allows editing of parameters and controlling the simulation run. It also offers a wide range of analysis tool that have been developed to assess the results of simulation experiments.

6. RESULTS OF THE MORESPACE SIMULATION

6.1. Utilization of Lecture Rooms

This data shows the number of hours each lecture room was booked by the booking procedure. This shows the theoretical utilization, the time the room is booked, but not the time the room is truly used. As past experiences have shown sometimes rooms may be booked for a lecture that does not take place.

Figure 2 shows the utilization of rooms in comparison to the available space separated into room categories.

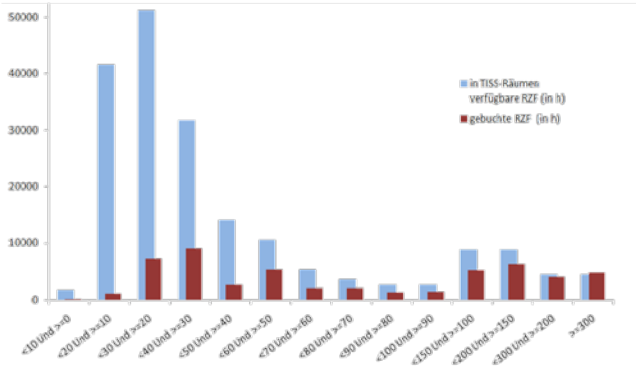

Figure 2: Room Utilization

6.2. Capacity Utilization of Lecture Rooms

This data shows how many students did attend a lecture in the simulation. The number expected is given; the according number of students is assigned. If the number of attending is lower than that it hints at a problem at the accessibility of the course.

6.3. Not Booked Events

The booking procedure tries to find a lecture room for each lecture planned. If it is not able to assign a room the according lecture is listed in this data. For the comparison of several simulation runs one has to make a distinct decision on which aspect to focus the attention.

Depending on this the key data has to be selected. The following example shown in Figure 3 illustrates how easily data can be misinterpreted in the comparison of two scenarios:

Scenario 1: 1 lecture from 11.00 to 15.30 for 56 students could not be booked in any lecture room.

Scenario 2: 2 lectures from 10.00 to 11.30 for 23 students and from 15.00 to 16.00 for 41 students could not be booked in any lecture room.

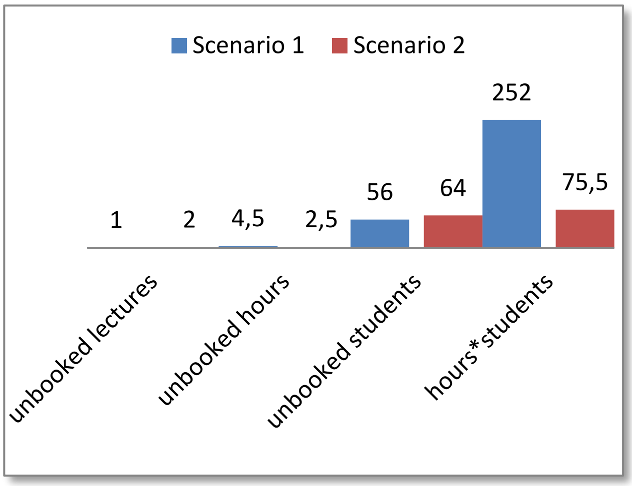

Figure 3: Key Data for Not Successful Booking

This demonstrates the importance of defining the correct key data; Depending on which value is considered the assessment of the simulation results can be interpreted completely different.

Considering the number of not booked lectures Scenario 1 seems to deliver the better result. The number of not booked hours quickly shows another picture: where in scenario 2 both lectures together result in 2.5 hours that could not find a room, Scenario 1's 1 lecture requires 4.4 hours of time.

The picture again changes if one looks at the number of students that cannot attend a lecture without a room: Scenario 1 is the better one in this regard. But taking the hours of lecture each student misses into account Scenario 1 suddenly looses highly against Scenario 2 again.

6.4. Accessibility of Lectures

The accessibility of lectures can be interpreted in two different meanings:

- Temporal accessibility: this indicates if a lecture overlaps with another lecture.
- The spatial accessibility indicates if a lecture can be reached in time: this considers lectures that take place after each other, even with a time gap between them but the location of the rooms is such, that it is not possible to reach the second lecture on time.

While the first kind can be easily determined by evaluating the given data, the second is much more difficult to estimate: the real time it takes from one lecture hall to another depends on far more than the spatial distance: The density of people moving through the corridors, the waiting time at elevators, the distance to staircases influences the walking time. This makes the evaluation of the spatial accessibility to one of the simulation results as it is able to deliver far more accurate results than estimation by distance.

7. CUSTOMIZING

To make the potential field of application as wide as possible the effort of reusing the MoreSpace model to a new application for a certain institution needs to be kept to a minimum. This is achieved by breaking down the functionality into separate components that work independently and are linked via a database that configures the single parts and controls their working together. Some of these components are generic enough to be integrated in any application without further adaption.

Others need to be customized: they offer a wide variety of functionality, that can be selected to be included or excluded as needed. The booking process model is divided into the room layout that is created dynamically at the beginning of the simulation run using generic predefined model objects and the space manager that uses the predefined process for room assignment. The simulation of customers is done in a separate model using an agent based approach; the basic input is the result of the booking process simulation and the room layout data.

The structure of the building and room layout and their attributes are given by the data that is stored in the database in a generic data structure that allows mapping every possible topology to the model elements. Both, model objects and database structure are defined in such a way that there will be no further development necessary to reuse them for different institutions. Only the according data needs to be adapted. This part of the model is included by default in the new application at the customizing process.

The behavior of the space manager is used to simulate alternative booking processes. Findings from surveys at different institutions concerning their booking process have resulted in a set of different rules and regulations that are used at different institutions. These rules have been implemented to be selected during the customizing process to be added to an application.

The behavior of the customers can be easily adapted by using certain parameters. The model of the room layout is generated based on the room layout data.

The customizing process builds the new application containing the room layout and the process definition according to the selected features. This is done using an interface without the need to go into the programming level. All selected components are connected and controlled by the simulation database.

The challenging part of customizing is adapting the MoreSpace importer to the new data. One can assume that that every institution has their own data management system and therefore the structure of the data concerning rooms, buildings, organizational units and also the room assignment plans differ greatly from each other. The basic core of MoreSpace is the simulation database, that contains the data requires for analysis, the basic model data, the input data for the simulation experiments, the result data and the data to be exchanged between the different simulation components.

The database acts as a controlling device that defines the individual simulation models based on the data it contains and exchanges information between two separate simulation models and the analyzing tool. This database is designed to stay the same for any application. The importer is used to map any data sets to the internal data structure that corresponds to the setup of the simulation model.

8. MORESPACE DESIGN

To get a basic understanding of the way the MoreSpace concept works two different terms must be defined: the MoreSpace Scenario and the MoreSpace Experiment. The MoreSpace Scenario is used to specify the concrete application. It contains all information about the buildings and their room layout as well as the list of events and the actual space assignment plan. The scenario includes all input data that is needed to initialize the associated simulation database.

A scenario has at least one user defined experiment. The experiment is used to work with the application by modifying configurable parameters for the booking process that influences the assignment of rooms as well as the parameters concerning the behavior of customers.

The user creates an experiment, selects the input data, defines ranges and co-domains and runs the experiment. The results are stored in the database. The setting of the experiment is done by a dynamic graphical user interface that allows a dynamic setting of user – defined parameters. Every result stored in the database and created by an experiment is reproducible by showing the defined parameters and settings. The results of the experiments in one scenario are also comparable because the input data is provided by the scenario.

9. FIRST EXPERIMENTS WITH MORESPACE

MoreSpace was first developed based on experiences and information collected at the Vienna University of Technology (VUT) and expanded in the next step to be able to fit the requirements of any university, school or similar institution. The basic idea behind MoreSpace is enrooted in the situation of many institutions with inner-city location: while the number of people requiring space increases space itself can only increase up to a certain maximum.

At the VUT this maximum has been reached: during the renovation in the last few years the number of rooms has been increased according to the available space. There are no further reserves to be used in the inner-city location. A simple mathematical calculation seems to prove that the amount of available square meters in relation to the number of students seems to be more than enough. Still it proves to be difficult to find a room for a lecture at short notice.

MoreSpace covers the analysis of the real system based on the current space management, a simulation of alternative space management and a simulation to verify the quality of the alternative results in regard to the customers. The analysis requires data about the current occupancy of rooms as well as detailed data about the room and building topology. It also takes the organization of the institution into account, especially as it concerns the affiliation of rooms to organizational units and therefore may present a restriction according to room availability.

The simulation of alternative space management offers the possibility to experiment with the process of booking and assigning rooms. It shows the effect of changes in the booking process by repeating the room assignment following the experimental process. The result is an alternative space assignment plan that can be compared to the original or other alternative plans.

To compare the quality of these space assignment plans the simulation of customers attending the events that take place in these rooms delivers additional results in regard to the demands of the customers.

Additionally the data analysis based on the high amount of data collected in the controlling database did not only show potential of improvements but very clearly where these potential lay. It allowed a detailed analysis of the current process as well as alternative approaches.

The amount of high quality data also offers the possibility to support decisions concerning the space resources on a daily basis, an added benefit to the daily decision making process in regard to room assignement.

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