Activity objects in CAD-programs for building design

A prototype program implementation

Anders Ekholm

Architectural and Building Design Methods, Lund Institute of Technology/Lund University

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Abstract: In the early stages of the building design process, during the programming and the proposal stages, both user activities and the building are in focus for the designer. In spite of this, today's CAD programs give no support for management of information about user activities in the building. This paper discusses the requirements on modelling user activities in the context of building design and presents a prototype software. The prototype is developed as an add-on to the architectural design software ArchiCAD.

1. INTRODUCTION

1.1 From drafting to modelling

The development of computer aided building design systems is currently shifting focus from drafting to modelling. With a model oriented CAD-program it is possible to develop an object based "product" model of the building. Building product models constitute a basis for achieving computer integrated construction and facility management, CIC/FM, processes. The shift from drafting oriented CAD to model oriented CAD enables new ways of managing and structuring design information (Eastman 1999).

CAD, computer aided design, has mainly been applied during the later stages of the design process when the building and its detailed design is in focus. In the early stages during the programming and the proposal stages both user activities and the building are in focus for the designer. Here, CAD has been used less frequently. One reason is the rigor that CAD-systems impose on the designer, as opposed to the quick and intuitive response of manual drafting. Another reason, relevant for both manual and CAD drafting, is that a drawing is a static medium poorly suited to represent the dynamic user activities. A third reason, specifically relevant for model oriented CAD, is that today's model oriented CAD programs, e.g. ArchiCAD or Architectural Desktop, mainly have objects that represent the building. They do not support management of user activity information, since they have no activity objects to which one can attribute a user activity description.

1.2 Current research

Prototype information systems with explicit representation of user activities has to the present authors' knowledge only been developed by Eastman and Siabiris (1995). They identify ”activity units” composed of furniture, equipment and activity area with the emphasis on spatial properties. Other approaches identify ”functional units” (Flemming and Chien 1995) or ”space units” (Carrara, Kalay and Novembri 1994). These represent functional requirements and generic spatial properties of the buildings spaces, and in that way indirectly represent the organisation units. The indirect approach is also used in “Alberti”, a commercial space planning software by acadGRAPH. The present author has discussed user activity modelling in earlier papers, see e.g. (Ekholm and Fridqvist 1996). A later example is the work by Hendricx (2000). None of these have been realised as working CAD-prototypes.

1.3 Aim of this project

Modelling of activities and processes is an area in strong development, but has so far not been developed to suit the needs of building design and facility management. The aim of this project has been to develop a prototype software that can model user activities in the context of a CAD program for building design. The objective of this prototype is to show some of the potential functionality in design and facility management processes. Hopefully, it may also generate not anticipated ideas of possible applications to those experimenting with it.

The following section of this paper discusses the theoretical framework for modelling user activities, and the information of interest in building design. The third section presents the actual implementation and ends with a discussion about future development and applications.

2. MODELLING OF USER ACTIVITY SYSTEMS

2.1 Conceptual foundations for building design

2.1.1 The theoretical framework

In order to develop theories and methods within the field of design, it is necessary with a well structured generic theoretical framework including semantics, ontology, and epistemology. The theoretical framework used in this development project is based on Mario Bunge's Treatise on Basic Philosophy, specifically the parts on ontology and epistemology (Bunge 1977, 1979 and 1983).

Several concepts used in this section have been presented in earlier writings by the author. The interested reader is recommended e.g. (Ekholm 1987 and 1994, and Ekholm and Fridqvist 1996, 1998 and 2000).

2.1.2 A systems view on organisations

A basic concept in a description of reality is that of system. A *system* is a complex thing with bonding relations among its parts, it has composition, environment and structure, both intrinsic and extrinsic (Bunge 1979:8). A *process* is a sequence of events in a system. An *activity* is a goal-directed process. The terms 'process' or 'activity' may also be used to designate the system itself since it is a characteristic feature.

An *artefact* is a man-made or man-controlled system; it is made with a purpose to make certain activities possible. A human activity system that involves the use of artefacts is also called a *sociotechnical* system. *Work* is a specific kind of activity, it is a useful activity (Bunge 1979:197). A sociotechnical system engaged in some work activity is in management science called an ”organisation” (Child 1984), ”human activity system” (Checkland 1981), or ”enterprise” (Bubenko 1993).

The organisations of modern society are complex sociotechnical systems organised in functional units composed of human individuals and equipment, including tools and machinery. An organisation has a spatial extension traditionally called *activity space*. The activity spaces are of different scale from the smallest, defined by the human body, tools and materials, to the space determined by the organisation as a whole.

To adopt a view, or aspect, on a system is to observe a specific set of properties. Of specific interest to design are the functional and compositional views. A functional view focuses on the system's relations to the environment and on parts that contribute to the system's function. A compositional view of a system identifies the compositional parts from which it is assembled (Ekholm and Fridqvist 2000). See Figure 1.

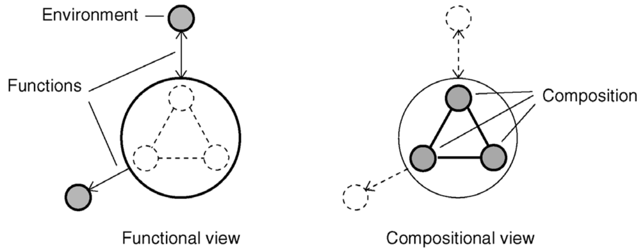

Figure 1: Functional and compositional views on systems

2.1.3 Design as problem solving

Design is an activity which aims at producing an artefact with specific required properties. Design may be seen as a problem solving process. A problem can be defined as a lack of knowledge about the properties of a thing or about how desirable properties of a thing can be achieved. Problem solving therefore is a knowledge acquisition process (Bunge 1983).

In general, a problem solving process proceeds in a sequence of steps. It starts with the recognition and definition of a problem in relation to some background knowledge, see also Figure 2 below. This is followed, first by synthesis, leading to a tentative solution, and then by analysis, investigating the proposed solution. The result of the analysis is added to the background knowledge. The cycle proceeds until a satisfactory solution has been developed.

Synthesis may be regarded as starting from a functional view on the design, while analysis starts from a compositional view. The synthesis question is: Which thing has these properties? And the analysis question is the inverse: Which properties does this thing have?

2.2 Building design

2.2.1 The role of CAD-programs

CAD-programs support the building design process in different ways. A traditional CAD-program for drafting allows the designer to document the geometrical properties of the design. A drawing supports both synthesis and analysis, however information capture from the drawing requires human visually based interpretation. A model oriented CAD-program allows the designer to document a much more complex conceptual model of the design in the computer. This computer based model, in construction IT named product model, does not require human interpretation for information capture, but may be directly accessed by different application programs.

2.2.2 User activity information

User activity information is used throughout the construction and facility management processes. When an organisation is formed or changed, it may need a new or renewed building for accommodation. The process of acquiring a suitable building starts with a description of the organisation and its activities. The *activity description* is used as a basis for developing a *space function program* which defines requirements on the building's spaces. The following step includes development of a *building program*. The building program together with the activity description and the space program are used as a background for building design, but can also be used for building performance analysis during the facility management stage (Svensson et al 1999).

As an example, the activity information needed for space function programming is listed below. The list is based on Hales (1984:17), and (Akademiska Hus 2000).

General activity description
- General description concentrating on factors determining spaces and installations

Activity relationship information
- Process sequence
- Material exchange between activities
- Communication, personal or through media
- Spatial relations, visibility, audibility, supervision, security, shared resources and other relationships;

Activity attributes
- Activity area
- Dimensioning measurements
- Duration
- Noise
- Heat production

Person information
- Personnel data; skills, working hours

Equipment information
- Furniture, machinery and equipment; quantities, measurements
- Products and materials

Building information

– Building (and process) support; HVAC-requirements, fire rating, sound proofing, electricity
– Lighting; daylight/black-out
– Atmospheric pressure

2.2.3 User activity information in building design

User activities in the building are seldom explicitly presented in drawings, but mostly left to imagine by the actors. Object oriented modelling opens up the possibility to explicitly represent user activities. Despite of this, today's model oriented CAD programs, e.g. ArchiCAD or Architectural Desktop do not support management of user activity information, since they have no activity objects to which one can attribute a user activity description.

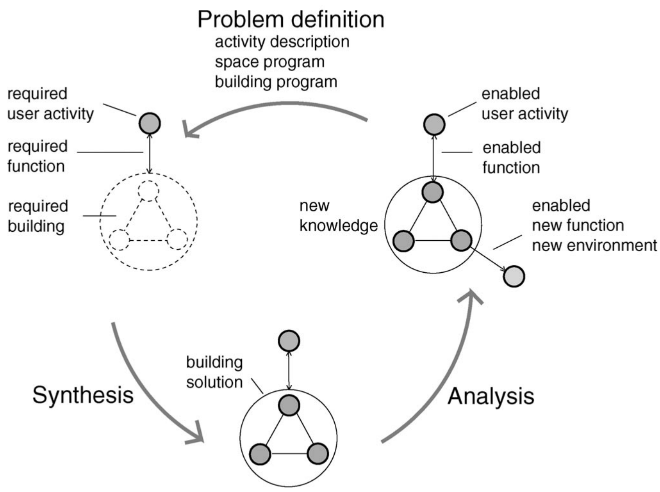

Figure 2. The building design process

A program that allows the development of a user activity description assists the problem definition work in the design process. See Figure 2. A model oriented CAD-program for building design also assists the designer's synthesis work, and allows the designer to document the decisions on the buildings properties. Building analysis includes analysis of technical performance, cost calculations as well as usability analysis. If the user activities are modelled in the same system, it would also support usability analysis. Usability analysis may be more or less dependent on human visual information capture, but since both the building and the activities are represented as object models it should be possible to automate certain aspects of the analysis. After analysis, the results can be used as background knowledge in another cycle in the design process.

A conclusion is that CAD-systems by automating information management to different extent can support the three fundamental steps in the design process of problem definition, synthesis and analysis.

3. THE PROTOTYPE ACTIVITY ADD-ON

3.1 Add-ons

An add-on is a separate program that expands the functionality of a another program, and can only be run within this. The prototype program developed in this project is an add-on to ArchiCAD. It has its own user interface accessible from the interface of ArchiCAD (e.g.: new menus, dialogues, floating palettes, etc.). The API, Application Programmer Interface, for development of add-ons enables access to the inner processes and database of ArchiCAD. With these capabilities it is possible to enhance the basic ArchiCAD elements, but it is also possible to use independent tools and techniques and integrate them into the ArchiCAD environment.

3.2 Conceptual schema of the Activity Add-on

3.2.1 Entities

It has not been possible in this prototype development work to implement functions to manage all the information needed for space function programming as listed in section 2.2.2. However, a future implementation is both possible and desirable. The following section describes the actual implementation.

The basic entity of the Activity add-on is the Activity. It is based on a functional view on an organisation or part of an organisation. An Activity may have other activities as functional parts or itself be a functional part of other activities. Activities are composed of Person and Equipment. The constituent Person and Equipment may be determined for an Activity at any level in the “hierarchy”.

Activities may have Name, Description, Duration, and Relations. There are four Relations that can be specifically shown: Visibility, Sound, Distance, and Adjacency. These may have values which, however, can only be described, functionality is not implemented.

A Person has Name and Description, it can only exist within an Activity.

Equipment may be composed of other Equipment. It may have Name and Description. An Equipment element can exist independently during the time period between the Activities in which it appear. Between Activities it has the same state as in the last Activity.

Compared with the information needed for activity description according to section 2.2.3 above, the prototype lacks a relation between activities and building spaces, as well as a resource entity.

The entities and their relations as implemented in the prototype are shown in the schema in Figure 3. The schema is presented in EXPRESS-G, a framework for graphical product model representation, based on the EXPRESS modelling language (Schenk and Wilson 1994).

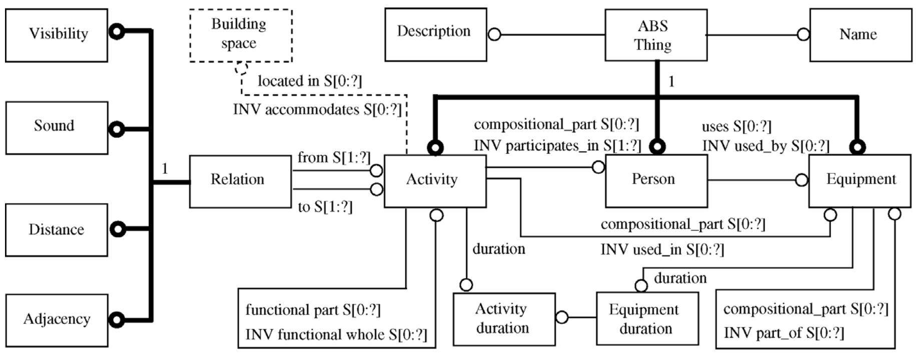

Figure 3: Conceptual schema of the Activity Add-on

3.2.2 The Object entity in ArchiCAD

The Activity Add-On can link Activity entities with Object entities in ArchiCAD. An Object entity is a library part within ArchiCAD, it can represent different things, e.g. people, furniture, specific building parts like kitchen fit-outs etc. However, the link can only be active if the Object entity has the “visible” variable within its parameters which can be edited by an advanced ArchiCAD user. Person and Equipment objects in the Activity Add-on are such edited ArchiCAD Objects.

Two new ArchiCAD Object entities have been developed for the Activity Add-on:

- The Activity Space Object which shows the spatial extension of the activity. It can be created, with the Fill→Activity Space transformation tool within the Activity Palette.
- The Activity Relation Object, which is handled by the add-on.

3.3 Functions of the Activity Add-on

3.3.1 Activity Menu

The user of the Activity Add-on manages an Activity System through the Activity menu in ArchiCAD. The Activity menu contains:

– Activity Settings; to switch on or off the Activity Settings palette
– Time Observation; to switch on or off the Time Observation palette
– Activity palette
– Save Report file

The Activity Add-on in the current implementation enables the user to determine and edit an Activity System. The main functions to configure the Activity System are handled from the Activity Settings palette, available as a

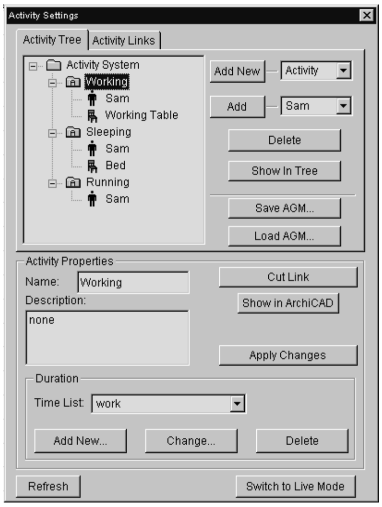

Figure 4: The Activity Tree dialogue box

dialogue box placed in the ArchiCAD window. The main functions are "Activity System", "Activity Links" and "Activity Properties".

An Activity System is made up of activities in a hierarchy of different levels. See Figure 4. Activities in each level are composed of Persons and Equipment. The first level of the hierarchy must be an Activity. The same Activity may only occur once within the Activity System, but Persons and Equipment can occur many times.

An Activity can be saved as an AGM, Activity Group Module. This module consists of the Activity and its parts as well as its composition of Persons and Equipment. An AGM can be saved in a library and be reused.

The relations between activities can be determined in the “Activity Links” dialogue box. The relations are: Visibility, No Visibility, Sound contact, No Sound contact, Connection, No Connection, Adjacency, and Distance. The links can be set at direction and certain grades of importance. The links are shown in a ”relation stamp” on the screen.

The Activity Properties includes name, description and duration. The user can control the appearance of Activities and the related objects in time through the “Time Settings” dialogue box. An Activity can be set to be either periodical or happen once. See Figure 5.

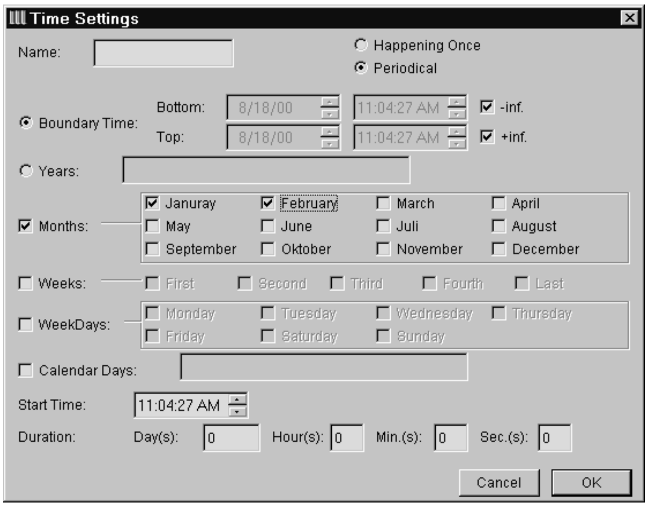

Figure 5: The “Time Settings” dialogue box

3.3.2 Activity Space definition

The user of the Activity Add-on may start the activity design work by defining a hatched area developed through some of the ArchiCAD geometry tools. Then, when the designer wants, it is possible to define the hatched area as an Activity Space using the Activity Space transformation tool. A similar function works for other ArchiCAD objects like Wall or Slab. This means that a designer initially can work with a geometrical representation, and at will determine whether the object shall be, for example, an activity, or a slab.

3.4 The School Test Case

The Activity Add-on has been applied to model a small school and its lessons. The different tools in the program have been used to define the School Activity System. An example of the design tool in use in the Edit

Mode is shown in Figure 6, where the Floor Plan and Activity Tree shows shows *Art* in class A, and *Computer* in class B.

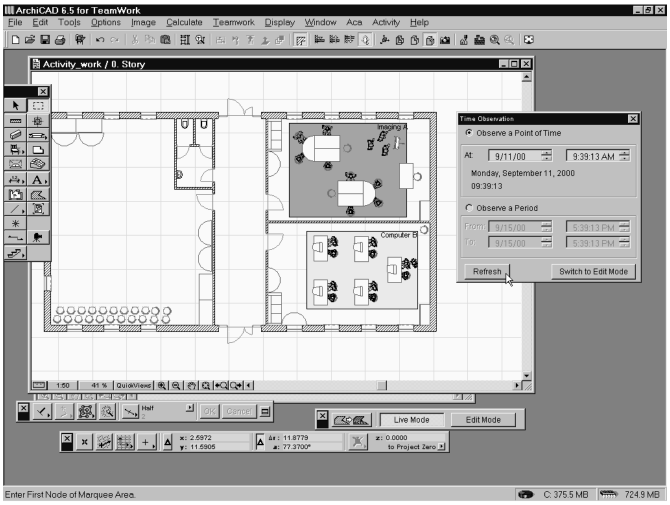

Figure 6: Art in class A, and Computer in class B, observed on a Monday morning

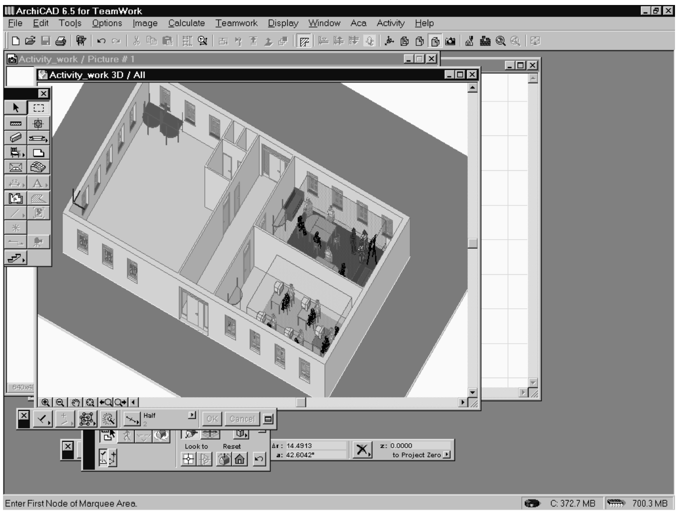

Figure 7: In the 3D mode also the extension in 3D of the Activity Spaces is visible

The activities are observed at 09.39:13 on Monday morning, September 11, 2000. In Figure 7 the same activities are shown in a 3D view. Also the extension in 3D of the Activity Spaces is visible.

3.5 Conclusions and future development possibilities

3.5.1 Conclusions

The Activity add-on to ArchiCAD strongly enhances the functionality of building design software in the problem definition and analysis phases of design. The integration of activity objects in software for building design opens new possibilities for building design methods development.

3.5.2 Further investigations

Several aspects should be further investigated. For example:

- Illustration of user activities
- Spatial lay-out design
- Temporal space use analysis
- Versatility analysis
- Space function programs
- Activity libraries
- Process modelling

Buildings are built to enable activities of different kind. During design or in facility management it is necessary to be able to *illustrate user activities* in 2D and 3D and how they are accommodated in the building. This functionality may be extended towards animated and interactive representations by sophisticated software and hardware. Traditional software for building design enables illustrations of people and equipment, but not as graphical representations of activity objects.

Methods for *spatial lay-out design,* wich coordinates spatial requirements of buildings and activities, may benefit from the availability of activity objects with relational and spatio-temporal attributes. Spatial allocation of an organisation can be supported by graphical representation tools like: adjacency matrices, flow-charts, blocking and stacking diagrams, graphic and net area displays, spatiotemporal diagrams etc. Such tools are computer implementable and could be part of computer aided organisational design programs. See e.g. (Kalay and Séquin 1998), Kumlin (1995), Hales (1984), Child (1983) and Muther (1973).

The time settings functionality of the Activity add-on clearly illustrates the possibilities to develop methods for *temporal spaces use analysis*. The use of a buildings' spaces is time dependent. The possibility to generate space lay-out plans for different times of the day gives a new insight in the possibilities to co-ordinate activities to achieve a more effective space use.

Methods for *analysing the versatility* of a building and its spaces are important both during building design and facility management. The versatility of a space is a measurement for its capacity to accommodate different activities. Flexibility, e.g. by movable partitions can be illustrated, by representing a partition as Equipment of an Activity System. As a background for methods development it would be of specific interest to analyse the SAR-methods developed in the 1970's by John Habraken and his colleagues (Habraken et al 1974).

Further program development should be made to allow the user to develop *space function programs* an important part of the problem definition work. Information about activities and required building properties are stated in the space function program, which is used both as a starting point for the building design process, and as a background for performance studies during facility management.

Activity systems together with their building requirements should be possible to store in a reusable form as *library objects*. One source of inspiration for developing and structuring such coordinated activity-environment objects would be the Pattern Language methodology, developed around the 1970's by Christopher Alexander and his colleagues (Alexander 1975).

The schema developed for the Activity Add-on could easily be extended to represent input and output of processes. The Time Settings function of the software also seems useful for *process modelling*. A process modelling function is not implemented in this prototype, since it is a functionality to be used in other contexts than intended here. However it is relevant to mention as a possible extension of the program.

4. ACKNOWLEDGEMENTS

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