The MultiCAD Project: toward an intelligent multimedia information system for CAD

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ABSTRACT

In this work, we present a set of proposals for the definition of a generalised multimedia information system. The system supports production of scenes using techniques of the declarative modelling by hierarchical decomposition. These proposals include a declarative design process model, the corresponding user needs and define information system framework. The resulting software system architecture is also presented and a prototype of it is implemented. The whole system named MultiCAD is developed as a joint project between laboratory MSI of the University of Limoges and the Information systems and applications Group of the TEI of Athens.

Keywords: computer graphics, CAD, conceptual modelling, design process, design knowledge representation, multimedia information systems, knowledge-based systems, decision support systems.

1. INTRODUCTION

There are currently very powerful CAD applications, someone of them apply to particular fields while others serve as general-purpose systems. However these systems are computationally and functionally heavy and are not free from criticisms regarding the effective assistance they offer to the user (Designer) and the opening of these systems towards the exterior.

As paradoxical as it seems, the current systems of computer aided design, often do not offer any assistance at the conception itself. The designer must know all the details of the object to be created before calling upon the CAD system. This is mainly due to the lack of levels of abstraction in the description of the objects, the impossibility to give imprecise descriptions and the lack of information on the non-geometrical aspects of the objects.

Another reproach, which one can make with the traditional CAD systems, is the lack of opening towards the exterior. Nowadays large quantities of information circulate through networks. This information is various natures: image fixed or animated, sound, text, etc. These various types of information can be transmitted they can also be used in a CAD system. Moreover the design process of an object appeals to the images of other objects, allowing thus the extraction of forms usable in the design of the current object.

In this work our objective is to propose a multimedia CAD system liberated of geometrical inflexibility that prevails in contemporary systems [Kochhar90]. Thus we will attempt to define the architecture of a complete intelligent information system namely MultiCAD. MultiCAD will be associated with a prototype of designer support software, namely MultiCAD I, which will be used for the creation of scenes. This system was defined for the first time in

the research report MSI 96-03 [Miaoulis96, Miaoulis98].

The MultiCAD system is based on the declarative modelling of scenes by hierarchical decomposition. The objective of this method is to remedy the disadvantages of the traditional geometric modelling by allowing the description of a scene by its properties, which can be imprecise and incomplete [Lucas89], [Plemenos91], [Plemenos95]. More accurately, the declarative modelling makes possible to indicate the properties which verify the desirable scene in several levels of detail allowing thus a top-down design.

The description of the scene by its properties is translated to an internal model consisting of a set of Prologue-like rules. From this internal model a declarative generation module, using an inference engine, engenders all scenes having the demanded proprieties.

2. DESIGN PROCESS AND MULTICAD SYSTEM

Any important human activity comprises a more or less distinct preparation phase which in a abstract level is defines the products or the actions which will be materialised later. To **conceive** a project we must describe well in detail its various aspects, develop prototypes if required, test and evaluate its qualities and its conformity in his descriptions. This sequence of actions is defined as the **design process** All the acts of the design produce **descriptions**, **representations** by using natural, formal or graphical languages. These acts are based on **theories**, implicit or explicit **methods** and on sets of **concepts** and **knowledge** in various fields of know-how (engineering, Architecture, Urban Planing, Mechanic, Art, etc) [Braha97], [Goti96] [Salomon95]. We call all this **Domain of Knowledge**.

The generality of **design process** gives rise to difficulties in modelling because of complexity of the task and the uniqueness of the designer and his perceptions. Having in mind a specific designer or type of act has risks of bias. Nevertheless the birth of formal methodologies of design, the theoretical work on the modelling of knowledge and process, the empirical analysis of the design act, the recourse to the decision theories, the artificial intelligence etc, make possible the determination of essential points of design process.

In our approach the **design process functions** is described through their decomposition, categorisation and inter-relations (i.e., in terms of the Input, Output, Control, and Mechanism classification) and the description of the information and the knowledge that an designer considers important to manage to accomplish his objectives.

The design process is considered as decomposable in several, successive distinct **stages** pointing to the initial goals. The design process can be viewed as a succession of transformation between descriptions. These descriptions can be classified to a representations hierarchy of most abstract to most concrete on an **abstraction levels axis**.

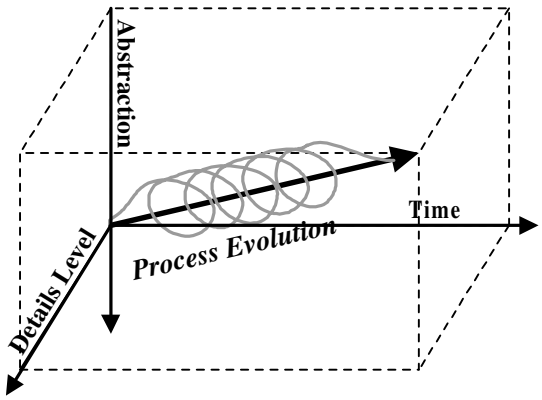
The second assumption is that the process of design follows a walk from the general to the specific. In the majority of the cases we start from a very general idea and work the details stage by stage completing its various aspects. The **axis of the detail levels** translates to the top-down and bottom-up approach in the design.

The evolutionary character of the design process is traced by the **axis of time**. Given a prototype of action, a paradigm, which obeys at a basic repetitive mechanism, the notion of the axis of time intervenes to the modelling of the whole process.

The evolution of design process

The design process is defined as a succession of similar stages, for establishing the complete (final) model. A spiral in a three-dimensional space (figure 1) can represent this succession of stages.

- The axis of **abstraction**,
- The axis of **levels of detail**,
- The axis of **time**.



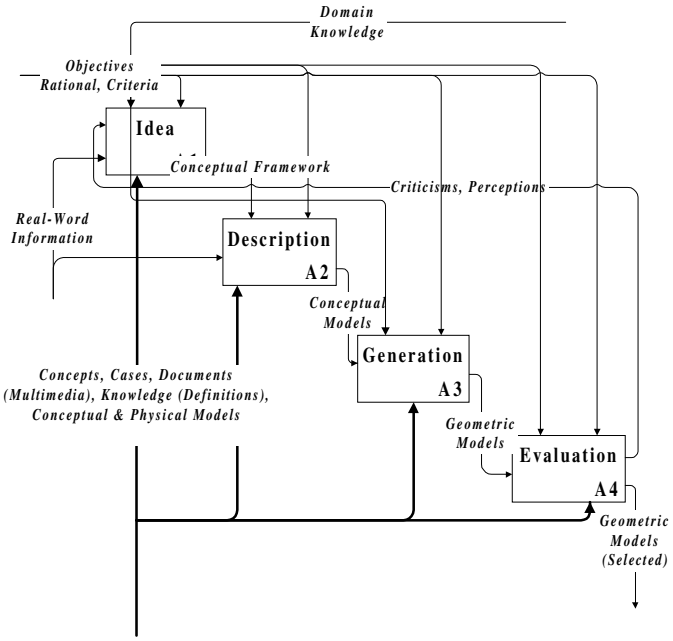
Evolution of the design process
Figure 1

An initial idea serves as a starting point. As time evolves the level of detail increases and the level of abstraction decreases, until the achievement of the process.

Activities of a typical stage

We propose a decomposition of the design process in four activities: formation of the initial **idea**, the **description** of the scene, the **generation of solu-**

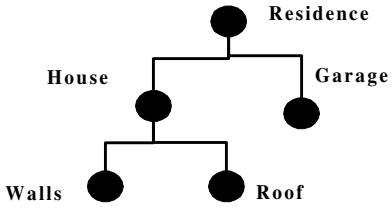
tions (geometrical forms), the **evaluation** of the solutions. In figure 2 the (IDEF-like) functional model of the process is presented. All this activity occurs in an open environment where the designer can **exchange** or **consult information** and **knowledge**.



Four activities of a stage of design process
Figure 2

The formation of the initial **idea** it is not directly computer aided. However it can appeal to sets of equivalent cases and documents.

The **description** of an idea can be done using natural or specific language. This phase can be supported by the computer. In declarative modelling the description phase is done by properties the scene, modelled in a top-down process (hierarchical decomposition) (figure 3).

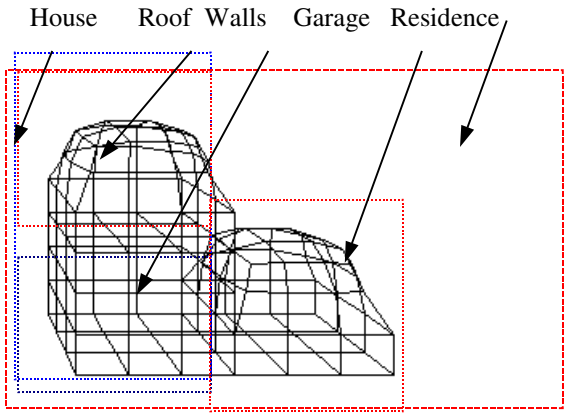


Decomposition tree
Figure 3

From graphical description, we can generate a text type document called internal model which will be exploits in the generation phase. This type of document can be modified and corrected using a text editor. Here is an example of internal model for the description of figure 3:

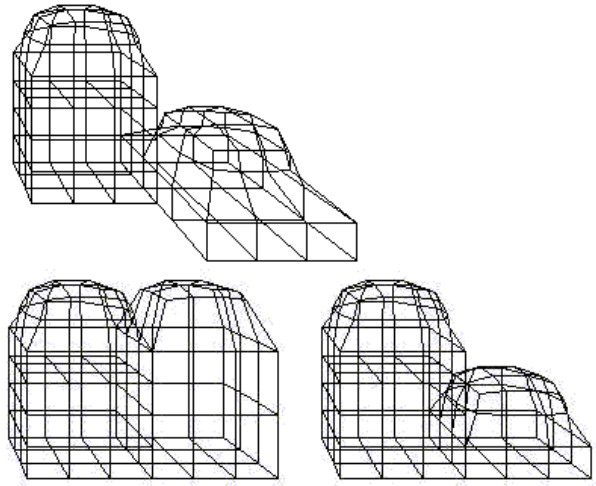
```
Residence (x,p) -> CreateFact (x,p)
                   House (y,x)
                   Garage (z,x)
                   PastedLeft (y,z,x);
House (x,p)     ->  CreateFact (x,p)
                   HigherThanLarge (x)
                   HigherThanDeep (x)
                   Walls (y,x)
                   Roof (z,x)
                   PutOn (z,y,x);
Garage (x,p) ->    CreateFact (x,p)
                   TopRounded (x,80);
Walls (x,p) ->     CreateFact (x,p);
Roof (x,p) ->      CreateFact (x,p)
                   TopRounded (x,70);
```

Figure 4 presents a wire-frames model.
There are other type of proposed descriptions which are based either on relational techniques for architectural systems (ICADS) [Chun97] or on natural language processing (NARIC) [Giunchiglia96]

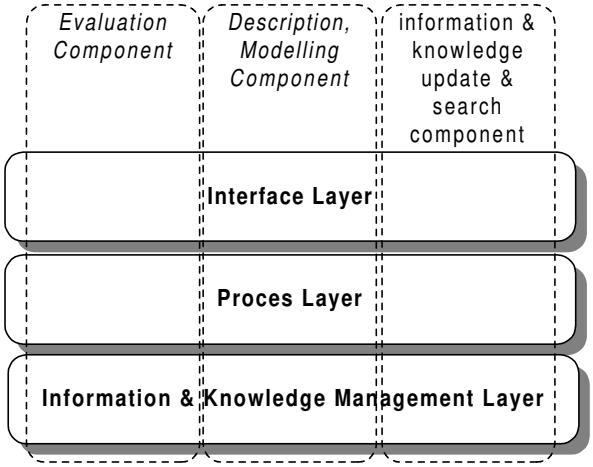


Wire-frames model
Figure 4

The **generation of the solutions** from a description provides the user all the scenes (solutions) which verify the description (figure 5). The phase of generation, (it could also be called phase of **search for solutions**) will comprise two types of actions: a traditional action of generation and a action of search for a solution from an existing database. The traditional generation produces solutions that compliant to the set of rules (constraints). The search for solutions attempts to identify a scene stored in the knowledge base and bears a great degree of similarity to the description at hand. The whole process can be enhanced through learning techniques.



Generated Solutions
Figure 5



Layers and components of IS
Figure 6

The **evaluation** makes possible for the designer to realise the consequences of his idea. The designer evaluates the solutions and makes choices; if it is required he can correct the description or he can refine his idea and reproduce the abstract model.

3. DEFINITION OF MULTICAD SYSTEM

The functional model of the design process (figure 2) is the necessary framework for determining the components and the functions of an information system (IS) for the Design. The nature of information and knowledge treatment justify the multimedia and the intelligent character of the IS.

The suggested functional architecture (figure 6) for the information system (and support software) MultiCAD apart from the definition of **types of the information and knowledge** and the **databases organisation** comprises the following principal **components** and **layers**:

- Tree components of (a) **evaluation**, (b) **description and modelling** and (c) **information and knowledge update and search**.
- One **interface layer** (visualisation, description, modelling, and query).
- One **process layer** for the generation of the solutions, the selection, the conversion and translation of the forms and their representations.
- One **information and knowledge management layer** for the structuring, the management and the exploitation of different databases (case, concept, knowledge, multimedia document)

Types of Information and Knowledge.

Within the framework of the MultiCAD information system several types of information like models; knowledge; concepts and multimedia documents are stored and circulated. Control information of different activities of the process is stored as designer attitude. More accurately:

- **Abstract models** (conceptual).

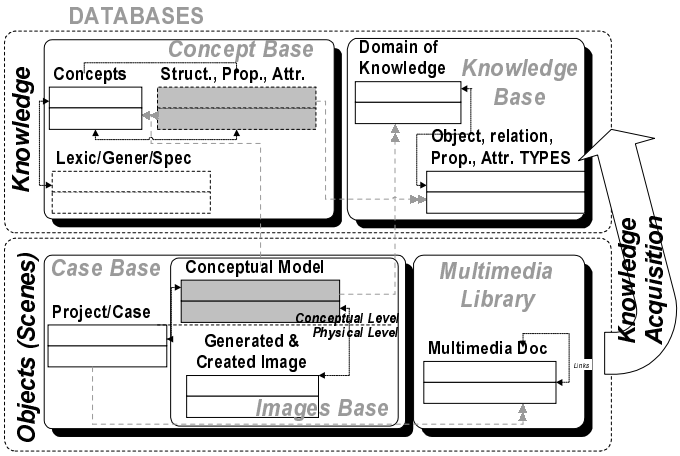
The essential abstract models are models of **scenes** (e.g. declaratives hierarchic models) or of **concepts of scenes**, models of **documents** (e.g. descriptive language of the document) and models of images (e.g. objects-relations model of the image). The models of **domain knowledge** translate abstract models of scenes and concepts to rules (constraints).

- The **physical models**.

The basic physical models are scene models (geometrical models - intermediaries models), models of documents (codes in characters), models of images (pixel or vector models etc).

The databases organisation

The system of storage is organised as a four linked database configuration. The case-base (or projects-base) [Wood96], the knowledge-base, the concept-base, and the library of multimedia documents (figure 7)



The database configuration
Figure 7

The Interfaces layer

A certain number of tasks can be carried out through the interfaces of the system. The principal tasks supported by these interfaces are the **intelligent visualisation of scenes and documents**, the **description and modelling** and the **formulation of requests**.
The task of **intelligent visualisation of scenes and documents** comprises main functions like:

1. The intelligent and interactive visualisation of **scenes**. This function allows in particular:

- Visualisation in **wire-frame** or with the **elimination of hidden parts** from the **geometrical models** or **intermediate models**.
- Calculations of parameters of visualisation such as luminosity calculations or good point of view calculations that allow the evaluation of the properties of a scene [Plemenos91], [Plemenos96].
- The interpretation of user commands.

2. The function of intelligent and interactive visualisation of documents and images.

The task of **description and modelling** allows a easy description, declarative or imperative, of the processed objects. Such objects are the scenes, the documents and the images etc.

The task of the **formulation of the requests** and the handling of databases implemented through several techniques:

1. A traditional formulation of SQL, Spatial SQL or " free text search".
2. An adequate formulation for the declarative modelling which can be based on the type of representation of knowledge (decomposition tree, etc.).
3. A formulation based on hyperlinks.

The process layer

The process layer includes primarily a module for the **generation or solutions** from a given description and a **geometric modeller** allowing the direct modelling of scenes or the reprocessing of scenes obtained by declarative modelling.

The **generator of solutions** allows generating or seeking all the solutions from a description. The **geometric modeller** is used for modelling scenes for which all the details are known, for additional handling of scenes obtained by conversion or declarative generation [Sellinger96], for modelling from images. This modeller must be general enough to allow the modelling by facets, pieces of surfaces (Bezier, B-splines or others) or volumes [Lee82a], [Lee82b].

Information &knowledge management layer

The information and knowledge management layer of the databases consists of a module of conversion, a module of knowledge acquisition and a system for searching the knowledge.

The **conversion module** is responsible for conversion between the various types of models. Several types of conversions are provided:

- Conversion from a type of abstract model to another.
- Conversion from an abstract model to a physical model and vice versa.
- Conversion from a physical model to another.

The **module of knowledge acquisition** is based on the existing knowledge base and (or) on an exterior site and (or) the intervention of the designer. The designer can affect the knowledge acquisition ether actively (directly editing the knowledge base) or passively (by learning techniques). Acquired knowledge is integrated in the reasoning of the system, which becomes increasingly powerful [Belabdelli95], [Plemenos95].

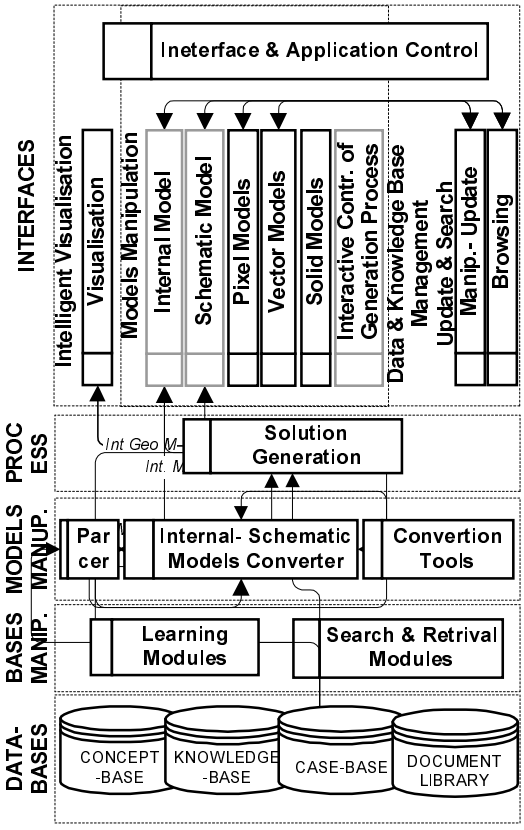
The **search of knowledge** generally takes place in the knowledge base but it could also relate to external sites, accessible by the network. The Knowledge can exist in several formats (scenes describes in various ways, images, texts, mixed) Thus, various techniques of information search must be implemented, in particular in the field of document and image retrieval. The information must be filtered so as to prevent unnecessary processing. These filters can evolve dynamically through a system learning mechanism.

4. IMPLEMENTATION OF MULTICAD PROTOTYPE

The software system «MultiCAD I» constitutes a prototype implemented within the framework of the defined multimedia intelligent information system and is developed in Object PASCAL (Delphi) for the Microsoft Windows environment.

The Architecture of MultiCAD Software

In figure 8 we present the general architecture, components and flow of information and knowledge of the «MultiCAD I» software system. This architecture is closely related to the general functional architecture in which this software is designed.

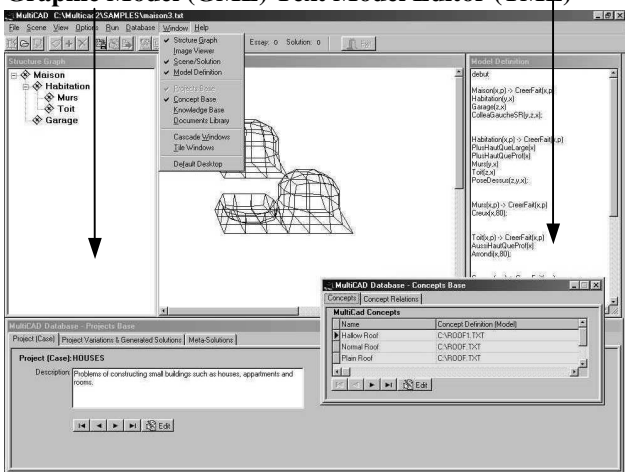


The architecture of MultiCAD I Software
Figure 8

The Human-Computer interfaces

In this part we present the system of Human-Computer interface designed and implemented in to the MultiCAD I software prototype. The main interface of the MultiCAD prototype is shown bellow:

Graphic Model (GME) Text Model Editor (TME)



The main interface layout
Figure 9

There are five workspaces in the initial screen (Figure 9). These are: The menus (pop up), the tool bar, the text models editor, the graphic models editor, the images editor and the data and knowledge base.

5. CONCLUSIONS AND FUTURE WORK

In present work, we have proposed a design process model for scenes based on the method of declarative modelling by hierarchical decomposition. From this model; we have tried to define all the elements of an information system of the designer called MultiCAD. The nature of process of this system appeals to the methods of artificial intelligence and to the techniques of search and of handling of images, texts, sounds and video. All these features justify its multimedia and intelligent character.

This definition results in the constitution of a set of specifications, probably still incomplete, for the definition of a basic architecture and in a platform for development of multimedia and intelligent software systems dedicated to the Computer Aided Design. The heart of these systems constitutes primarily of MultiFormes type declaratives modellers. We also briefly present the first implementation of software of this type called MultiCAD I.

Some of the aspects of MultiCAD platform (e.g. Knowledge Acquisition) are not yet sufficiently developed. They will be further analysed in upcoming publications.

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