CAFM DATA STRUCTURES: A REVIEW AND EXAMPLES

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ABSTRACT

Geographic information systems (GIS) focus on the management and mapping of outdoor information, their data structures are object oriented. CAFM systems manage and map indoor information. The concepts of information management and data structures in CAFM are quite similar to the concepts used in GIS. For the introduction of a CAFM system a data model is developed through the modelling language UML. The overall aim was to develop a general information model for CAFM at Stuttgart University. The development of UML is described and a short introduction in the UML class diagram is given. For the data model we use the class diagram for visualization purposes.

1 INTRODUCTION

The development of CAFM (Computer Aided Facility Management) is an upcoming topic in industry and administration. Every organisation is faced with the hard competition in the market and therefore forced to develop efficient structures in facility management. For CAFM systems, data structures and development of these structures are very important. The research topic of the paper is therefore focussed on the development of a consistent data model for CAFM.

Existing CAFM software packages are either based on CAD systems or without graphics in standard databases. The link of attributes with graphics of CAFM information does not often represent a generic data model due to the development of these systems.

The aim of the research presented here is to develop a generic data model for CAFM information. The first step is choosing the right modelling language, as in computer science several modelling languages exist. The main difference between these languages is the object-oriented or procedure-oriented modelling.

Object-oriented modelling languages subdivide a problem into the smallest independent part and represent the hierarchical relations between these objects. Procedure-oriented (algorithmically based) modelling languages succeed in single steps in order to reach a problem solution. This concept works very well for a defined problem in a well-defined environment. But CAFM information and the analysis of this data should hold for medium-term and long-term planning (maybe for more than 50 years), thus the prediction of future analysis requirements is not or only partly possible. As a logical consequence it seems that object-oriented examples for CAFM data modelling are a reasonable strategy.

The notation of Booch, OOSE (object-oriented software engineering) from Jacobson and OMT (object modelling technique) from Rumbaugh, to name only the most popular data modelling languages, have been defined to efficiently model in an object-oriented environment. Out of these methods UML (unified modelling language) is developed. It is a combination of Booch, OOSE and OMT. UML is a visualisation language. A complex data model can easily be represented by UML. Moreover, UML is also used for the development of complex software packages. For both applications UML allows a precise and complete specification of complex information models.

UML is divided in structural phenomena, relations and diagrams. The modelling in UML has the big advantage that the graphical approach gives an easy overview of the problem. In this paper the use of this modelling technique will be presented by the example of the CAFM data model of Stuttgart University.

The modelling approach based on UML for facility management of Stuttgart University (CAFMUS) is divided in four main categories. These four branches are supply, infrastructure, communication and administration. The central point of interest of the model is the room. Every branch is linked with the room, because every room has power supply, communication facilities phone, internet etc. and links the room with other rooms. The administration branch defines the occupation planning and usage of the rooms. Infrastructure describes the hierarchical structure of the university. The highest level is the university, next level is the location of the part (Stuttgart University is divided in two main campuses, Vaihingen and City campus). The next level is the building, then part of a building, floor, part of a floor, room. This example starts with a general level and ends up in the room or even a part of the room. The decomposition of the problem from a coarse level to high resolution level can easily be seen.

The example of CAFMUS modelling shows the flexibility of the UML notification. In order to get an overview of existing information and lacking information of Stuttgart University in CAFM, the UML data model was of great help in combining all the distributed information in one data model. The big advantage of this model is now that all connections between the different organisation units and sub-units can be shown and the efficiency of the whole system can be improved.

In order to develop a data model for a CAFM system the definition of the FM process of the company must be done. This process is the basis for the whole CAFM system. A CAFM can only support the Facility Management Process. In chapter 2 the definition of this process for Stuttgart University is given.

Data modelling for CAFM systems is the work of integrating all topics related with building management. In order to build a data model for a CAFM system one is forced to bring all the different understandings of management in technical, financial sense and usability together. The financial management of a building has its focus on the cost centers and the total costs of the building. The main goal is to reduce the total costs. The focus of technical management is on the functionality of the building. Every room has to have a certain temperature, humidity, electricity, phone-lines, network, internet connection and so on. The main part of technical management is to keep a building running. The next part is the housekeeping aspect with an university occupancy planning for lectures and institutes. All information for the duties mentioned above must be represented in a CAFM system.

The next step after definition of the information needed is the process of building a data model. Therefore a modelling language is needed. The choice of the language is described in chapter 3. Chapter 6 defines a basic object-oriented data model and shows an example for the Stuttgart University. Chapter 7 will give a summery and outlook for further work.

2 DEFINITION OF THE FACILITY MANAGEMENT PROCESS AT STUTTGART UNIVERSITY

In this chapter the facility management process of Stuttgart University is presented. The focus in this presentation is on the parts dependent on building information. The life cycle (figure 1) of the building is the orientation for the process of facility management. The aim of Stuttgart University is to support the whole life of the building by a CAFM System, not only the short term of planning or only the part of using a building. The whole process must be in focus of the FM process. So information for all phases of this process must be stored and be available for the users.

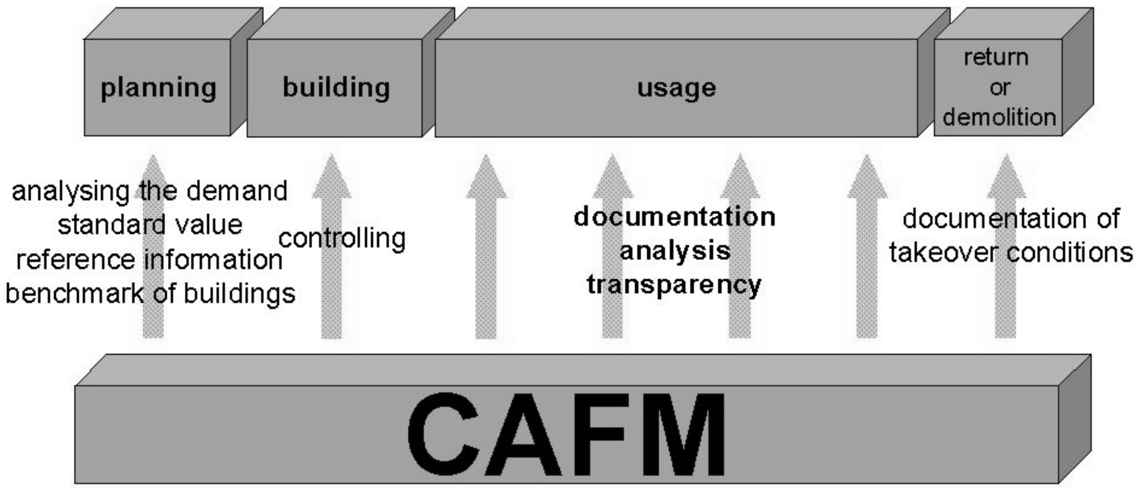

figure 1 usage of CAFM in the life cycle of a building

This life cycle concept of facility management can also be found in Braun et al. (1996). The advantage of this concept is that all information of the facilities are available just in time. The time dependency is also important for the database because also time dependent information must be stored in the facility management system. A real time database is not necessary because the facility management process (in the first approach) is a management process and not a real time process. The maintenance of the building, climate control etc are managed in a separate system that is specially designed to do this real time work. In this paper the time aspect will not be further discussed. For this workflow a data model that contains all information needed without redundancy and deadlocks must be designed. The dynamic processes in facility management can not all be modelled in advance because collection of all processes is very time consuming and specific for every company. So a facility management system grows with his age. One workflow after another will be implemented. One prerequisite is that basic information in this system are included from the beginning. The modelling of these data is therefore one of the most important steps in the development of a CAFM system. The more information is stored in a CAFM database, a change in e.g. graphic data model is very cost intensive and leads to the side effect that virtual objects will be introduced to keep the data model working.

3 OBJECT ORIENTED VERSUS PROCEDURE ORIENTED MODELLING

What is the right modelling method and what does data modelling mean? As mentioned above in the introduction two main data modelling methods exist. The first one is the procedure-oriented modelling. Procedure-oriented modelling is based on the program plan. In this plan the single steps towards the solution are defined. This plan reflects the algorithm to solve the problem. In order to write programs and model the information needed in this programs, one must know the solution very exactly. Complex situations are very hard to be modeled in this way. With the upcoming higher programming languages the development of program description languages started. In figure 2 the historical development of modelling languages is represented.

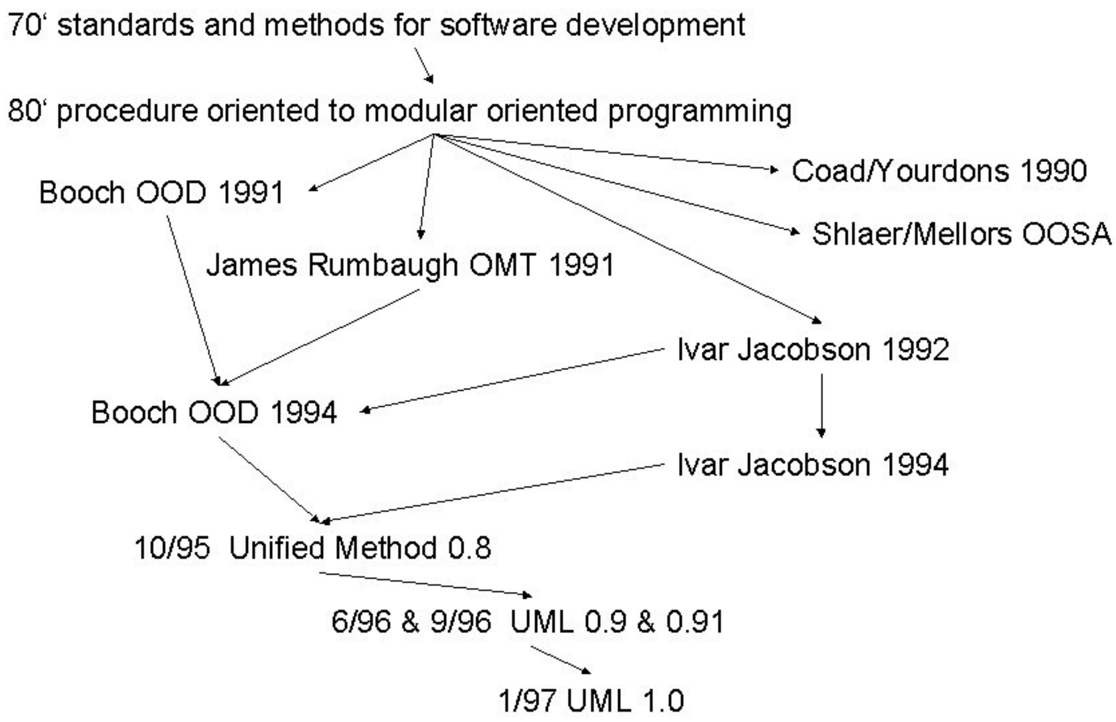

figure 2 development of UML

To start with standards and methods for software development were proposed in the 1970s. The next step was the introduction of procedure-oriented and modular-oriented programming languages. With these languages the modelling process was dependent on the language used. With the first object-oriented languages several approaches to a standardized methodical approach to software development occurred. Out of all these methods the UML (Unified Modelling Language) emerged as a combination of the methods of Grady Booch, James Rumbaugh and Ivar Jacobson. With UML a standard for software modelling and development was born. UML is a standardized notation for business processes and object modelling.

4 DEMANDS ON THE DATA MODEL

What are the demands on the CAFM data model? The aim is to represent all essential information for the facility management process in a consistent data model. Not a 100% representation of the reality is needed but the information model must fit the requirements for facility management. The processes that are important for the management have to be represented in the data model. In figure 3 the general demands on data models are defined.

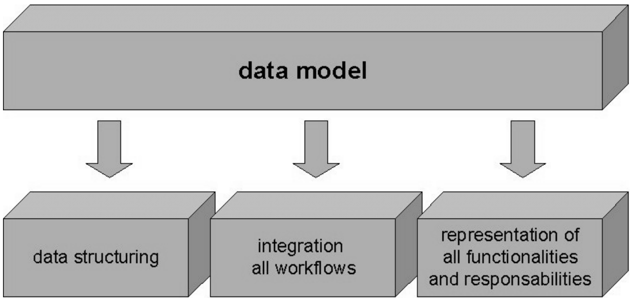

figure 3 main demands on data models

- data structuring
- integration of all workflows
- representation of all functionalities and responsabilities

In every software project the user requirements, data sources, functionalities, workflows are collected and evaluated. In our case the collection of this information was done with a questionnaire T. Schürle et al 1998. The result of this questionnaire was a database with all user requirements. This database is the starting point for the development of a consistent and structured data model. This data model integrates the collected workflows and the basis functionality. Information needed for the workflows are also part of the modelling.

5 SHORT UML INTRODUCTION

The Unified Modelling Language is a visual modelling language. The language defines the notation of diagrams for modelling. The diagrams defined in UML are: use-case, class diagrams, interaction diagrams, state charts and deployment diagrams. For the information modelling of a CAFM system we now only focus on the class diagram. The aim of this is "only " the visualization of the complex data model for CAFM. The dynamic part of the modelling is not part of this paper, because including the dynamic parts of the model we would design a new CAFM program. The aim is to collect all information for facility management and define a data model for a computer based system in a structured way. The data model shall give us a hint where information is lacking and new workflows have to be introduced to gain this information. This short UML introduction will therefore focus on the class diagram.

Figure 4 shows the symbolization and connections between objects in UML. A class is symbolized by a rectangle . The name of the class is written in bold letters in the upper part of the rectangle. After the line in the rectangle the attributes are listed. The second line separates the attributes from the methods defined for the object. Thus a class with all its attributes and methods is represented by a rectangle. The attributes and methods can get a status like public or private so the visibility of these can be defined. In a coarse level of the model not all attributes and methods can be shown if only the main dependencies are of interest.

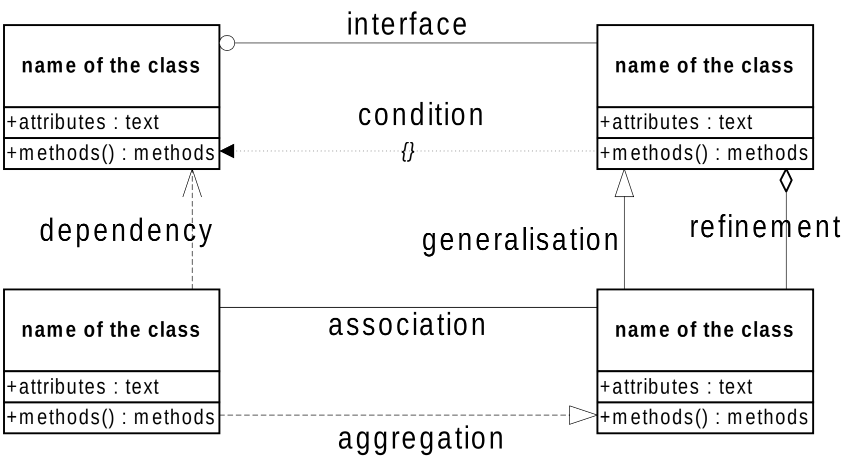

figure 4 UML features of the class diagram

In chapter 6 the basic object oriented data model for CAFM is shown in UML notation. For the visualisation of the data model we used the program VISIO Professional. This tool is very easy to learn and the UML model generated with this tool can be exported in a database system. Moreover this tool provides a good user interface and all the elements are easy to understand. The definition of the classes is supported by a menu driven input of the attributes and methods.

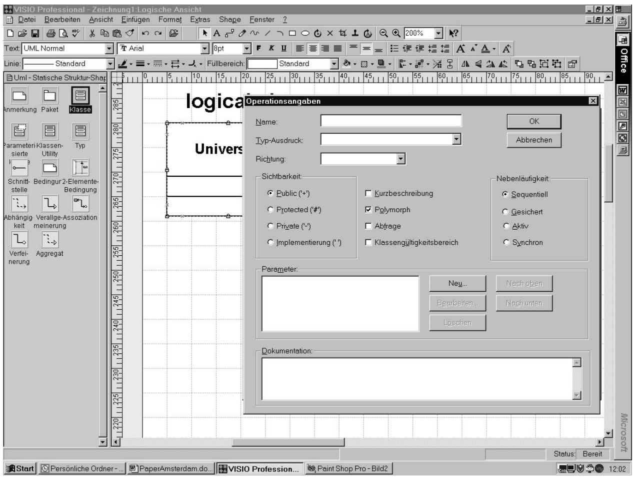

figure 5 definition of class functions

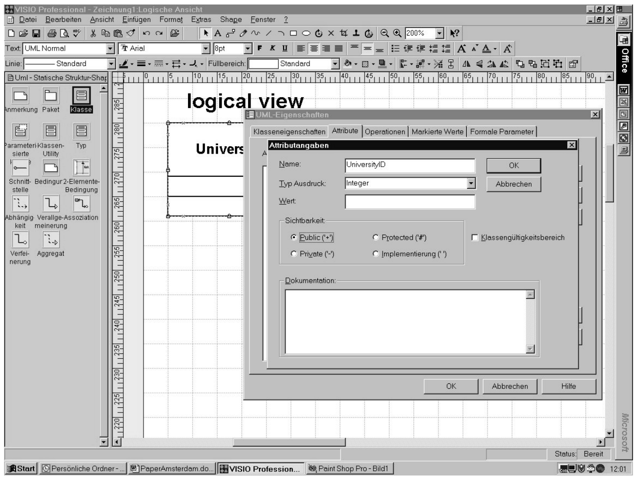

figure 6 definition of class attributes

In figure 5 and figure 6 the graphic user interface of the VISIO professional program shows the input of the information for the methods and attributes.

6 BASIC OBJECT ORIENTED DATA MODEL FOR CAFM STUTTGART UNIVERSITY

The basic data model for computer aided facility management Stuttgart University consists of three main themes. The first theme is infrastructure (shown in figure 8). It begins at University as the name and place (e.g. Stuttgart) next level is location. The Stuttgart University is distributed in 3 main locations in the area of Stuttgart. Next level is building, followed by building part and floor, floor-part and then room and part area of the room.

Graphic data in CAFM are handled similar to the GIS graphic data model. In object oriented systems the graphic information is stored in the object. The class definition is extended from the pure alphanumeric object to a graphical object. The representation of these objects is like in GIS scale dependent. The methods defined in the model as "show the information" are complex methods. Each class has its own scale and user defined representation. Figure 7 shows different representations for one room.

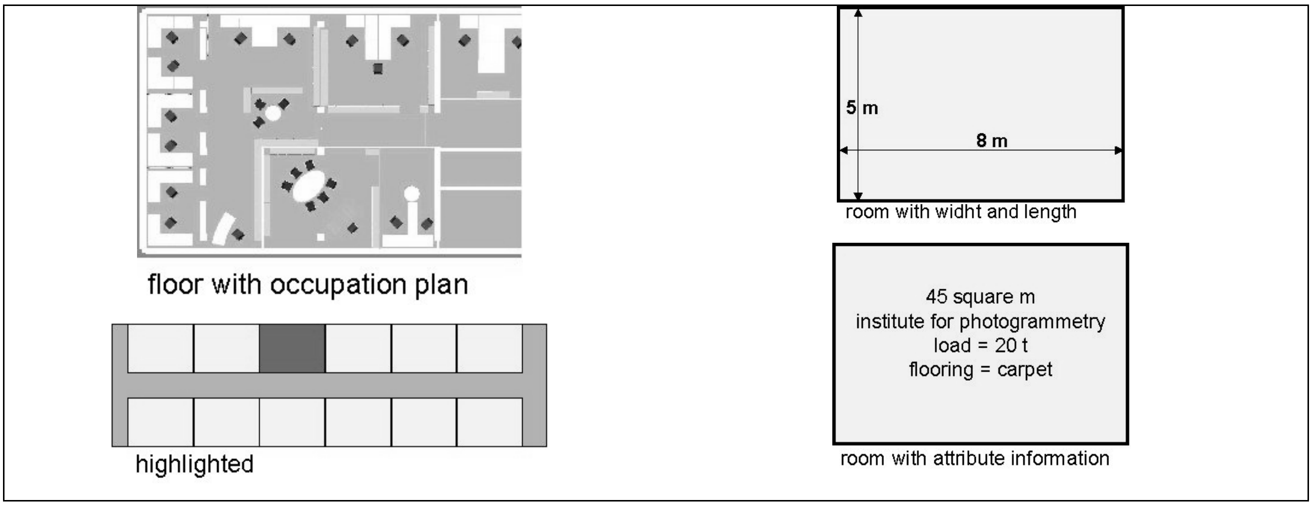

figure 7 different representation of a room

Beside the information model in the class diagram a representation model for CAFM information has to be developed. The method "show information" includes the representation possibilities of the class. Also user rights for the information must be checked in order to grant access to classes and objects. Different users get different access to the information in the database. Information in the CAFM system are up to 20% sensible information. For this reason a user-access concept is integrated in every CAFM system and effects the data modelling. As a deduction out of this the class diagram of the information must be supplemented by a user control class diagram and a graphic representation class diagram. For the development of a new CAFM system all these classes have to be defined. The approach we choose is not to develop a new system but to control and to evaluate existing software systems with respect to the data model. Each company has its own structure and own facility management focus. A specific data model as most commercial software packages offer are in most cases not suitable. The systems have to be customized. This process is cost intensive. A good preparation for this process is a consistent data model. The integration of this model and adaptation to a commercial software is much easier because the steps of information collection, structuring, and integration of workflows is already done.

figure 8 class model for infrastructure

To go into more detail we have to look e.g. to the part area of the room in figure 9. Here the attributes and main methods like show data, modify data for the class "part of area" are defined.

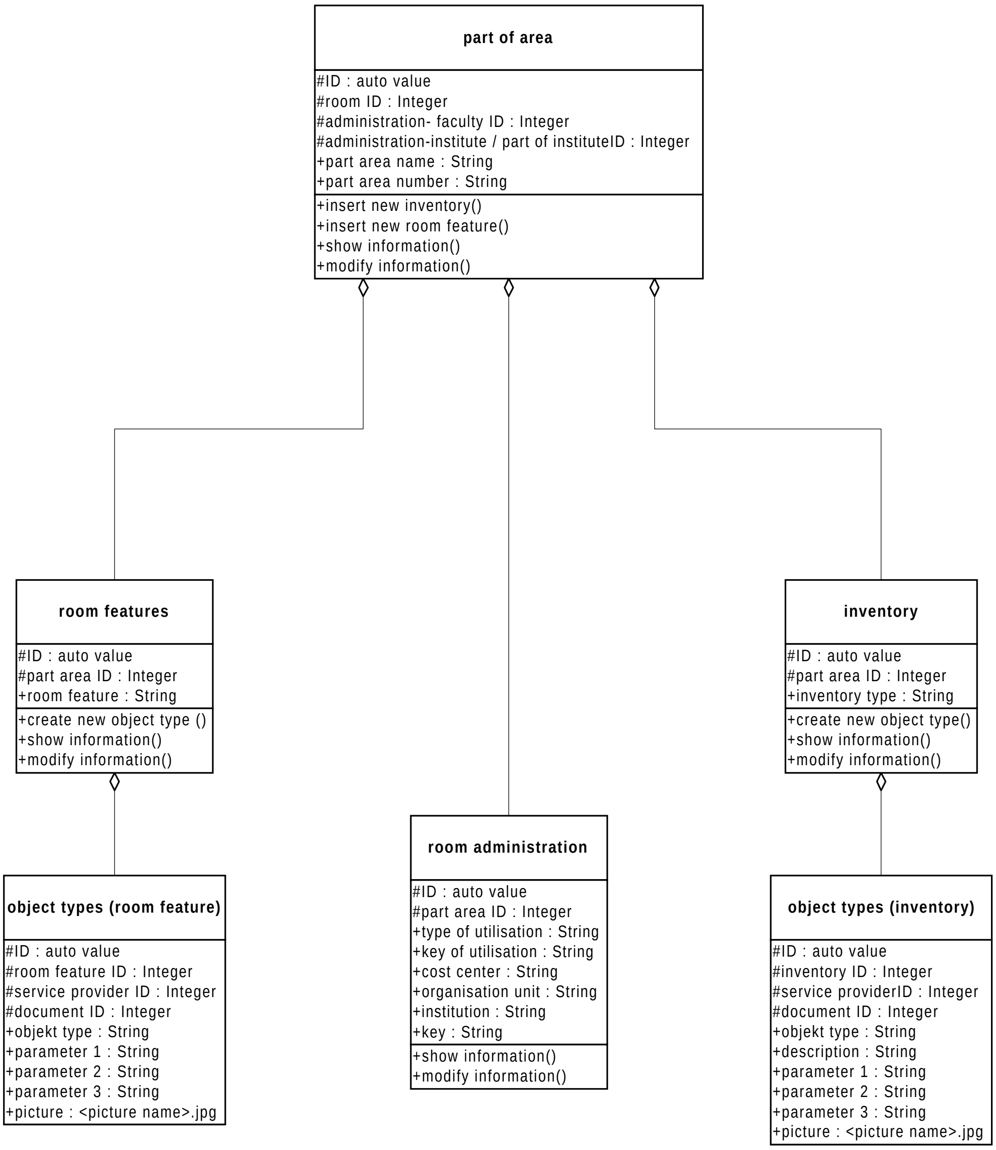

figure 9 class diagram for "part of area"

The modelling of geometric objects in infrastructure ends at the class "part of area". This is the smallest graphical object of interest. Smaller objects with respect to area management are not subject of facility management. The concept of "part of area" is e.g. useful for shared rooms. Different cost centers share one room like a laboratory. For an area analysis like how many square meters are owned by a certain cost center, also the shared room must be counted. Other "part of area" could be subtraction areas like the footprint of a cupboard. In cleaning tendering such areas are subtraction areas and reduce the costs.

The complete UML model for facility management is too large to present here. The model includes 5 main themes with 50 defined classes. This model is now the basis for the customizing of a CAFM system.

7 SUMMERY AND OUTLOOK

The use of UML as modelling language for the modelling of the CAFM System for Stuttgart University shows the potential of this method. The visualization of the data model with UML helps to understand even a complex data model. The faults and missing links between classes can easily be detected by "walking" through the model and searching the connections between the classes. The generalization in the technical management like the classes supply and disposal for electricity and different water came with the modelling as we detected the similarity between the disposal and supply of water and electricity. Both have an incoming and outgoing lane. They are distributed in a floor distribution. VISIO professional is an easy to use modelling tool for the class model. The main advantage for our model was that we only wanted to work in the class model. For a complete software development this tool is not suitable. UML offers the definitions for the modelling of class dependencies. The language itself is powerful to develop a software the use of it is unavoidable. UML without support by a tool like VISO or OWT or Rational is not advisable. The graphical visualization and also the graphical design of the model is very useful for avoiding errors.

Concerning the data model we tried to model on a very general level. The classes and attributes are in most cases aggregations. The implementation will bring more detailed successors of the main classes. The main focus in this model was on the connection between the main themes infrastructure, technical management, and administration. The model was not intended to build up a new CAFM program. Details for implementation must be added. The advantage of this general level is that the model is transferable to other companies and universities. The basic model is also suitable for the start of the development for a new software.

The modelling of information in the facility management is very important for the customizing of standard software products. Further deficits in the information, lacks in connections between themes in the data model, can be detected. For efficient facility management a consistent data model is the basis for the computer aided process. Without this model databases will not be able to adapt to new requirements that emerge in the future.

The information model is also the basis for a XML (Extensible Markup Language) document type description that we will develop for exchange of information between different facility management software and different applications like GIS and facility management software. The quasi standard of XML offers the possibility to establish a standard data model for more than one application. Each application just takes the information needed for its own tasks.

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