Multimedia Teachware in the Field of Architectural Design
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ABSTRACT
Software systems for educational purposes have been developed and used in many application areas. In this paper we will describe a development in the field of building science. CIAD is a teachware system directed to be used in the education of students of architecture as well as a tool that gives a survey to architects and engineers in the practice. In the first place it provides information about the use of computer science technologies in the building design process. Furthermore, information about the architectural design process itself is included. Based on an analysis of general requirements and specific demands of the application field we describe our solution concept. Very important conclusions are that the system has to integrate the use of all media which are usually used by architects by offering a flexible and well-designed user interface and allowing a high degree of interactive work. After covering the development process as a combination of top down and bottom up strategies we describe the overall structure of CIAD as a modular system which can be extended and updated easily. Finally, we give an overview about some parts of the system to demonstrate the implementation of the concepts mentioned above.

1 MULTIMEDIA TEACHWARE
We will start with a discussion about quality criteria for learning materials in general. Afterwards, we apply and transfer these criteria to the process of teachware development considering the question how to make “good” teachware. Before we will define the terms teachware and multimedia in general.

Definition “Teachware”
Teachware is software that is especially made for a specific teaching task. The main goal is to teach a person without the physical presence of a teacher but with the advances of an interactive learning environment.

In [Gal92] an multimedia environment is defined as follows:

Definition “Multimedia Environment”
An “Multimedia Environment” is an environment which is determined by the integrated use of information and communication technologies.

It implies:
- presence of different technical systems to record and transmit information
- presence of different symbolic systems and languages of information decoding
- presence of different communication systems and technologies.

Multimediaility therefore is not only to be identified with the mere availability of several media, as it is unfortunately in many cases, but with their integration.
1.1 Computers and Multimedia Technology in Teaching

The application of computer programs for teaching purposes has been a field of interest since the 1960-ies. At the beginning there was an estimation that computers, called "teaching machines", should be able to take over more than 50% of every kind of education in a very short time. The development so far includes many projects resulting in inappropriate computer aided learning systems. It has shown that this expectation was significantly wrong. Furthermore, the overrating of the possibilities in computer aided learning or teaching has caused many reservations with respect to the use of computers for educational purposes [Wolf92].

In the last years the situation has changed because of new technologies like multimedia. Their common use has been enabled by the significant increase of hardware performances and other developments in the field of computer science. Another reason is that people in general are used to audio visual presentations, e.g., television, computer games, etc. and tend to pay more attention to this kind of presentations than conventional ones.

About the role of computers in learning processes [Parn92] stated that computers are powerful tools for education people. The main reason is the fact that the people are fascinated by the interactivity of the computer. In this way computers are very good means to provide motivation for learning.

Comparing the statement by Parnas with the problems mentioned above the contradiction seems to be obvious. [Maye92] also takes into account this problem and presented the conclusion that the approach of computer aided learning did not fail because it does not work. Computers were even very effective for learning given the right context and the right support.

Therefore, we conclude that general problems that have to be taken into consideration in the development process are:

- Is the context in which we want to use teachware suited for computer aided learning?
- Which kind of support is needed to provide an effective way of learning?
- How can we avoid known disadvantages of traditional teachware?

1.2 Requirements for Multimedia Teachware

In this section we will compile general requirements for multimedia teachware. We only intend to give an overview. A more detailed description is included in [ScS95].

(1) Learning should be interesting
The learning material must be motivating and encouraging the student to learn more. Enjoying learning is an important feature [Bork92].

(2) Interactivity is a fundamental feature of every kind of teachware
The fact of being interactive is the fundamental difference to other learning methods. Like shown in many applications learning is better accomplished if the learner is driven to participate actively in the process.

(3) Individualisation of learning is necessary
The help that each student needs in a highly interactive learning environment is dependent on that student. Every user should have the possibility of setting his own working pace according to his own interest and capacity. This feature is related to the aspect of interactivity. It is interaction that makes individualisation possible.
(4) The Learner-Control Paradigm [Bark89]
It describes the significance of learner control within an instructional dialogue. Students should be made to feel that they are in control what is happening during an interactive learning session. Therefore, facilities must be provided to enable the student to select and control
a) what is learned
b) the pace of learning
c) the direction it should take
d) the styles and strategies of learning that are adopted

(5) The principle of Surrogation
The student should be given the impression that he or she is participating in a real-life situation. Techniques like surrogate walks, laboratory simulations, surrogate travel, role playing and surrogate sport [Bark92] could be used within teachware systems to simulate real-time processes.

(6) Learning materials should use many media
Aspects of using multimedia technology are discussed in many other sources. In this paragraph we will only deal with the "added value" of multimedia. What can we claim for this technology?

(a) It can improve the quality and granularity of human-computer dialogue by enabling us to approach dialogue design with a more powerful armoury of tools for communication.

(b) The combination of media in displays carries with it a vividness that cannot be questioned. This provides a higher level of interest by the student leading to better learning results.

(c) The presentation of one piece of information with different media increases the degree of understanding.

(7) Combination of hypertext-orientation and system control necessary
Teachware should be developed as a synergetic synthesis of the two approaches mentioned above. The former could not provide control about the learning process. This results in an unstructured way of working, the user tends to loose control. The latter causes the disadvantage of less motivation because of non-flexibility. A combination would be a much better solution.

(8) Teachware has to consider aspects of human information processing
It includes features like the different kinds of human information processing as well as features related to the different kinds of human memories e.g. like methods to achieve storing in the long-time memory by providing mechanisms for the generation of chunks [Wol92].

(9) Multimedia teachware has to fulfil general requirements for software
Very generally, teachware as a special kind of software has to fulfil all requirements that could be expected for every software product like correctness and robustness. The development of teachware is an expensive and complex process. It is necessary to use a development methodology that provides reusable software that is easy to maintain.

(10) The development of teachware is a very complex process
The production of an instructional software system, especially the development of its user interface, is often more complex than for conventional software [Bark92]. The arising complexity is caused by the need to take into account the various pedagogic factors that will lead to effective and efficient knowledge transfer between:
a) those who author the interactive software
b) the knowledge corpus upon which this software is based
c) the learner population that is likely to use the resultant courseware.

Therefore, the compiling of knowledge represented within the teachware can be considered as an important part of the whole development process. During all phases of the development we have to handle the problem of complexity. Modularisation is one of the key issues to achieve this.

1.3 Multimedia Teachware in the Field of Architecture

Teachware has to take into account the specific characteristics of potential future users like their relation to computer science technology or their level of knowledge about the use of computers. For the area of architecture we can describe the situation as follows:

(1) The field of architecture is suitable for the application of different computer programs. Many tools are in common use within this field.

(2) The use of advanced computer science technology in the field of architecture is relatively limited. The use of conventional software dominates. Architecture is not a typical application field where innovative computer science technologies are used.

(3) Many computer programs are at least partly inadequate to the needs of architects. A acceptance problem often occurs e.g. caused by software with shortcomings in the design of the user interface.

(4) We can state significant problems in the practical use of software systems. Generally, the relation of architects to computer science technology could be summarised as a "sense of fear" [Sari93].

Considering the points mentioned above we conclude that:

- Teachware for architects has to be aware of the acceptance problem. It results in increasing quality requirements for the software product with respect to problems such as user interface design.

- If we are able to solve the acceptance problem a positive "side effect" may be a better understanding of computers in general by the experience of working with an appropriate tool.

- Aspects which provide possibilities to the user to be creative by working with the system are very important. In contrast to engineering fields the relation between design and art has significant more importance.

In section 1.1, we have stated that computers are very effective tools for learning given the right context and the right support. We discussed the context for our teachware development in this section. It can be pointed out that regardless of some problems related to the application of computers in architecture this area can be considered as a field which provides a suitable context. In the development process all requirements given in the first chapter have to be taken into account in order to realise "the right support".

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2 THE CIAD-PROJECT - A GENERAL DESCRIPTION

CIAD (Computers In Architectural Design) is a teachware system developed for two general purposes:

(1) to provide information about computer science technology applied in the architectural design process

(2) to provide information about the architectural design process using these computer applications.

CIAD should be used in the education of students of architecture as well as a tool that gives a survey to architects and building engineers in the practice.

This field of knowledge is very complex and the best way to learn about this is to have small groups of people taught by an expert in the field. The students will get their knowledge out of the first hand and it is easy to ask questions. The interactivity is perfect. The problem is of course that this will be too expensive and too much time-consuming as well for the teacher as for the students.

Teachware that can be used at any moment the user wants to and that offers also an acceptable degree of interactivity can be also considered as a very suitable way of learning without requiring as much time and financial resources. However, the investments are quite large in the development phase but once made it can very easily be multiplied and distributed.

The following list gives a survey about the topics this teachware system deals with:

A: Fundamentals
Fundamentals of computer science and some other relevant fields are covered to provide basic information needed for the work with other parts of CIAD.

B: The use of computers in the building sector
A survey summarises the possibilities of using computers within the building process. It is directed to give an impression about the great variety of tasks where computer can be used.

C: Computer Aided Architectural Design
In this part we deal specifically with the conceptual design phase and with the materialisation phase. We give an overview about methodologies that can be used for conceptual design, explain the sub-activities of the materialisation phase and describes computer science applications which are typically used in this processes.

The most important part of this development is the third part. The other two parts are covered in order to give a more general view on the topic. They impart fundamentals making the work with the main part easier.

One side effect of our development is the propagation of architectural design in three dimensions. This methodology offers many advantages compared to designing in 2D, but requires on the other hand much more computer support. Within the CIAD project we concentrate on computer aided architectural design in 3D and intend to demonstrate its possibilities and advantages.

The teachware is practice-oriented. We try to simulate real-world problems in building design and the way in which the computer may help solving them. Another objective for this research is to estimate future development in the area covered. This includes the presentation of current research activities.
3 THE DEVELOPMENT OF CIAD

In this chapter we will discuss the development process considering aspects like:
- the acquisition of knowledge presented in the teachware
- concepts for achieving a modular structure of the system
- the participation of users in the software development process.

3.1 The Modular Structure of the CIAD-System

We already pointed out that CIAD covers a very complex area of knowledge. This
and the necessity to built up a teachware system consisting of different entities lead to
the conclusion that modularisation is a key feature for the development.

In general, the modules could be divided into two categories:
(1) Primary Modules
All modules directed to impart knowledge about computer aided architectural design.
(2) Secondary Modules
This category contains all modules related to general topics such as the use of
computers in the building sector or to fundamentals.

The classification does not imply an order of importance. It is only based on the fact,
that the primary modules are directly related to the subject. In contrast, secondary
modules are dealing with the context in order to impart basic knowledge.

The primary modules can be classified depending on the kind of learning mode. We
support three modes:
- “Theory”
These modules are directed to impart theoretical knowledge about the subject
discussed. The main goal is to extent the knowledge of the user about the concerning
field.
- “Practice”
In this modules the knowledge already imparted will be illustrated by means of
examples. Practical aspects are discussed.
- “Exercises”
The user get the possibility to make exercises or is requested to make some tests.

This leads to a hierarchy of modules. Figure 1 illustrates the upper levels:

![Diagram](image)

**Figure 1**: The upper levels of the module hierarchy
The modules “conceptual design”, “materialisation”, “computer science” and “computer applications in the building sector” themselves consist of different sub-modules depending on:
- a more detailed classification of subjects
- the selected learning mode.

As an example we will deal with the area “materialisation”. For the description of the sub-processes we use the Delft model [Wild89] [Sari91]. It describes the materialisation step as a iterative process of five stages:
- Knowledge System
- Generative Typology
- Dimensioning
- Knowledge Engineering
- Detailing

Specific categories of software that are covered within the scope of this module are applications of databases, expert systems and 3D-CAAD programs. It is illustrated in figure 2:

![Diagram](image)

*Figure 2: The sub-modules related to the subject “materialisation”*

Every sub-module consists of different sub-modules of a lower level covering theoretical and practical information about detailing as well as some exercises. With the hierarchy described in this chapter we can state that the requirement “modularisation” has been realised.

### 3.2 The Hardware and Software Environment

The CIAD system should in the environments of universities as well as in architectural and engineering offices. Therefore CIAD should run in PC-based environments.

Many tools that can be used for the development of teachware. In general there are three categories of teachware development tools [Bark89]:

(a) Programming languages
(b) Author languages
(c) Authoring systems

The third approach offers many advantages in the scope of our development:
- CIAD has been developed by a team of architects and computer science specialists.
The use of programming languages requires specific knowledge. Because architects generally do not have this kind of knowledge, the co-operation in the implementation
After the analysis and specification of the development task the other four phases are performed cyclic. They are closely related and often performed in different sequences. At any of the three stages that are mainly directed to the software production - “Design”, “Acquisition & Preparation” and “Realisation” the future users are incorporated into the development.

The five phases could be described as follows:

**Phase 1:** “Analysis & Specification”
This step includes in general the same tasks as in conventional software development projects. The functional requirements have to be determined. One main issue is the specification of the kind and the amount of knowledge included in CIAD. The main result is the overall structure of the system consisting of a hierarchy of different modules.

**Phase 2:** “Design”
Based on more general specifications that are the result of the first step the different modules are designed. The result is a blueprint that is also referred to as a story board in the literature. It is a description of the sequence of the presentation by different media within the teachware. This includes the compilation of needed material and knowledge.

**Phase 3:** “Acquisition & Preparation”
In this step the implementation phase is prepared. Needed materials are acquired by producing different pictures, videos, audio sequences, etc. Furthermore, some processes of knowledge acquisition related to specific topics are included.

**Phase 4:** “Realisation”
All acquired and produced elements are used in the implementation of the teachware following the blueprint. By using Authorware as a development toolkit this task has been made significantly easier.

**Phase 5:** “User Incorporation & Test”
All intermediate and final results are discussed with and evaluated through the user. By means of prototypes this incorporation is possible already at early stages without finishing whole teachware modules.
In our development the acquisition and preparation phase demanded much resources and time. Some of the tasks have been:
- the selection and execution of example design that can be used for demonstration purposes within CIAD
- the rendering of these designs to produce video sequences or high-quality graphics
- research about computer-aided architectural design software used in the practice.
This category of tasks required significant resources. For CIAD we estimate that about 35% of all resources have been used in this area.

4 SOME MODULES

In this chapter we will present some modules which are already implemented. We will show some specific modules addressed to specific subjects in the scope of the concerning field. They are described much more into detail in [ScS95].

4.1 An Exercise Module for the Detailing Phase

In this section we will cover a primary module dealing with an exercise related to the materialisation step detailing. By means of different examples the user gets information about the process. After that he is requested to re-execute the different steps in the correct order.

In general the exercise can be divided into two parts:

1) Demonstration of the Process
In a animation sequence made from different renderings of the example design the composition process is explained.

2) Re-execution of the Process
The user is requested to compose the different elements in the correct order as demonstrated in the first step. After selection an element the system checks the correctness of the selection and gives explanations. If the selection is correct the user gets some information about the element he composed in the right way and is requested to go further. Otherwise the error is explained and he gets a second chance to select the correct element. If he fails again, the element is placed automatically with an extended explanation. At every time it is enabled to get general information about the materials the house consists of by clicking on a specific button.

4.2 A Module dealing with Complex Spatial Geometry

In the design process in the field of architecture three dimensional forms play an important role. Many architectural forms are generated using respective groups of polyhedra. The work with these three dimensional design elements requires a spatial thinking which is not supported by the known mathematical descriptions of the shapes. Furthermore the architect must have an intuitive thinking to decide the suitability of possible shapes. To develop this 3D thinking is the main objective of this teachware module. It corresponds to some primary modules addressed to the area of conceptual design regarding the use of complex geometrical structures in this phase.

The properties of the different polyhedra classes are described in a detailed way and the user is able to gain knowledge through interactive work according to his specific requirements.

In general the parts contain information about the general characteristics of the different categories of bodies. Afterwards, typical examples are shown and sometimes described exactly in mathematical terms. All parts of this module allow the user to play with the bodies by rotating, moving and changing the presentation mode. Bodies
can be presented as a solid or a wire frame. Additionally it is possible to zoom in or zoom out the drawings. While manipulating the geometrical elements the user develops a 3D thinking and feeling of the space and the forms.

4.3 A secondary module dealing with the use of multimedia devices for different types of computers

The module “Multimedia Devices” illustrates the use of external devices required for multimedia purposes. The module realises two main functions:
- to give information about the different external devices like printer, CD-ROM drives, etc.
- to explain the connection to computers including network facilities
- some exercises.

4.4 A secondary module dealing with the hardware available in our department

This module explains the different hardware and software resources that are available in our department. It also includes processes to impart knowledge and some tests and exercises.

5 CONCLUSIONS AND FUTURE WORK

We have made some tests with the parts of CIAD implemented already. The evaluation of potential users indicates a high level of acceptance. Up to now the computer itself seems to be a good motivator for architectural students to deal with problems related to the use of information technology in architectural design.

Interdisciplinary co-operation is an important aspect in the teachware development process. A team of specialists in architecture, building engineering and computer science needs detailed knowledge about areas like ergonomics or perceptive psychology too.

Many extensions of CIAD are possible. They include the extension of the scoring system to come to a real intelligent tutor system that is able to adapt to the individual preferences and needs of an user. In this case material about the user has to be collected to generate an individual dialogue design.

[ReMe89] summarises the final evaluation of the suitability of teachware with the following question:
“Could we design a course that was more effective and efficient for both the learners and the lecturers?”

Future applications of CIAD or parts of the system respectively will show how this question has to be answered with respect to this teachware development. Based on our experience so far we suppose that it can be answered in a very positive way.

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