Simulation of Architectural and Urban Morphology

From automated 3D Modeling to virtual reality : problems and challenges

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Abstract:
The **Remus** project aims at conceiving a simulation tool for both architectural and urban morphology, building a computer system using artificial intelligence tools, and computer graphics. **Remus** is made of a base of architectural knowledge, an expert system, and an interactive graphical environment for generating and displaying architectural objects. In this paper are presented new developments concerning evolution toward virtual reality models.

1 - Context of the Remus project

Urban simulation, either for historical or for forecast purposes, needs many different pieces of information to produce good quality realistic images. Often, this information came from heterogeneous software environments and are of different types. Some are not directly known but must be estimated or generated for simulation, in particular information concerning buildings and urban furniture.

The problems we have to solve are the conflicting objectives of the system :

- *best rendering* to display images giving satisfactory impression,
- *easiness of virtual walking*
- *global realistic view* because modeling of quarters, or even of whole a town, needs that views which are presented look like aerial photographs or perspectives found in architectural books.
- *faithfulness* of architectonic elements which would be in agreement with reality as close as possible in spite of size of data.

Some city modeling systems use existing maps and urban data as complete as possible : this allows full reconstitution compatible with reasonable size reasonable and time [BSC96]. **Remus** system, in contrary, is able to treat approximate plans and imprecise typology for automated reconstitution. Moreover, to attain the best result, when some parts cannot be produced automatically they are imported by conversion of classical CAD models [QZM93].
For example in case of the ancient city of Marseilles for which has been produced the movie "Les Envois de Marseille" the available information were only some foundations

and a capital. But, knowing similarities with greek city of Olynthe where buildings have been found, we have been able to introduce appropriate rules of production in the system.

2 - Typo-morphological approach :

From the urban and architectural point of view, our work aims at realizing an operational description model for the structured representation of objects, without ambiguity, using the knowledge about the area.

The production and use of a semantic model, supposes to admit a strong hypothesis : the architectural and urban knowledge universe is "regular", it can be described and represented, therefore we can produce a model.

Two thousand years of production of the occidentals cities reveals us the structures and objects that compose them, a corpus of knowledge that is expressed in vocabulary, know-how, legislation.

Names designating objects, adjectives that qualify them, verbs that designate actions, allow us to apprehend and to reconstitute the semantic universe of forms and the rules of their production. Especially the explicit rules that allow to manage without ambiguity objects in the tri-dimensional space (composition and wedging).

The knowledge of the urban and architectural morphology is therefore comparable to a structured universe of elements described in term of identifiable generic objects and able to produce particular objects by filiation.

The representation of the knowledge's universe that we propose uses:

- physical objects, architectural and urban elements,
- relationships that connect these elements.

Elements are characterized in the real world, by:

- attributes (morphological, architectonic or position)
- the different parts that compose them,
- graphic representations

Relationships between objects are two types:

- relationship of filiation : specialization
- relationship of composition : aggregation

Relationships of composition consist in ordering objects according to a set of rules.

The aggregation of the set of these objects constitutes then a more complex object.

Thus urban entities can be described by classifying their generic classes, identified by the typo-morphological analysis.

The approach based on the knowledge, is implemented in different part of the software: knowledge's basis, expert system, tri-dimensional modeling environment, user interfaces and instrumentation modules, which allow to solve some problems in complex management of the urban information.

3 - Object oriented approach in knowledge representation

The oriented object representation of knowledge is born from the concept of "Frame" proposed by Marvin MINSKY in 1975. Based on the structuring of knowledge into closed set that regroup declarative and procedural information relative to a same object or a same situation within an entity. The basic idea is to have a structure of representation in which all relevant information and procedures for this information can be retrieve. The "Frames" are constituted with the set of property fields, that describe the object or the situation. Each of these fields represents a complex information whose semantics has to be specified. In practice this approach is translated into some fundamental concepts such that classes, inheritance, encapsulation etc ...

The main concept is class which permit to describe a conceptual information. A class is known by the properties' specification of an object . These properties can be defined in several levels of abstraction, translated into a hierarchy of classes, this allows to describe at each level solely the totality of information that are added to those of highest conceptual levels. This mechanism of inheritance allows each class of the hierarchy to access to information of highest classes. One speaks vertical inheritance to symbolize this rising research of information..

The allocation of value into fields describing an object produce instances, which represent an element of the real world.

The object oriented representation of knowledge has several advantages. Mainly it allows to structure strongly the totality of knowledge. More, the representation of procedural information as well as declarative within the same entity facilitates the control of knowledge associated with an element. The cutting of knowledge in several conceptual levels provides a framework facilitating the transfer of information to the machine by inviting, at each level, to to be preoccupied only relevant information for this level.

Mechanisms of inheritance allow factorization of the redundant information. The encapsulation, only an object can access directly to its own values, and the notion of default value authorizes the system to work in partly described universe, often like in architecture and in town planning.

The choice that we have made for **Remus** has focused on the language Smalltalk80 [GR84]. This object oriented language defined in 1972 by the team of Alan Kay allows to implement an object oriented representation of the knowledge

4 - Implementation of Remus

The **Remus** system is composed of 4 parts :

- a knowledge database
- an expert system
- a 3D modeler
- an user interface

The choice of Object Oriented Model for the whole **Remus** system is need to integrate in a same environment a set of techniques using deeply different data. Object approach allows to regulate information exchange between heterogeneous elements. Only interrogation protocols of an object are known by others elements in the system, independently from representation and algorithms used to satisfy a request. At every stage in the development of the project a piece of the system can be replaced by another, with the single condition that exchange protocols messages are the same. So we substituted in **Remus** expert system Ship-Planer in prototype version by NeoPus system in pre-industrial phase : this replacement has been done without modifying other elements (modeler, interface), except description of knowledge database and syntax of rules.

In a same manner, integration of an altimetrical module for placement of buildings was easy. The module was made as a stand alone triangulation software, and after we realize only a development of a communication protocol between classes describing terrain and classes describing volumes [MZ94].

5 - Description of Remus

5.1 The knowledge base

The knowledge processed here is structured in two complementary parts :

- a corpus of knowledge elements which we call structured object
- a corpus of rules of production

To define a general model, we must first define : the corpus of objects composing the architectural and urban universe, the relations managing them, and find a mode of definition and identification of their attributes. The identified objects are hierarchically organized. The object based formalism of representation allows this mode of expression for knowledge.

a - structured objects : as shown in Smalltalk, architectural objects are hierarchically organized according to two taxonomies : "sort-of" and "part-of", from a root-class : "CorpusElement

b - relation of filiation : "sort-of". This relation, as well as the inheritance of properties, is directly offered by Smalltalk. The class-within-class mechanism allows to specialize objects while looking through the heritage-tree

c - relation of composition : "part-of" this relation manages the link between an object and its components. This link is essential for a property, inside an object to be directly shared with all its components (i.e. : color, material...), it is a way to factorize information so as to express it under a more exploitable form.

d - rules of production : they are rules of composition that act on the architectural objects already, or in the process of creation. A rule base can describe an architectural typology. That is a means of expressing typological knowledge according to the "modus ponens" reasoning : if (condition), then (action). This mode of expressing knowledge allows separating knowledge proper (corpus of the architectural objects) from the applied chain of reasoning which has to be expressed by rules.

5.2 Description of the architectural objects

Research on architectural vocabulary has allowed to describe the model according to :

- type of objects
- relations between the objects
- tattributes of the objects

An architectural object is an instance defined by several attributes (field, slot, according to the terminology) that corresponds to instancing variables of Smalltalk such as : "material, owner, listElement" defined in the root-class, and transmitted to all subclasses by the inheritance mechanism, the number of attributes increases with the specialization of the objects. To each architectural object is associated a procedural aspect : Smalltalk methods, which allow sending messages and communicating with the system components. Here are some examples of attributes for architectural objects, definition given at the root level :

- a 3D morphology which is a geometrical primitive instance of the modeler. The 3D morphology is a 3D geometrical volume (or assembly of 3D volumes), themselves also defined by attributes and performances.
- a 2D morphology which represents a plane projection of the 3D morphology.
- a typology (if not specified, it is a Notype typology).
- an owner (relation of composition).
- a list of elements (relation of composition, if not specified, it is an empty collection).
- dimensions (height, width, length).

Architectural objects are defined by the typology to which they belong. The architectural typology appears as a sequence of key-value doublets, subclass of «Dictionary" from Smalltalk. This aspect of the typology is associated to a base of rules for the expert system that adds to the definition we have given for typology.

5.3 The modeler :

The object oriented approach allows, among other things, a perfect partitioning between the different software components. So, in **Remus** , the modeler can operate on its own, that is to say in an autonomous application, without any expert system, or it can be included into the general application. Communication between the different components is carried out by the sending of messages to the objects that are necessary to the achievement of urban elements in the process of modeling.

A first part of the work needed for the constitution of a modeler is to describe a class hierarchy necessary to the architectural objects morphology (limited in this study to polyhedral objects). It covers the description of geometrical objects needed for a modeler to be used for most architectural elements [CDZ95]. The composed object concept is managed by dictionaries made of key-value doublets, the key allowing to name objects that are either elementary geometrical objects or assemblies as dictionaries. Operations carried out on these composed objects are propagated to the parts that constitute them.

The classes of the geometry category describe both the nature and the behavior of the elementary shapes to be used. It is a surface modeler with management of both the interior and the exterior of volumes.

6 - Input data

The vocation of the **Remus** system is to become an interface to many system of cartographic management, in order to complete two-dimensional information about parcels, constructions, etc by three-dimensional information deductible from the typology. But **Remus** also aims at completing the outputs produced by software using stereo-photogrammetrical retrieval methods.

Today, interface is being provided by Carine, cartography software of the City of Marseilles ; this SIG, produced by ICOREM has cadastral, topographical, archaeological, technical, statutory, and thematic data, as well as data about the underground networks, all data being permanently updated. We also use information from Trapu of IGN.(National Institute of Geography in France)

An integration with Ricardo was made in 1994. Ricardo is a thematic software designed by CERMA and whose present version shows innovative characteristics, particularly corresponding to :

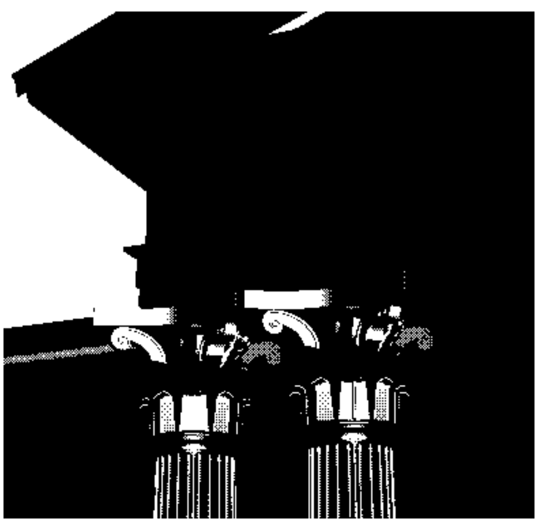
- the creation of a complex data base associating both numerical and geometrical data, and using the object strategy.
- the notion of multiple inheritance with topological organization of the base
- the extended globalization allowing automatic attribution of values calculated from values of the same bank, or other data banks.

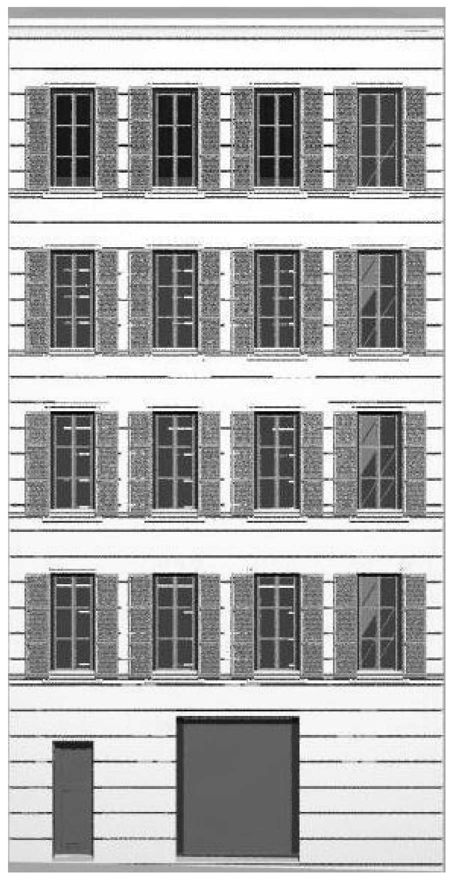
The software makes it possible defining applications from a data organization, into item bank as sets of homogeneous entities.

Now some part of **Remus** can understand a setting of a DXF datas for example in altimetrical module ; And in next future we make an interface with VRML datas.

7 - Output data

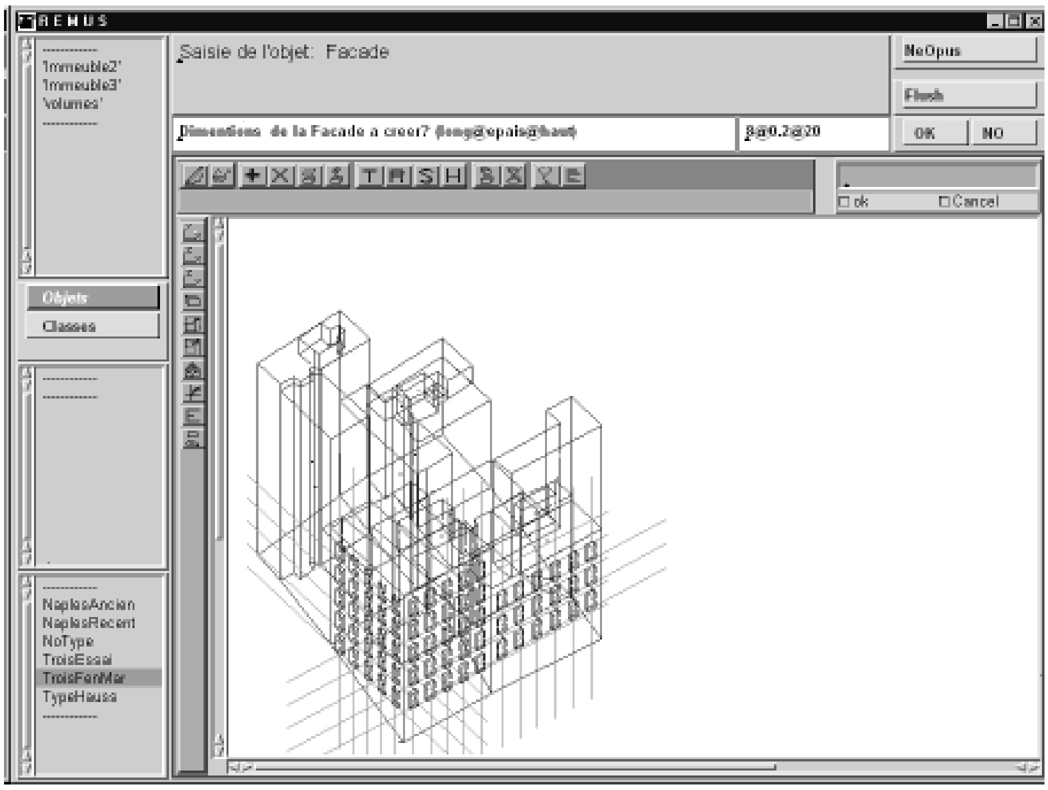
The modeler manages B-rep structures, so it is easy to export polyedric volumes together with information for rendering : vertex normal vectors and characteristics of materials.
But the size of data implies also managing levels of details, depending on requests. From low complexity (tenths of primitives, thousands of polygons) to large complexity models (hundreds of primitives, millions of polygons), the challenges are to be able to present realistic views in every situation, choosing the optimal number and types of primitives adapted to the goals. In VRML this is partly possible with inline techniques, allowing rapid display of global view and loading of small architectural elements only when needed.
Using data structures of the system, output is also done in format of the popular ray-tracer POV-Ray, which is a CSG description with some additions of facets. This is possible because rules of automated production are in fact also adapted to CSG modeling, typical example being those of front walls where windows are simply created by boolean difference and cornices by boolean union.



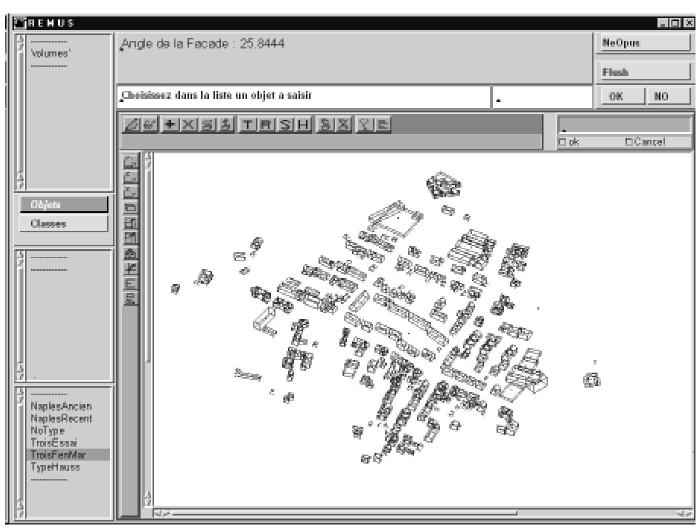


8 - Examples
A first trial was done by modeling of a 19th century quarter of Marseilles ("Hausmann" type) but Pascal language used for development didn't allowed easy evolution toward another typology. When converting in Smalltalk and implementing the expert system a more typical urban tissue of Marseilles has been used as test data and we obtained satisfactory results.

Currently, work has been done by Mrs Adriana Bauculo Giusti with students in University of Napoli to implement an axonometry of their town, extracting significant graphical elements by a huge work of typo-morphological analysis needed for this representation [Ba195] [Ba295]. This work, linked with knowledge of cadastral data, seemed an ideal starting point to apply **Remus** method to Napoli. A cooperation began and would permit a virtual walking in some streets of Napoli during next spring [Ba395]. Tests are done now to perfect knowledge base, mechanisms managing it, and improve user interface. In the frame of cooperation between Gamsau and Gidcad in University of Belgrano at Buenos-Aires, **Remus** system will be used also by researchers to model a quarter of Buenos-Aires.



For test data "Oedekoven" given in VRML they have been read without problem by **Remus** but without knowledge of typo-morphology of towns in Rhenany-Westphaly no significative results have been obtained.



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