Calligraphic Interfaces and Geometric Reconstruction

Manuel Contero, Ferran Naya, José María Gomis, Julián Conesa[1]

Departamento de Expresión Gráfica en la Ingeniería, Universidad Politécnica de Valencia
[1]Dto. de Expresión Gráfica, Universidad Politécnica de Cartagena

Abstract

Analysing the CAD market over last years, we can conclude that there is a small evolution, in the development of user interfaces. Nowadays, all the commercial applications follow the WIMP (Window, Icon, Menu, Pointing device) paradigm. This justifies the fact that CAD software still has a minimum impact in the conceptual design phase, where the "paper and pencil" approach is the basic support for expressing the designer creativity. In this context, the research group REGEO (http://www.tec.uji.es/regeo) has developed in the last years some algorithms in the field of geometric reconstruction. In the paper, we present the current work the group is involved around geometric reconstruction and calligraphic interfaces.

We think that a system aimed to facilitate the preliminary design phases must be designed to conform user habits, and not to force users operate in an environment that not exploits their sketching skills. It seems a contradiction to develop a user interface that forgets a common ability for designers. For this reason we think very interesting combine our previous work about geometric reconstruction with the emerging field of calligraphic interfaces. In the last years we have developed a software application called REFER, oriented to build a 3D model using an axonometric projection as input. At this moment this reconstructor is robust enough to deal with simple polyedrical geometry. Its input is a "perfect" drawing generated by means of a 2D CAD system in DXF format. We call it perfect because al the vertexes are correctly defined, and the edges are straight lines connecting vertexes. The REFER applications uses an optimisation approach to solve the reconstruction problem, and its output is a surface model. To provide REFER a friendly interface we have adopted a sketching based one. The user communicates with the application with a stylus and a graphic tablet or LCD tablet. Simply he sketches an axonometric perspective drawing that serves as input to the reconstructor. We will present a new REFER module designed to capture sketches, that with the proper pre-processing are used as input to the reconstruction phase. Also we present in the paper a second module devoted to export the reconstructed object in VRML 2.0 format (ISO 14772). Of this way, we present a self-contained application including a sketching interface, a reconstruction engine and a VRML 2.0 export module.

1. GENERAL PRESENTATION

Analysing current CAD systems we can conclude that it has had a great evolution during the last decades. Today, feature based solid modelling and constraint based modelling are concepts widespread implemented. But user interfaces have slow evolved from old UNIX-like command line user interfaces to the WIMP (Window, Icon, Menu, Pointing device) paradigm. However, this kind of interface is still little friendly in the first stages of the design process where the engineer expresses his creativity with paper and pencil [1][2][3].

The primitive CAD systems used devices like light pens for data entry, but nowadays mouse is the king pointing device. Graphics tablets are still used, but by means of templates use the same "point and click" philosophy.

However, during last decades different research lines has been explored to improve man-machine interaction related to CAD systems, with the first references from last 60's and beginning of 70's [4][5][6]. One of these research lines is about using and electronic version of the paper and pencil tools. The more similar devices for it are a stylus and a graphic tablet or LCD tablet. During early 90's Microsoft intended to promote "Windows for Pen Computers", an operative system built over standard Windows with a set of extensions to support a user interface based on the interaction with a stylus and a LCD tablet. It was a failure because of the small processing power of those "pen computers". But present computer processing power makes feasible implement alternative input modalities. New interface technologies are emerging using sketching, drawing and pen input to support man-machine communication. The term "calligraphic interface" covers this new kind of user interface. Examples of new devices supporting these new technologies are the popular PDAs, and the prototype Microsoft showed last November in the COMDEX fair called "Tablet PC".

Most part of applications developed under the "pen computing" umbrella use gestures [7][8] as the basic command input. Besides hand-written and drawing sketch input is supported by these systems. For example, early 2001, IBM presented the Transnote laptop computer that captures handwritten ideas on paper and transfer them to the computer, where they can be organized and searched.

In this context, there is a research line related to use sketch input to build 3D geometric models. There are two main trends. One is based in interacting with user by means of gestures that are recognised as modelling commands. The second approach is based in geometric reconstruction parting from an object projection. A third hybrid approach combines both gesture input and geometric reconstruction.

Examples of the first type systems, that we will call "gesture based" are:

- SKETCH [9] focused on architectural design, where the modelling commands are gestures. For example, three concurrent lines on a point define a block primitive. Positive volumes are drawn from top to bottom, and negative ones from bottom to top. SKETCH-N-MAKE [10] works in a similar way but is oriented towards machining simple parts
- Quick-Sketch [11] is a tool oriented to mechanical design. Provides a constraint based drawing environment. Builds 3D models by means of a set of command gestures.
- Teddy [12] allows modelling freeform surfaces with a very simple interface. The procedure consists in drawing the object silhouette, and then the application provides a polygonal mesh adapted to the object silhouette. The application is Java based and runs in an Internet navigator.
- GIDes [13] builds 3D models from a perspective projection or multiple diedric projections. The system provides a gesture alphabet for building a reduced set

of geometric primitives. Also provides a dynamic gesture recognition, for confirm design intent.

The second research line, that we could name "geometric reconstruction" takes as input an axonometric projection and provides as output a 3D geometric model. There are two main approaches to carry on this process. One is based in the Huffman-Clowes [14][15] labelling algorithm. The second approach uses an optimisation [18] formulation based on human perception. It takes in account the mental process, simplifications and assumptions we take when are seeing a perspective drawing. The optimisation procedure provides in many cases not feasible solutions, mathematical correct, but visually incorrect. It must be pointed out that, from the point of view of Geometry, it has been always very well known that full recovery of a geometrical 3D model from one single projection of it is not possible. Nevertheless, from the field of psychologists it is also very well known the fact that humans seem to have no problems to identify 3D models depicted in 2D images. What is more, it seems to have a great consensus about which is the “correct” and “single” model all humans see in every picture. The reason comes from the fact that humans, when “reading” drawings, do implicit recovery actions. According to Gestalt school, this is because human perception holds some common characteristics, called “principles of organisation”. Applying Consequently, pure Visual Perception rules must also be considered to face the reconstruction problem. This rules are implemented by means of a mathematical formulation that is solved by an optimisation process. Several reconstruction engines have been developed by authors like Marill, Leclerc, Fischler, Lipson and Shpitalni [16][17][19]

In last place there is a third way, that combines both gesture and reconstruction approaches. It follows a hybrid technique. The most interesting systems are:

- Digital Clay [20] works with polyedric objects. It uses a calligraphic interface for data input, that after proper pre-processing is introduced in a reconstruction engine based on the Huffman-Clowes labelling algorithm, then the reconstructed object is exported to VRML format
- Stilton [21] is oriented to the architectural design. Implements a calligraphic interface directly on a VRML browser. Its reconstruction kernel uses the optimisation approach and operates with genetic algorithms

Our application fits in this third group, integrating an optimisation reconstruction engine and a sketch based input.

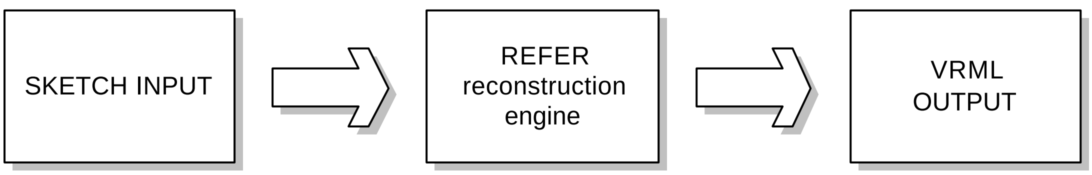

Figure 1.- Architecture of the developed application

2. SYSTEM ARCHITECTURE

To implement a prototype application to explore the feasibility of a conceptual design tool based on calligraphic interfaces and geometric reconstruction, we have worked in providing our REFER reconstruction engine [22] with a user interface for sketching simple polyedrical parts. This reconstruction engine is oriented to build a 3D model using an axonometric projection as input. At this moment this reconstructor is robust enough to deal with simple polyedrical geometry. Its input is a “perfect” drawing generated by means of a 2D CAD system in DXF format. We call it perfect because all the vertexes are correctly defined, and the edges are straight lines connecting vertexes. Also, we have designed an output module to export reconstructed objects to VRML (ISO 14772) format.

3. SKETCH INPUT

Sketches and diagrams are the natural way of communications for designers and engineers. Nowadays, low cost graphic tablets are widely available. Thus, providing a natural interface for our reconstruction application is done by a sketching application that provides a friendly input to the reconstruction engine. Communication with graphics tablets is provided by the Wintab API (http://www.pointing.com). Wintab is an open industry interface that directly collects pointing input and passes it in a standardized fashion to applications. This API is widely supported by graphic tablets manufactures, so we have developed a C++ library to implement a sketching application. This application manages the collected data, performs de the proper pre-processing, performs a line fitting algorithm, adjusts vertexes and outputs an internal DXF file to feed the reconstruction engine.

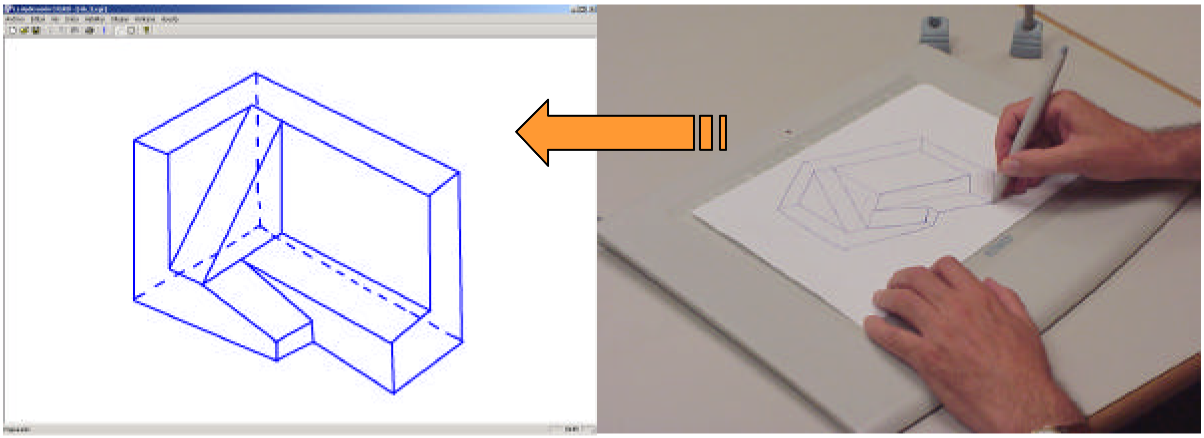

Figure 2.- Sketch input

4. RECONSTRUCTION

Geometrical Reconstruction is the name usually given to the problem of how to recover the geometrical information of 3D objects contained on their 2D images, in our case, this image is an axonometric projection. The Reconstruction problem can be described in terms of a mathematical optimization problem, departing from the key idea that (X,Y) coordinates of every point in the graph are equal to (X,Y) coordinates of corresponding vertexes in the model. Thus, the problem can be described as:

Minimize F(**z**), where

- $\mathbf{z} = (z_1, z_2, \ldots, z_n)$ is the set of z-coordinates that constitute the independent variables vector.
- n is the number of vertexes or "control points" that fully determine the shape of the model.

In other words, Z coordinates are the variables. As a consequence, an infinite number of models are valid, because they all can be projected in the same figure. The full set of infinite three-dimensional objects whose orthogonal projection is equal to the given graph usually is called "orthographic extension". The second key idea in the proposed approach is to develop some criteria to choose one particular model among the infinite ones contained in the Extension. In general, there is only one “good” solution, in terms of “psychological plausibility”. That is, human observers seem to have no doubts to choose the appropriate solution among all those constituting the Orthographic Extension. “Regularities” are the way to make explicit such human perceptions. In the geometrical reconstruction field, regularities are interpreted as “those properties of the image that must correspond to some properties the searched model also has”.

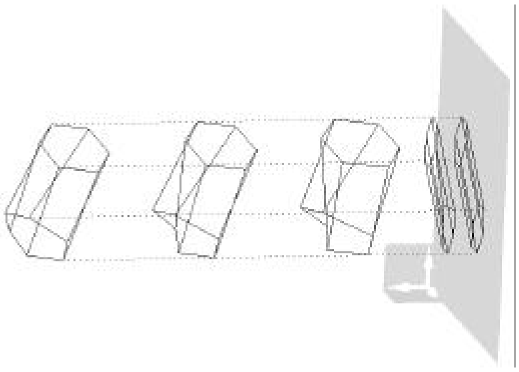

Figure 3. Inflation process. Some intermediate models, together with the final one

Consequently, it is supposed that, by inspecting the image, the necessary number of properties describing how the model must be can be founded, and the good solution can be described. The Objective Function can be easily defined in terms or regularities in the following form:

$$\boldsymbol{F}(\boldsymbol{z}) = \sum a_i \boldsymbol{R}_i(\boldsymbol{z})$$

Where,

- a_i is the *i*-th weighting coefficient, and
- $\boldsymbol{R}_i(\boldsymbol{z})$ is the *i*-th regularity.

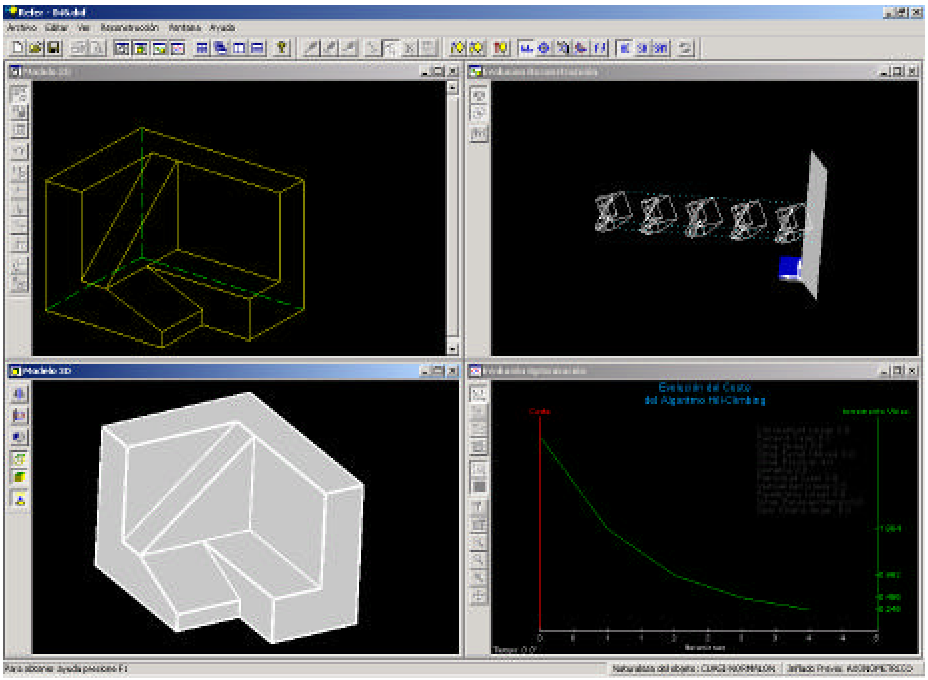

Figure 4.- Reconstruction with REFER application

Regularities must be expressed in terms of the independent variables (z), and must be formulated to be equal to zero when a complete compliance of the condition is achieved, and very different from zero for clear non-compliance. Consequently, weighting the different regularities is necessary because ranges of different regularities can differ a lot, and a normalization is needed to prevent undesired priorities. In addition, under some circumstances may happen that not all of them have the same importance in the model.

Some of the regularities supported in the current version of REFER are faces planarity, lines parallelism, isometry, lines collineality, standard deviation of angles, corner orthogonality, lines orthogonality, faces perpendicularity and lines verticality.

5. VRLM OUTPUT

The generation of the VRML file [23] is made after faces recognition. VRML files are structured in nodes, and nodes in fields. Reconstructed geometry is coded in an *IndexedFaceSet* node. This node represents a 3D shape formed by constructing faces (polygons) from vertexes listed in the *coord* field. The *coord* field contains a *Coordinate* node that defines the 3D vertexes references by the *coorIndex* field. *IndexedFaceset* uses the indices in its *coorIndex* field to specify the polygonal faces by indexing into the coordinates in the *Coordinate* node. An index of "-1" indicates that the current face has ended and the next one begins. Last face may be (but does not have to be) followed by a "-1" index. If the greatest index in the coorIndex filed is N, the Coordinate node shall contain N+1 coordinates (indexed as 0 to N). Each face of the IndexFaceSet shall have:

- at least three non-coincident vertexes
- vertexes that define a planar polygon
- vertexes that define a non-self-intersecting polygon.

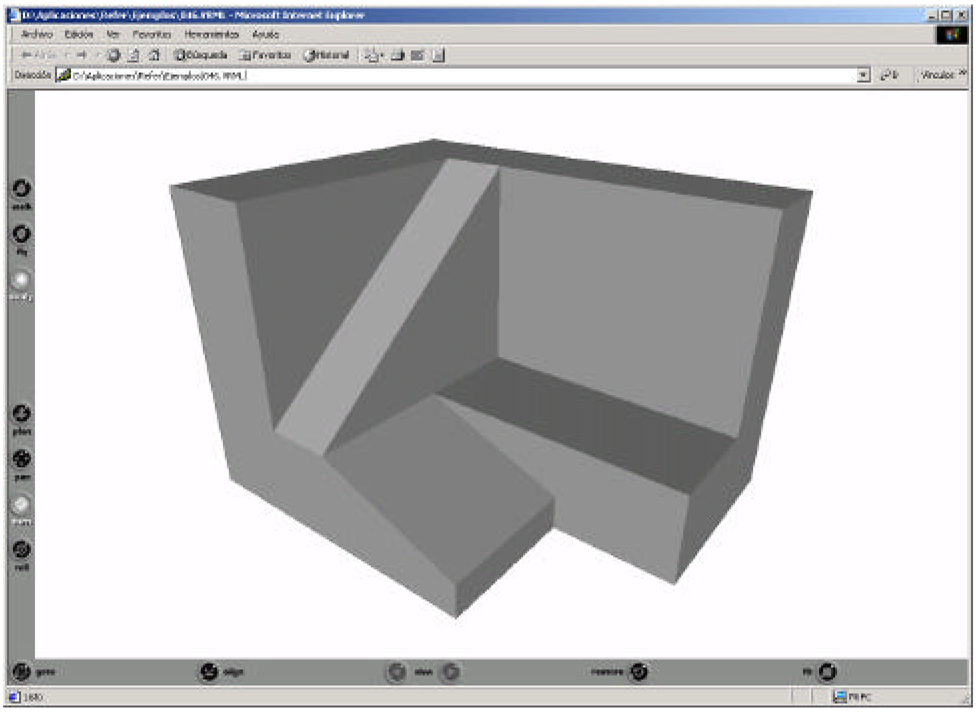

Figure 5.- VRML visualization in an Internet navigator

6. CONCLUSIONS

In this paper we have presented a self-contained application including a sketching interface, a reconstruction engine and a VRML 2.0 export module. Although at this moment only supports polyedrical objects for processing, it shows interesting possibilities of development. It offers a complete different user experience compared to traditional CAD systems, and preliminary tests show a high user satisfaction. The developed application is in a very early development stage, but promises interesting results. We have designed it as a test bed to explore different user interface alternatives. The basic function for this system will be as a preliminary geometry input. In the near future, we think that this software could be part of a more powerful design environment that combines a basic axonometric sketch input with a gesture controlled modeling application to refine geometry. Also, in the next months an STEP AP 203 export module will be available to incorporate reconstructed geometry on a standard 3D CAD modeling system.

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