An Approach on 3D Digital Design

Free Hand Form Generation

by

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Abstract

To sketch is to translate a concept from mind to its first representation. Conventionally sketching of a three dimensional idea is drawn on paper or by building a physical model, and then adjust it into digital translation. The thesis hypothesizes that architects employ tangible interactions to assist design-thinking tasks in early design phases. This thesis suggests another approach on 3D digital design, as a complementary resource for expressing a concept, hence enriching the creative process.

A proposal for a new CAD paradigm, based on freehand form generation is detailed here, as well as the development and testing completed during the course of the research. This work describes the required characteristics of this kind of system and discusses the possibilities afforded by this new medium of expression, pointing its strengths and current limitations.

The fundamental guidelines to this research were: (1) non intrusiveness of the input and visualization devices, (2) wireless free hand drawing in 3D space, (3) instinctive interface and (4) exporting capabilities to other CAD systems.

In conclusion this work argues that 3D design, based on free hand form generation, allows for an enhancement of the traditional creative process through spontaneous and immediate translation of a concept into 3D digital form.

Keywords

3D Free hand input, LED Tracking, 3D Sketching, 3D Interaction Techniques, 3D Input Devices, Tangible interfaces.

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Illustration Credits

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part I. Introduction

Even though witnessing the great evolution in CAD systems in the last forty years, its use as a design tool in concept design is still very complex and unnatural when compared with the spontaneous paper and pencil. This is due in part of the fact that these "unfriendly" systems impose very rigid and structured dialogues, disturbing the creative influx of ideas.

So, it is not surprising that designers find sketching on paper as an irreplaceable stage of the creative process.

In spite of the amount of research in the field of Design methodologies, paper sketching remains the main method of concept design. This leads to the conclusion that the fundamental paradigm on the development of user interfaces 3D modelling should be based in sketches.

However, the current process of design is, usually, a sequence of 2D hand sketching, 2D computer drafting, 3D modelling, and finally rendering. As a result, there is a gap between the first sketches and the remaining design process. Designers are missing the potential of developing ideas directly using the same tools that will be used later for the rest of the project's development and representation. Also they are missing the opportunity, resources and benefits of using virtual reality and 3D modelling from the very inception of the design process.

1.1. Human Computer Interaction

Usually we believe that Sutherland's Sketchpad Ph.D. thesis [Sutherland, 1963] has essentially marked the beginning of computer graphics as a discipline. And from that time there is a long history about the computer graphics for use in design. From the initialled light pen, to mouse of mid-1970s, to stylus of early 1990s again, and to voice and Virtual Reality (VR) -based interactive equipments, the interface of the design tool is also becoming more natural. So there is an intimate relation between the design and human-computer interaction (HCI). And with the further development of HCI, the computer supported design technique also is enhanced greatly on its interactive mode. Especially at the early design stage, the communication and operation approaches are usually different from that of the general CAD for engineering design. More natural and efficient interaction style, such like gesture, voice and VR, has been used in the design systems, to improve their interaction ability on processing the ambiguous and imprecise sketching input. Also, sketching itself is always studied as an intensive interaction process, based on the characters of design thinking, sketching behaviour, expressing of design idea, and the communication in design process.

1.1.1. Interaction Techniques

1.1.1.2. Indirect Input

Most 3D input devices only act in an indirect way, like a 3D mouse:

Figure 1: 3dconnexion ® SpaceMouse Plus and "Wanda" joystick

3D mice are indirect 3D input devices because they do not replicate a path the user's hand follows or its position in space. Instead, they send a command to the computer indicating the kind of motion the user wants to execute: up, down, left, right, rotation along the Y axis, rotation along the X axis or rotation along the Z axis. This can be done either be moving or turning a knob or by some kind of inertial device.

Figure 2: IGesture Pad http://www.fingerworks.com/igesture.html

The iGesture Pad is a large-area, touch pad that is both mouse and multi-finger gesture input interface. Mouse operations like point, click, drag, scroll, and zoom are combined seamlessly with multi-finger gesture in the same overlapping area of the iGesture Pad's surface. The iGesture Pad gives you control of graphical objects using gestures. [1]
Or like digitising devices:

Figure 3: MicroScribe® G2 digitising device. Microscribe:
http://www.immersion.com/digitizer/products/microscribe_g2.php

These devices are not appropriate for sketching, the same way a pen allows in 2D. Because either too indirect (appropriate for browsing and inspecting) or too cumbersome to move freely with the hand (appropriate for precise digitising).

1.1.1.3. Direct Input

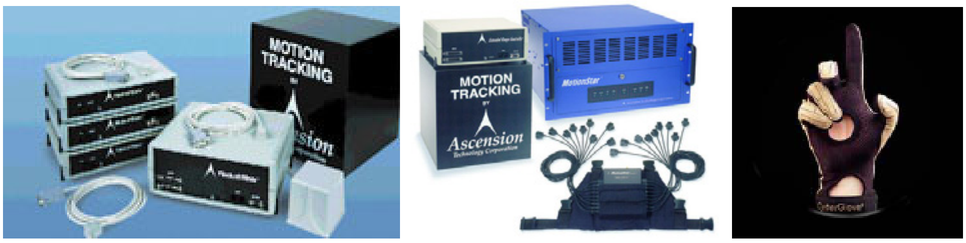

Figure 4: left: Flock of Birds®, center: Nest of Birds® (wireless), Ascension Technology Corporation: http://www.ascension-tech.com/ right: Cyber-Glove http://www.vrsolutions.com.au/vrsproducts

There are however direct 3D input devices, such as the Nest of Birds ® and the Flock of Birds ® from Ascension Technology Corporation. These devices feed the computer with the 3D position and sometimes orientation of the input device: x y z coordinates and the instantaneous angles of rotation (orientation) along the X, Y and Z axis. These devices create a direct translation of the input device status in 3D space.

The Flock of Birds and Nest of Birds systems use magnetic sensors to track the position of a number of small 3D input devices. This approach reduces the problems with occlusion, but is still sensitive to metal in the test environment and needs heavy hardware.

The system has its greatest strength in the precise positioning and orientation in 3D space and the robustness to occlusion. Its weaknesses reside in the cumbersome hardware that has to be set up (appropriate for laboratories). The other main problem is its cost: over £3500 [2] for a 2 sensor Flock of Birds configuration.

The CyberGlove is another kind of input device that maps the configuration of the users hand at any given moment. This system is very good for gesture recognition and manipulation in virtual reality systems.

Together with 3D space positioning capabilities can be used for 3D freehand design generating surfaces. This can be achieved (as described in 2.2. Related Work) by using the hand configuration as changing profile and extruding it along the hand movement in space, although this combined setup can become very expensive.

part II. Background

2.1. Introduction

This thesis analysed a series of projects related to some sort of free hand form generation. The projects chosen for more in depth analysis are the ones found to approach more directly the objectives stated before: direct three dimensional input, natural interface and a free hand approach.

2.2.1. Sketch-based CAD Systems

Perhaps the earliest computerized sketching system (in fact the earliest CAD system) is Sutherland's sketchpad [Sutherland, 1963]. In that system, the user could draw using a light pen on a screen and manipulate graphic primitives such as arcs and lines. Since the development of Sketchpad, numerous graphic drawing packages have been developed, but only a few of them have tried to "understand" the picture being drawn, in the sense that they detect relationships not explicitly specified by the user, or connect individual components to form a "larger context", as humans may do when looking as a sketch. Moreover, not many of these systems support true freehand sketching, let alone freehand sketches of three-dimensional objects. Kato et al [Kato, 1982] describe a system for interactive processing of 2D freehand-sketched diagrams. Jenkins and Martin [Jenkins, 1993] describe a system called Easel for online (interactive) freehand sketching of two dimensional graphics comprised of lines, arcs and *Bezier* curves. Their system is certainly aimed in the right direction as it attempts to conform to some of the crucial aspects of sketching discussed in the previous sections by accepting direct freehand sketching and tolerating inaccuracies. The system avoids the use of menus so as not to impede the creative process, and therefore automatically distinguishes between stroke types and infers implicit constraints among them. Fatos and Ozguc [Fatos, 1990] describe a system for 2D architectural sketch recognition with lines, arcs and corners. Hwang and Ullman [Hwang, 1990] describe a system for capturing "back of the envelope" sketches. Eggli et al [Eggli, 1995] propose a solid modeller incorporating a sketching tool, their system is three dimensional but the sketching itself is always constrained to some plane, thereby avoiding the problematic inverse-projection reconstruction phase. A similar system for designing solid objects using interactive sketch interpretation is described by Pugh [Pugh, 1992].

2.2. Related Work

2.2.1. Several 3D Sketch Based Methods

Several systems for modelling by sketching already exist. System Sketch [Zeleznik, 1996] allows the user to create simple geometrical scenes using a set of predefined gestures. There are also systems for sketching of CAD drawings [Lipson, 1997]. These systems are a valuable help in creating models consisting of geometrical primitives, but they cannot be used to model free-form shapes, on which this work concentrates. Teddy [Igarishi, 1999] is aimed especially on modelling of simple free-form objects (like teddy-bears). The system is able to inflate 2D closed curves into 3D objects, which can be consequently edited using simple gestures. During the whole modelling process the system maintains a polygon mesh of the model, displayed in a non-photo realistic way.

Another system for free-form modelling was described by Karpenko, et. al. [Karpenko, 2002]. Instead of using a polygon mesh, the authors represent the model by a variational implicit surface. By sketching, the user edits a set of constraints defining the surface. This work tries to simulate the drawing process of artists, who start sketching using simple 3D shapes - blobs, which are then connected into more complex shapes and refined.

The ARTHUR project [3] involves the development of a system to augment round table design team meetings in architectural and urban design projects. The user interacts directly with real world placeholders. The location and orientation of these is tracked by the computer vision (CV) system and is mapped by the interface onto virtual objects. These virtual objects displayed through the see through Head Mounted Display are mapped onto the placeholders. The mapping gives visual feedback about the performance of the CV system.

One of its object creation tools called the "Ribbon tool" tacks the motion of a placeholder in 3D space, creating a ribbon form along a track. This ribbon is a way of sketching, acting almost as a line. The profile of the ribbon shape is always the same producing a strip like form. It is a good way of adding form on a project being developed using the ARTHUR approach and can also be a surface creation tool on its own.

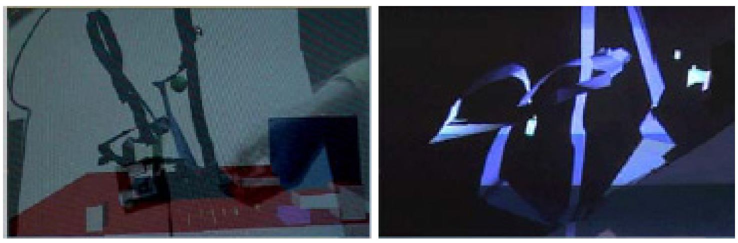

Figure 5: Modelling with the Ribbon tool in Augmented Reality (left) and in Virtual Reality (right). Images kindly provided by the UCL ARTHUR research team

Subsequently, two projects are going to be analysed and discussed. These projects research on the same objectives of innate form generation.

2.2.1.1. Project #1 – "Modelling with Gestures"

The 3D Sketching project [Pratini] [4]

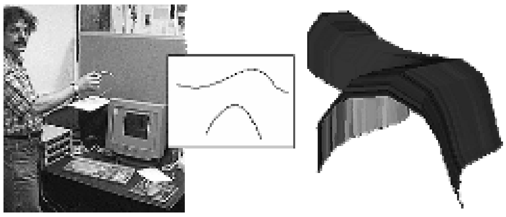

Figure 6: The 3D Sketchmaker Project Edison Pratini

The 3D sketching project relies on the Flock of Birds hardware. The designer constructs a profile that is afterwards extruded along a 3D path in space sketch using a Flock of Birds sensor.
It was conceived so as to substitute the first 2D sketches on paper an then using the surfaces in a 3D graphics editing application.
It approaches clearly a 3D sketching application; there is a component of real 3D drawing in space; a direct approach, rather then an indirect manipulation.

Strengths
The direct 3D input via the Flock of Birds sensor is a step towards direct 3D form generation.
The possibility to start sketching immediately without training is a good feature as the system does not put out users unacquainted with this kind of design technology.
The export feature is very useful because the sketches can later be edited and incorporated into more complex designs.

Weaknesses
The "third" coordinate, volume, is achieved using the extrusion of a profile along a 3D path, that renders seemingly elaborate surfaces, but is in fact a limitation, because it can not be changed during design time.
The hardware is expensive and still there are "wires" attached to the body.
Although the system allows for 3D form generation it is not complex enough, adding the capability to sketch with two Flock of Birds sensors would add lot more flexibility. Complex forms could be generated, and not limited to the original profile used in the extrusion.

2.2.1.2. Project # 2 - "Drawing with the Hand in Free Space"

Creating Organic 3D Shapes with Gesture in a Semi-Immersive Environment [Schkolne, 2002]

Figure 7: Drawing with the Hand in Free Space - Creating Organic 3d Shapes with Gesture in a Semi-Immersive Environment [Schkolne, 2002]

This concept was realized using the responsive workbench system, a large table that acts as a display surface to display geometry in the space of the user, and sense the hand and a number of tangible tools to translate motion and action into form.
Wearing head-tracked stereoscopic shutter glasses, objects appear to float above this table within the user's body space. In this environment, a number of physical tools are used to create and manipulate shapes. The user wears a glove on the dominant hand which senses the shape of the hand. Along with a motion tracker on the wrist, these hand motions are turned into shapes by a computer which displays them in real time.
As an alternative approach to traditional 3D modelling software utilizing a complex interface, that restricts free conceptual thinking, they have developed a simplified interface that is based on physicality, making marks with the body in space.

Strengths

The system uses the hands and tangible tools as interface devices to interact with virtual environments; this enables the user to bypass the initial learning period more complex and keyboard based systems have.
Real world tasks using real world paradigms, object modelling and assembling in virtual environments assumes the user will use the tools and perform the functions exactly as in reality except that the objects only exist as virtual 3D constructions.
The system has the ability to separate and aggregate objects so they can constitute building blocks that can be manipulated as a group.
The main problems of 3D object manipulation are solved: intuitive translation and rotation in 3D space without extensive user training.

Weaknesses

The paper proposes somewhat awkward interface devices; everything is still connected to the system, forcing the user to drag a cord. This aspect works well in the "responsive workbench" but will be a problem in a CAVE system because the user will move his body a lot more.
The main problem is that the system is still too inept: big objects in the hands and few functions. The next step should be the migration to hand/finger position and gesture recognition. Also the inclusion of hot spots on the virtual environment that can be uses as easy function menus, leaving the recognized gestures to pure 3D tasks: rotating, scaling, translation, deformation of surfaces and objects, and haptic feedback.

This project represents a great step into conceptual virtual design through an natural interface. Applications of surface drawing are being investigated in collaboration with Designworks/USA, an industrial design firm. This has certainly pushed the project further ahead. The medium as it stands is primarily suited for organic shape design. Perfectly flat planes, hard edges, and precise symmetries are not supported by the current interface.

part III. This Approach

3.1. Statement of the Research Problem

Traditional (non natural and spontaneous) interfaces force 3D modelling using 2D interfaces and hardware to manipulate 2D representations of 3D objects. This "blocks" the mind, forcing the user to concentrate on the interface rather than the design. It's quite similar as to thinking of the pen rather than thinking on the words when writing.

The aim of this research is to determine the possibilities of non- intrusive real/virtual interfaces for 3D digital design using a 3D tracking system.

An application was developed to track lights in 3D space and draw surfaces according to those movements.

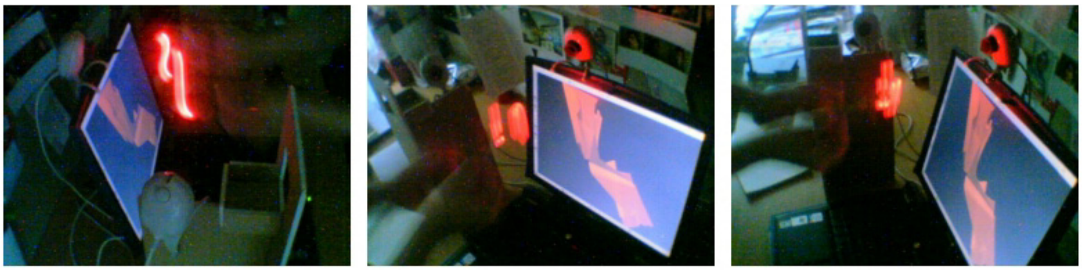

Figure 8: Using the LED's to draw. Photos by the author

3.2. Research Objectives

Mix reality concepts, as the frontier between real and virtual, the common space for humans and computers to interact seamlessly, guides the objectives of this work.

The need to overcome the problems in interfacing - clumsy devices and limited real world applications to be used effectively – is the underlying ambition of this work: to bring mix reality closer to the expectations it has raised.

The research objective is to assert the possibility of natural, non-intrusive 3D modelling and interfacing. This should be tested against real world, practical and effective applications, such as concept design.

Precision is not an objective, simplicity in drawing complex 3D forms is. Precision is achieved after export to 3D drawing applications as mentioned before, because they have all the tools to use the 3D sketch and transform it into a finish digital design.

Training of the user will always be needed as well as some adaptation time, but the extension of the grammar used to communicate with the application and the devices physically connected to the user will be reduced as much as possible.

Depending on how tuned the tracking technology is, the shapes drawn can be more abstract, and the application's main use will be 3D form generation, more chaotic and organic.

Below there are two diagrams that show the differences in a traditional design methodology and the sequence of phases in using a 3D digital concept methodology:

Traditional Sketching:

Paper Sketch → 3D Physical Model → Digitised Model → Cad Model → Physical Prototype

3D Virtual Sketching:

3D Digital Sketch → Cad Model → Physical Prototype

Illustrated by the above diagram, this project also tries to prove is that if a 3D Digital system is sufficiently efficient to be able to translate spontaneous ideas into form a few steps are saved.

The possibility to generate 3D shapes from real 3D input, i.e. an input device moving freely in 3D space, rather than using CAD paradigms like a 3D form being extruded, from a profile along a path in space (as illustrated next):

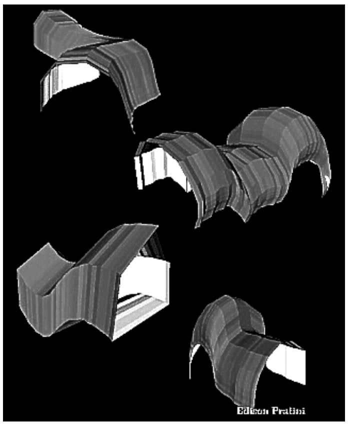

Figure 9: Shape extruded from a profile moving in 3D space [Pratini]

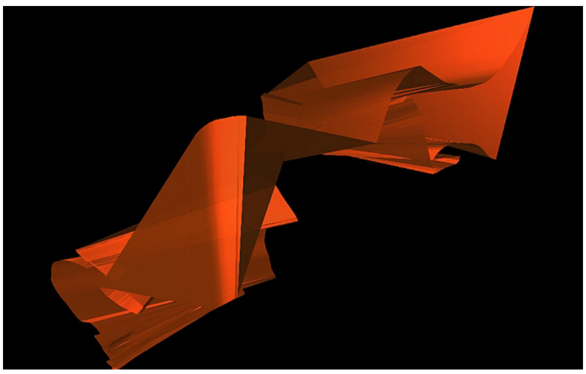

Figure 10: 3D shape generated from the paths of 2 lights moving freely trough 3D space. Created by César Branco

These interfaces, based on simple, inexpensive, non intrusive devices, such as web cameras and small lights, should enable a non skilled user to intuitively start designing with no or minimum CAD skills.

To answer these questions an application was built to assess the difficulties inherent to such a system and to answer the main research objectives:

- Identify possible strengths and weaknesses of 3D digital design systems versus traditional sketching.
- Are there any inherent flaws in this kind of procedure or methodology of concept design?
- Does this process needs a complex, unfriendly grammar?
- Are visualization systems a handicap?
- Identify technological constraints to the development of 3D digital design: visualization, tracking and processing power.

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part IV. Methodology

To determine the possibility of a system as stated previously, a simple 3D digital design application was implemented using small lights and web cams. The lights attached to the user's hands will be tracked by two or more web cams to determine their coordinates in 3D space (real space), and then fed to a virtual environment created using OpenGL Performer, where the sketch will be drawn.

The sketch's virtual forms are then saved to a file format readable by CAD systems or a 3D Studio like application.

The shapes generated and the user feedback will be analysed to understand the amount of effort still needed to develop this kind of low-cost configurations, what directions should the research follow, or even if this approach is not valid and needs rethinking.

A user (César Branco) with no CAD or 3D Studio experience, but with extensive 2D computer (Macromedia Flash) and paper sketching was asked to test the system during development and after it was finished. The objective was to have feedback from an increasingly trained user, to be able to perceive the status of the system, from light tracking to surface rendering.

4.1. System Design

The objective is to build a system that can produce 3D information about 2 LED lights moving in space. I decided to continue the work done in previous projects and connected two web cams to a laptop and track 2 LED's.

Figure 11: LED's, laptop connected web cams and shape generation. Photos by the author

No wire connected to the input device was a critical requisite to be met. Keep the input simple (and inexpensive) but still able to feed the design module with coherent 3D information.

One key feature is the ability to export the generated shapes and lines to a format that can be explored and very importantly edited using other systems, such as VRML browsers, 3D Studio like applications or Auto CAD.

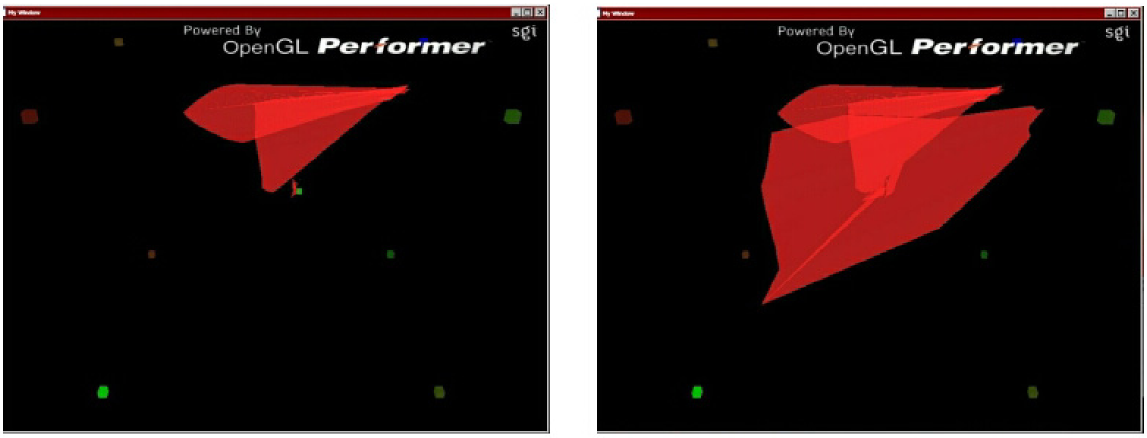

Figure 12: Drawing surfaces in Performer. Created by the author

4.2. Hardware/Software Configuration

The system used DirectX 9.0 to manage the two web cams, tracking two lights on both web cams continuously. Each light detected on the first web cam is matched to itself on the second web cam.

The position information about the lights is written on shared memory by the tracking device and read from shared memory by the design module (Open GL Performer program).

Shared memory provides a fast method for real time data interchange between several programs. The design module always reads the most up to date information about the LED's.

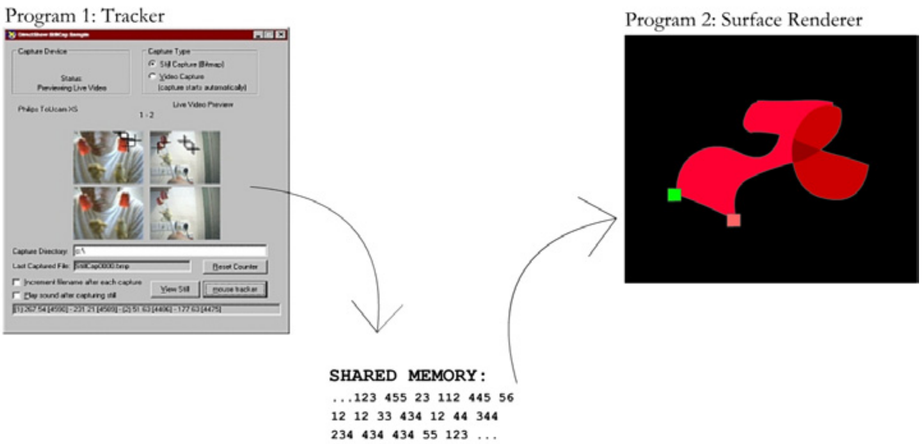

Figure 13: Communication between Direct X tracker and Performer sketch program using shared memory

This way the system reads the LED's positions through the web cams and the Direct X program and then it sends it to Open GL Performer in real time that renders the generated 3D design.

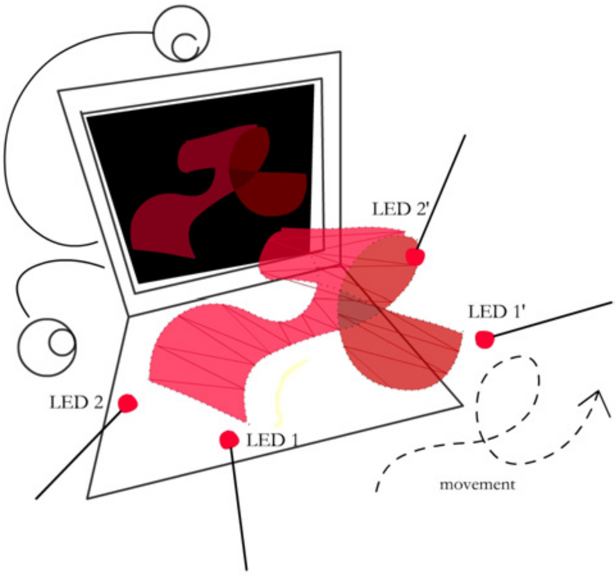

Figure 14: Diagram of the form - generation system

4.2.1. The 3D Tracking and Input Device

An important part of the configuration is the tracking system. There was the possibility of using highly developed hardware or software such as the well known Flock of Birds from Ascension or Artoolkit from HIT LAB, University of Washington. This thesis suggests something lighter: no wires, no vest, no boxes connected to the computer, no head mounted display and minimum calibration.

Artoolkit is a marker based system that relies on computer vision techniques and on head mounted display attached to the user. A marker can be attached to the user hand to track movement and other marks placed in the environment as place holders for objects and shapes. The further the markers are from the user the bigger they have to be.

Flock of Birds is a system that tracks small sensors attached to the end of a wire connected to hardware built to track the magnetic sensors. The more metallic objects there are in the surrounding environment the bigger the error in the sensor tracking.

Both systems rely on devices connecting the user to some hardware that feeds the design applications with 3D data, either a web cam on the user's head or the Flock of Birds sensors in her hands. This means dragging one or more cords around in the environment connected to expensive hardware.

The objective is to try something that would be completely free to move in, inexpensive to make and easy to replicate.

The purpose of the tracking system is to follow 2 LED lights in space, feeding the design module 3D information about the path each light follows (2 lights to draw surfaces, 1 light to draw a line).

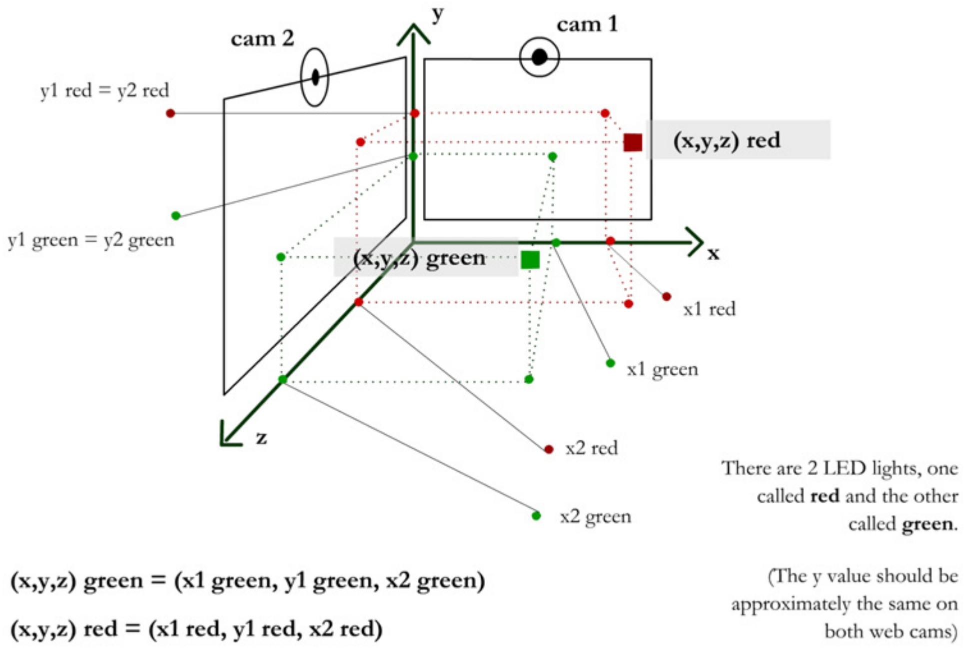

Figure 15: Web cam layout to extract the LED's 3D coordinates

One web cam provides only 2D information, x and y. The system needs "depth" information, z, so another camera is installed. To save the program some calculations and the user some tedious calibration, the cameras are placed orthogonal to each other (see Figure 14).

The two cameras are connected to the computer and the images analysed by Direct X 9 image libraries. The tracking program finds the 2 brightest spots on each camera, applying a smoothing algorithm to detect sharp changes in light position.

Every frame the 3D position of each LED is written to the shared memory reserved for communication with the design program. Together with the coordinates the intensity of the LED's on the two cameras is also sent, permitting Open GL Performer to execute further testing and to smooth the 3D movement.

4.2.2. Software

Open GL Performer was used to draw the surfaces, partly because the technology is known from previous projects, partly because it has good rendering capabilities.

4.2.3. The Surface Rendering Application

The surface rendering application reads the LED's positions from the tracker (through shared memory). These positions are them united in triangles forming a triangle strip (Figure 17).

The shape is generated as the result of an imaginary line uniting the two lights as they move through space (Figure 16).

Three modules were implemented to test the movement through space and the possibilities of the system: first lines where drawn, then surfaces and last lines and surfaces together.

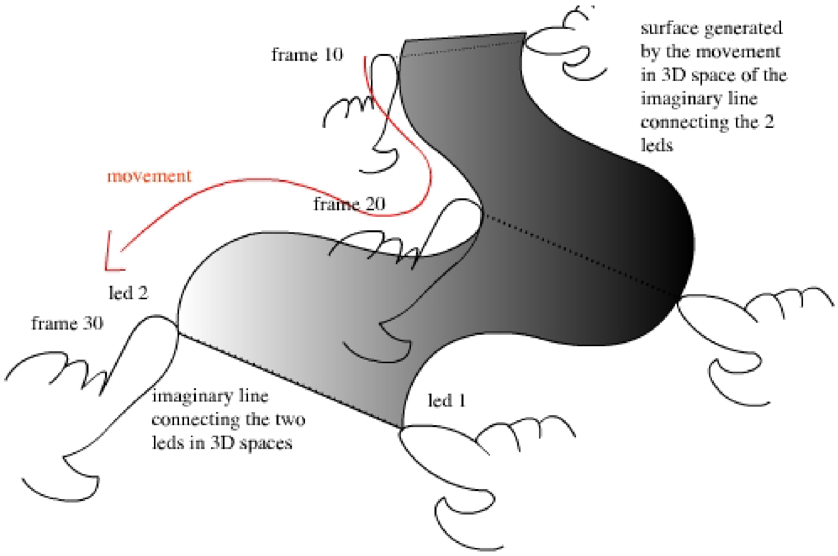

Figure 16: Movement in 3D space as a surface generator

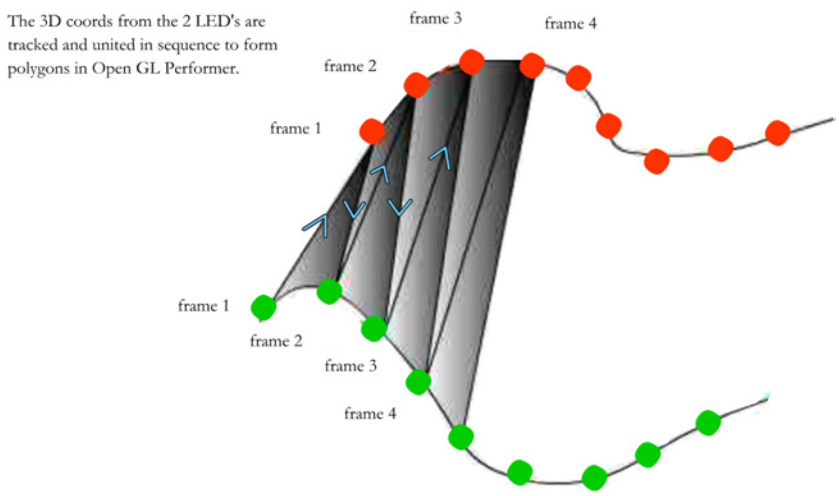

Figure 17: Triangle creation sequence as LED positions are united in every frame

Unlike other 3D sketching systems, this method allows for a varied range of surface types to be rendered because of the varying distance between the two lights. Their relative position can be constantly changing generating ribbons, bows, eight shaped surfaces or just simple strips with different widths along its length.

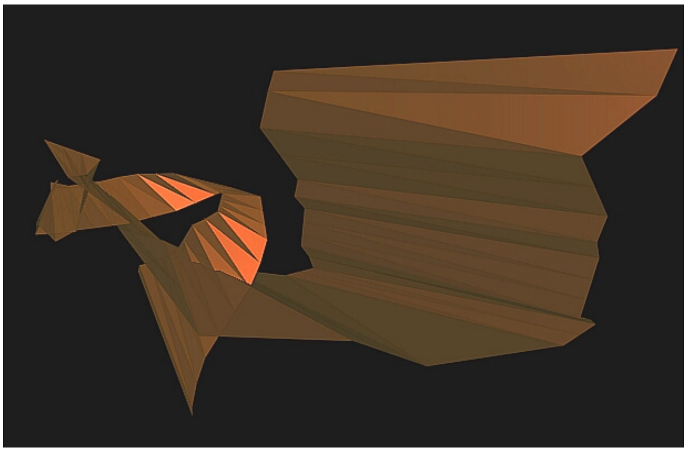

Figure 18: Shape generated by the system. Notice the polygons as rendered in Open GL Performer. Created by César Branco

part V. Development

The system was developed in five stages:

- The first phase was to connect 2 web cams to the laptop, analysing both their images in real time using Direct X 9;
- The second phase was to follow (track) two lights on two images from the web cams;
- The third was to combine the light coordinates in 2D (the cameras image planes) to 3D and send it via shared memory to performer;
- The fourth stage was to create surfaces from the coordinates the tracker was feeding;
- Finally the system had to be tested and tuned in order to be able to produce "a high-quality" surface.

The completion of these stages allowed for some testing with lines, surfaces and lines and surfaces combined.

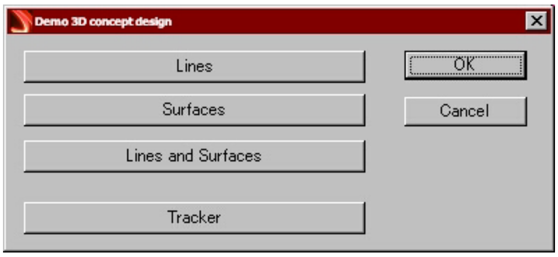

Figure 19: General menu of all application modules

5.1. 3D Lines

The application has a module to drawn lines in space, following one LED using the tracker information. This drawing option gives the user the "sketchy input"- an ability to test its movements, determine the boundaries of the drawing space and "feel" the tracking program.

The lines are rendered using the **PFGS_LINESTRIPS** Open GL Performer primitive. The lines are constructed only when one LED with sufficient intensity is visible.

The lines are exported to VRML format so they can be analysed and imported by other programs.

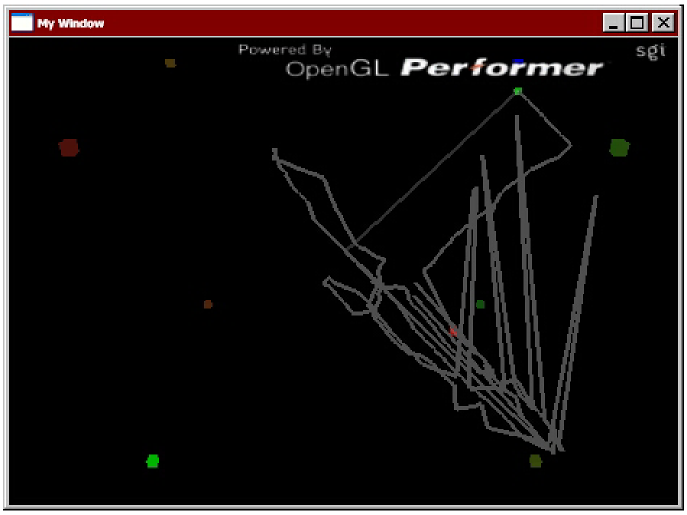

Figure 20: Lines being drawn in Performer. Created by the author

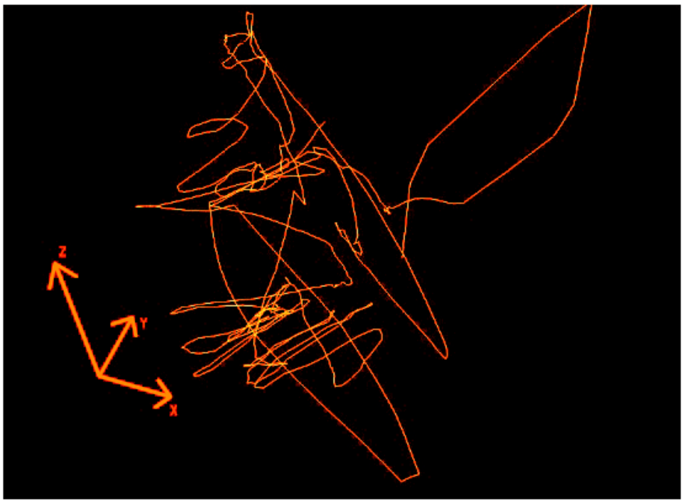

Figure 21: Lines drawn in space visualised in a VRML browser. Created by the author

5.2. Surfaces

Next, the surface module was implemented so the user can generate surfaces, and experiment the digital design.

The surfaces are rendered using the **PFGS_TRISTRIPS** Open GL Performer primitive. The surfaces are constructed only when two LED lights with sufficient intensity are visible.

The surfaces are exported to VRML format so they can be analysed and imported by other programs.

Figure 22: Surface being created in Performer. Created by the author

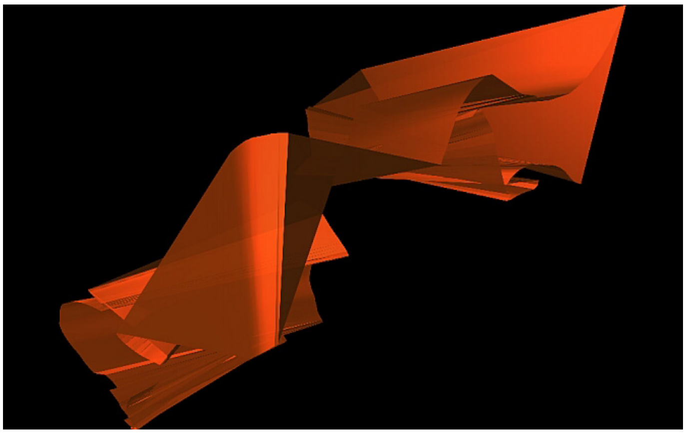

Figure 23: Surface drawn in space. Created by César Branco

5.3. Lines and Surfaces

A combination of the previous modules was also implemented, with a more artistic ambition, having the same export capabilities. The lines are drawn when only one light is visible and the surfaces are drawn when two lights are visible,

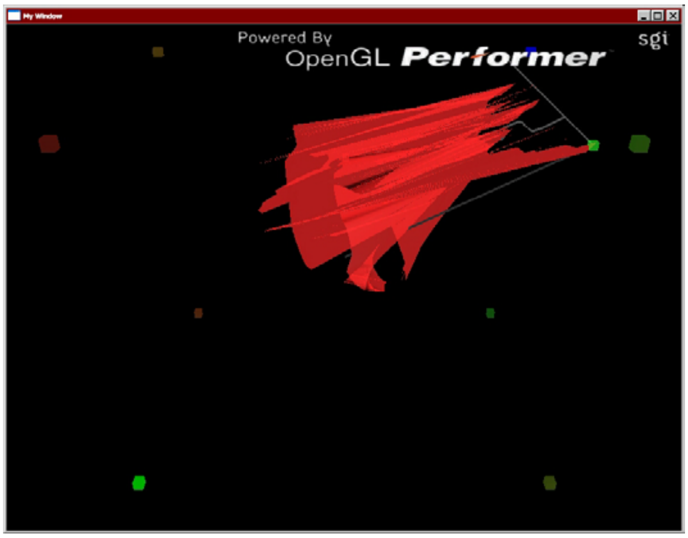

Figure 24: Surfaces and Lines being drawn in Performer. Created by the author

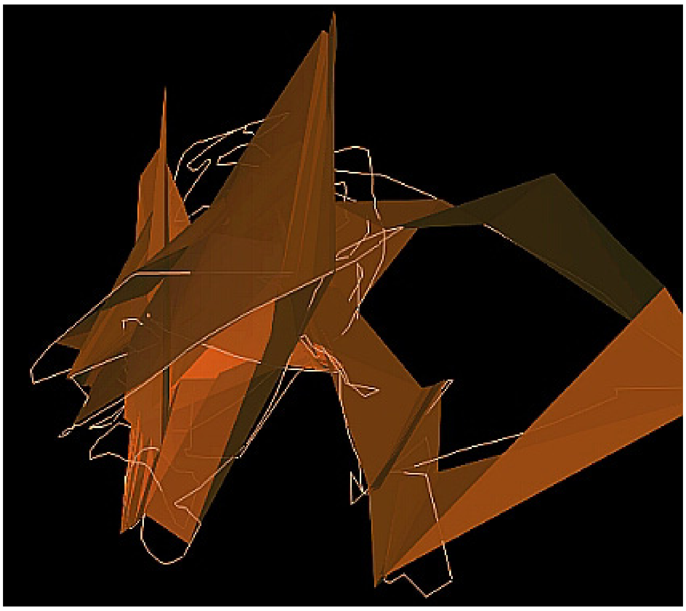

Figure 25: Lines and surfaces drawn together in space. Created by Raoul Kunz

5.4. Algorithms

5.4.1. Tracking Algorithm

The system finds the two most bright spots on each web cam, and correlates them (first light, second light), using the Y coordinate on the second camera. See Figure 15. The X coordinate on the second camera, for each light, will be the Z coordinate in 3D space. This information, along with the intensity of each LED in the two cameras, is sent to Performer, so it can decide if a light is bright enough to be considered. The threshold intensity for a light to be considered as valid input is defined in the Performer program.

5.4.2. 3D Smoothing Algorithm

The surface rendering application keeps a record of the LED's 3D coordinates over the last few frames (40-80 frames). It uses these values to calculate the average of the LED coordinates smoothing the path each light takes.

This procedure is needed because the LED's flicker and even if the user keeps the lights still, the tracker will always determine slightly different coordinates, causing an "un-smoothed" surface to have spikes.

5.4.3. Light Swapping Algorithm

Sometimes the tracker will send the coordinates of the lights in different order; if the lights get too close in one of the web cameras the tracker might swap their positions. One LED that might be number one in one frame could be number 2 in the next.

To prevent bending of the generated surface due to changing LED order from the tracker. Performer calculates the distance (in 3D) between the first light in frame **N** and the second light in frame **N-1**, if it is closer to the second light in frame **N-1**, the program swaps the order of the coordinates.

5.4.4. Normal Calculation Algorithm

The surface rendering application needs to determine lightening information so the surfaces have a coherent look. Every frame, as two new 3D points are added to the surface, the normal vectors at these new vertices have to be calculated. Actually, the vectors are calculated for the previous two 3D points because the slope in the new points is yet unknown.

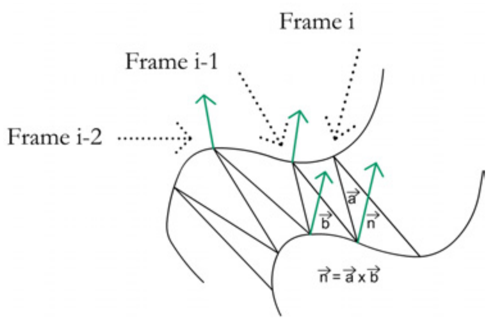

Figure 26: Calculating normals. Created by the author

The normals are calculated using the cross product between the vectors formed by the last two points added to the surface (previous frame) and the last point of the previous frame and the first point of the current frame (see Figure 26).

5.5. Interfaces

Inter process communication – shared memory

The communication between the tracker and Performer is made by using shared memory, for performance and real time access to the information acquired by the tracker. One of the advantages of shared memory, as opposed to sockets, is that the surface rendering application always reads the most up to date information. The frames as considered by the tracker can't be synchronized with performer frames, but Performer needs to see the data as the tracker produces it at any given moment, not caring about the information in memory when it was performing some other action (such as drawing).

The tracker only writes memory and Performer only reads; therefore no inter-program synchronization is needed.

5.5.1. WRL and 3D Studio Export Module

In order to be somewhat useful, not only a fun gadget to generate funny shapes out of the air, an export function was implemented. The choice of format was .WRL files (VRML) because it can be read by 3D Studio and from there saved as CAD *.DXF or *.DWG files. Also because the *.WRL format is well known and easily opened in a computer with a web browser. This way anybody can experiment their own shapes without installing complicated, "computer hungry" software.

This module works transparently to the user, as she/he uses the application the shape is periodically being exported: every 300 frames and every time the drawing is stopped because one or both lights are not visible or bright enough.

The next three pictures show the same shape in a VRML browser, 3D Studio and Auto CAD.

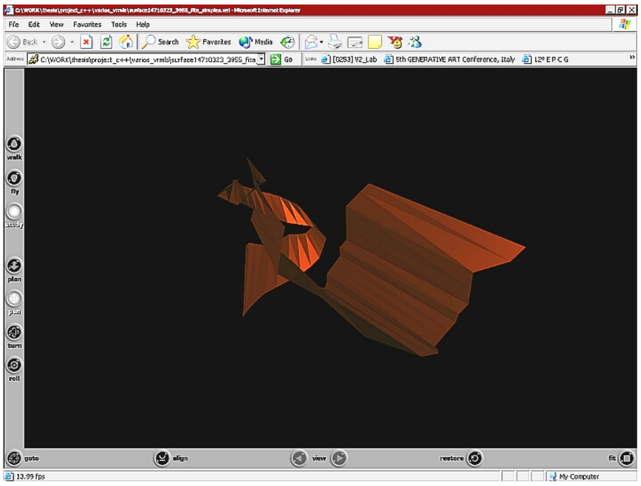

Figure 27: Sketched shape exported and opened in a VRML browser. Created by the author

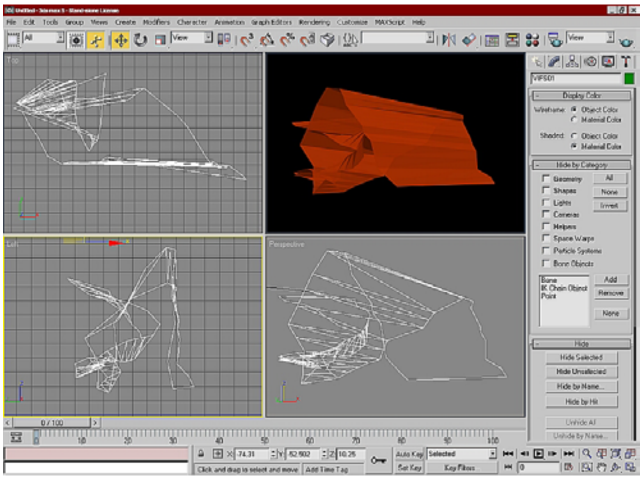

Figure 28: Same shape in Figure 18 imported by 3D Studio. Created by the author

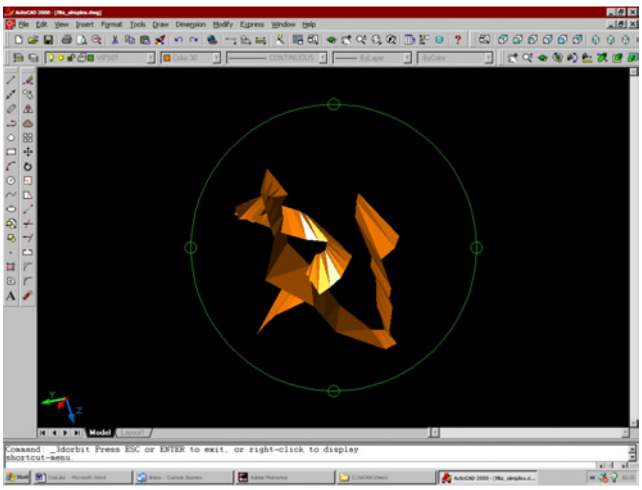

Figure 29: Auto CAD working on the same shape. Created by the author

part VI. Testing

6.1. Continuous Testing by a Test User

The program was tested during its development, until the late stages by a test user for permanent feedback. He is a web developer with experience in software programs such as Macromedia Flash, 3D Studio. As this user became increasingly trained using the software (generating some of the screenshots included in this report), a test round with users unfamiliar with the software was needed for a non-biased feedback.

6.1.2. Phase 1

The aim was to determine the first reaction to a system completely out of the traditional user input paradigms. Essentially a qualitative study, as some other primitives, inspection capabilities and undo/redo functions have yet to be built. To determine future directions after the completion of this dissertation there is the need to now the reaction to a two hand input, a free hand moving interface.

The first testing phase was conducted with several test subjects. The testing of the sketch/modelling making program was conducted by the developer of the software. A brief explanation was given about the system configuration, interface paradigm and objectives. The three modules were also explained: lines, surfaces and both primitives together.

The test users filled a survey after they tested the program (see Appendix A), where they gave their opinions about the system: strengths and weaknesses.

The limitations of the set-up were also explained: the tracker and lighting conditions problem and the narrow field of view problem.

All the users approached the system in a playful way, trying to "feel" the three dimensional capabilities. But coping with the system limitations restricted the more serious attempts to sketch a "less artistic" shape.

Tests were conducted with 16 subjects of different professional backgrounds and different computer design skills.

The different backgrounds are distributed as follows:

- 5 designers
- 5 computer science graduates
- 5 architects
- 1 philosophy PhD student

The different computer design skills are distributed as follows:

- 5 Auto CAD experience
- 8 3D Studio
- 14 Photoshop
- 16 general every day computer use

A series of questions were asked (See Appendix I). The most relevant being:

Question 1: How easy to use was it?

Question 2: How do you find using this system as tool for 3D concept design?

Question 3: How would you use it again?

Test user background	Question 1	Question 2	Question 3
Designer 1	Very easy	Fun	Draw pictures that I can't draw
Designer 2	Easy	Meaningful	Digital Art
Designer 3	Mildly tiring	It generated surprising results	For fun
Designer 4	Very easy	Too restrictive	Augmented Reality/modelling
Designer 5	Very easy	It generated surprising results	Sketch in collaborative design
Architect 1	Very easy	It has to be more developed	Children education and entertainment
Architect 2	Very easy	It generated surprising results	Digital Art/Fun
Architect 3	Very easy	Too restrictive	For fun
Architect 4	Easy	Too restrictive	For fun
Architect 5	Easy	Collaborative Design	For fun
Computer Science graduate 1	Easy	Fun	For fun
Computer Science graduate 2	Easy	Too restrictive	For fun
Computer Science graduate 3	Somewhat Easy	Too restrictive	Augmented Reality/modelling
Computer Science graduate 4	Easy	Modelling Form use/Art	Augmented Reality/Digital Art
Computer Science graduate 5	Easy	Too restrictive/Surprising results	Cave environment
Philosophy PhD student	Somewhat Easy	It generated surprising results	Digital Art/Fun

The results of their experiences with the system are analysed next and the conclusions on user feedback follow at the end of this chapter.

6.1.2. Phase 2

After the first testing, there has the need to make some improvements mainly:

- Increase the field of view of the webcams.
- Use a wider Screen.
- Slow down the speed of the program.

A video camera with a wide field was used to capture de x, and y coordinates. This doubled the space for the x and y. Additionally, a projector and a screen were used to make the result more visible. The speed of the program was slowed so that users could have more time to think during sketching.

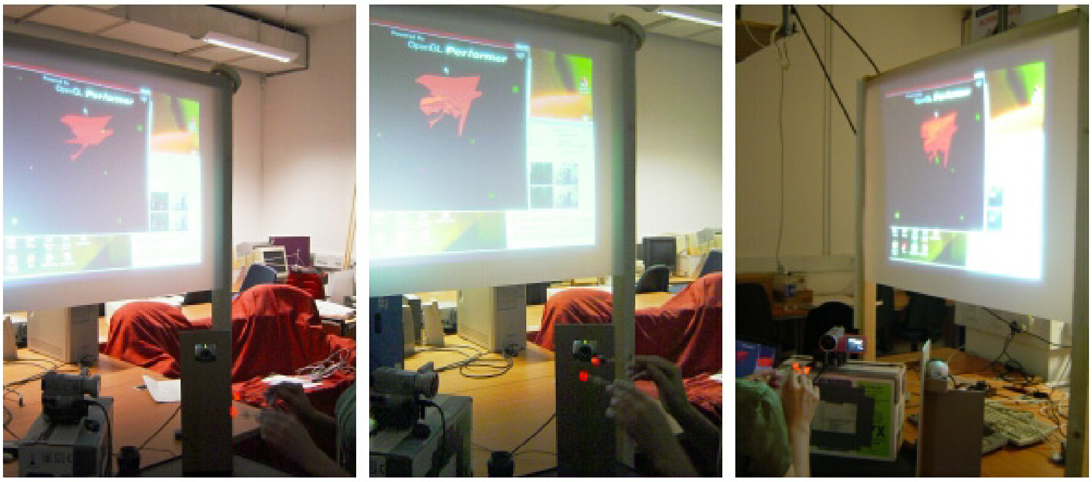

Figure 30: Testing the user interface design. Phase 2

6.2. Results

6.2.1. Shapes

The test users started making some sketches trying to get familiar with the system. The objective was to see how the users dealt mainly with the following features:

- Do they try to use 3D space, crossing the lights up and down, left and right?
- Do they try to sketch a specific form or do they just play around for a while?
- What are the main problems in using the system, conceptual or technological?

Figure 31: Two views of the same line sketch. Created by the author

When using the lines mode the users tried to sense the limits of the 3D working space as defined by the field o view of each camera.

The lines allow for a less worried testing because only one light needs to be visible by the cameras, So the users swirl the light around, trying to see the curls in the Performer window.

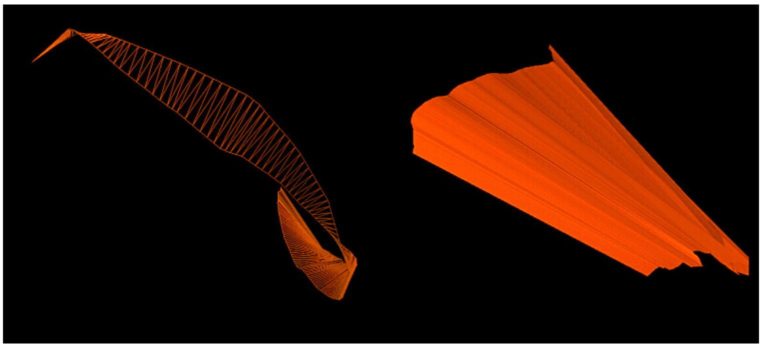

Figure 32: Simple surfaces. Created by the author

Some users tried to draw simple surfaces, slowly, to understand the behaviour of the shape generating program. The movements were slow so they could be able to see the shape taking form.

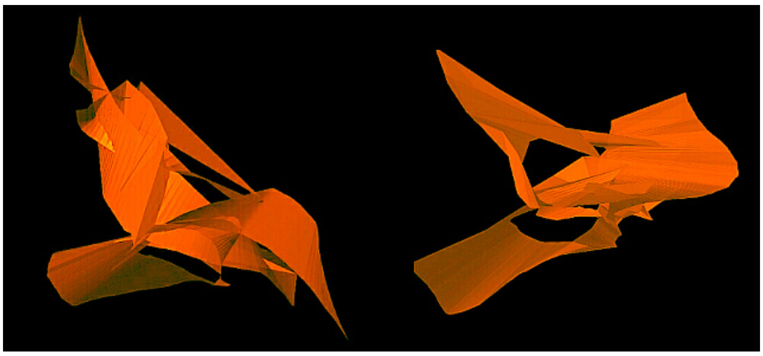

Figure 33: Fluid shapes. Created by the author

Some of the users that tested the system longer, started to perceive the way how it responds, and begun designing in a more natural fluid way.

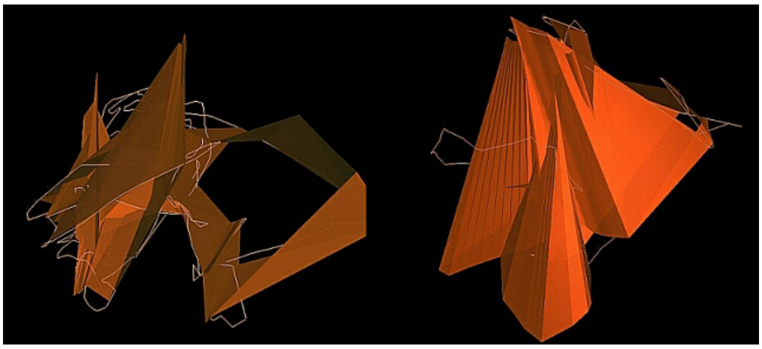

Figure 34: Lines and surfaces together. Created test user Raoul Kunz

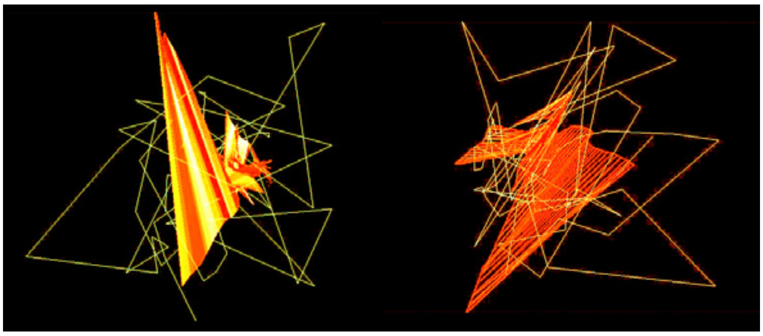

Figure 35: Lines and wireframe surfaces. Created by the author

At the moment of this testing session the application allows for more artistic experimentation. One test user (studying architectural drawing) in a design background especially liked the lines and surfaces module. Notice the first sketch in Figure 34, with a clear loop and line following it. There is clearly some intention, although he complained about the limited field of view, he made this sketch after a few attempts.

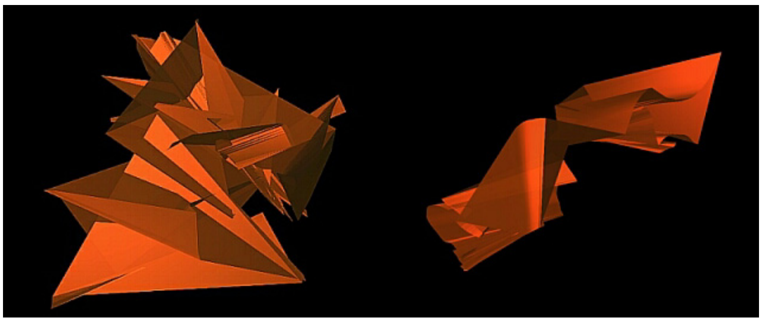

Figure 36: Tests conducted before and after slowing the speed of the program and widening the field of view of the cameras. Left: image created by Damir Pavusin. Right: image created by César Branco

Examining the upper image the one the left is a result of rapid experimenting, giving a shape full of spikes, but the one on the right was made with some intention after a few tries. To overcome the "spiking" of the generated shapes, the program was slowed down by bringing the 3D points closer together. A user then moved the LED's slowly, seeking a ribbon form. The resulting shape was smoother and less chaotic, revealing some more planning once the system was understood.

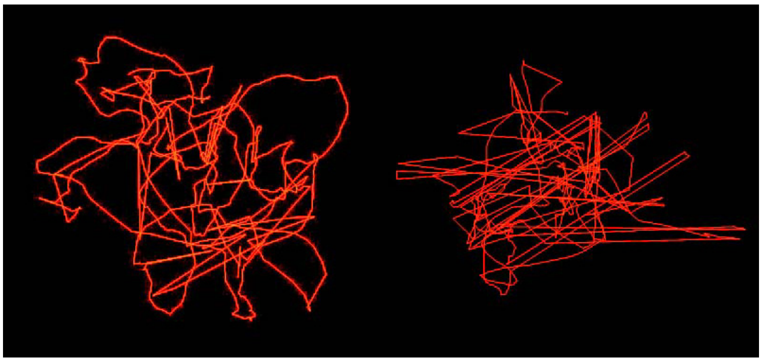

Figure 37: Line designs created by different test users.

The line module also provided unexpected design interest from the test users. Curiously some users found the lines mode giving more volume and 3-dimensional sense of shape than the surfaces mode.

From the image above we can also see the different results according to the user. The Designers and Architects had a different approach, making the movement in a more fluid way.

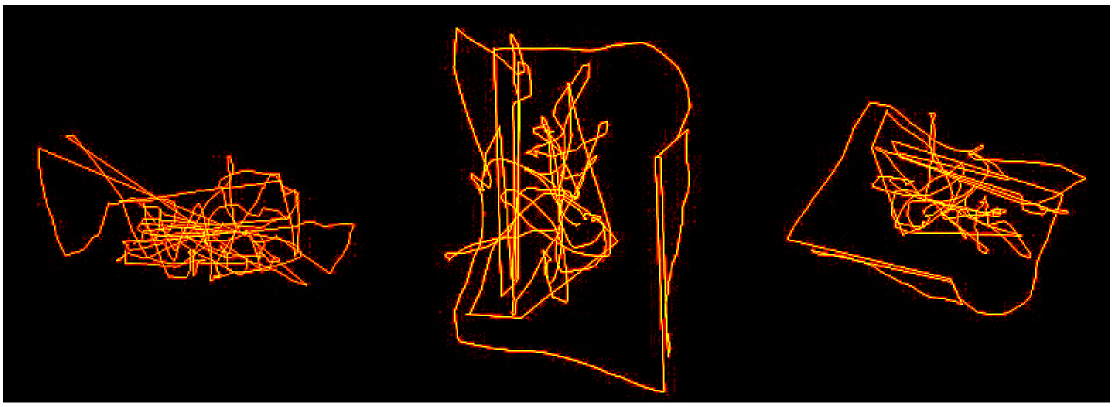

Figure 38: Three views of the same line sketch. Created by Ava Fatah gen. Schieck

Some users used the line module to explore the limits of the drawing space. The previous picture shows clearly those boundaries.

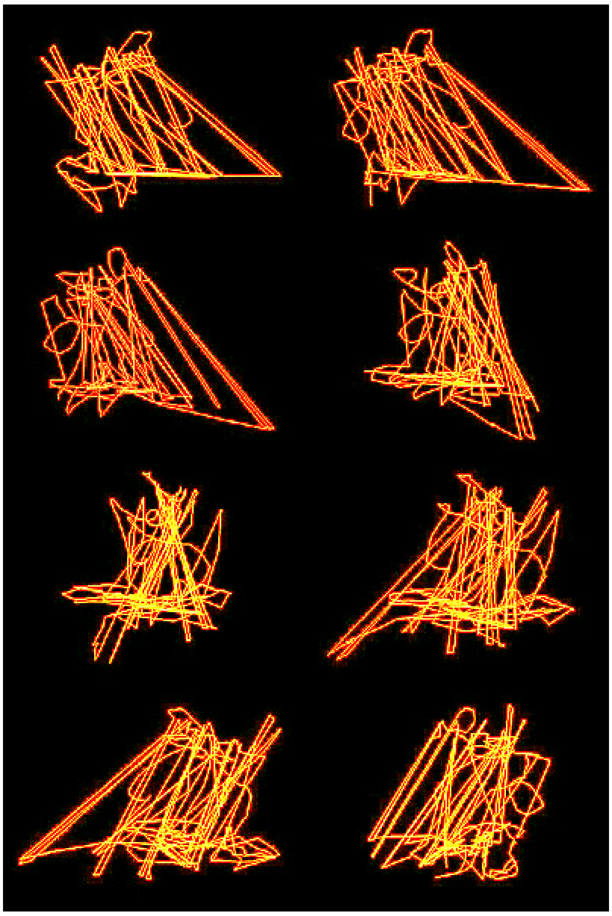

Figure 39: Eight views from same design. Created by César Branco

The above set of screenshots (Figure 38) exemplifies how the line module was used for more elaborate experimentation and design. Drawing with lines in 3D space makes the design attempts easier because only one light must be handled and maintained in the field of view of the web cameras.

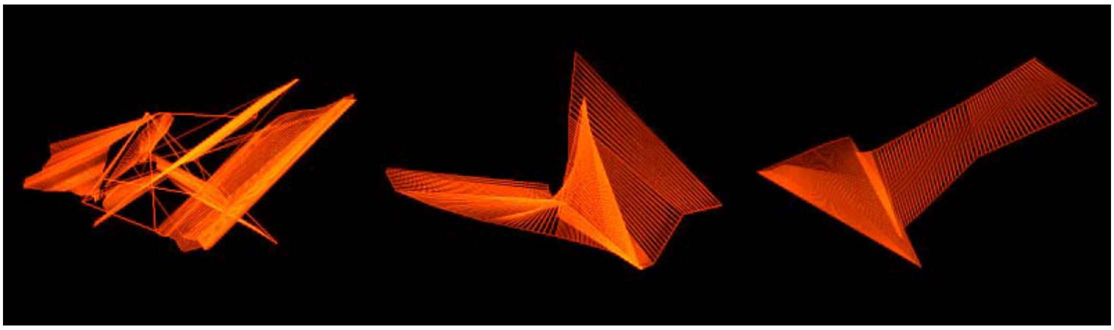

Figure 40: surfaces in Phase 2 visualised in wireframe in a VRML browser

Notice the improvements field of view in the above image made in the Phase 2 of the testing. These surfaces are much wider than the others.

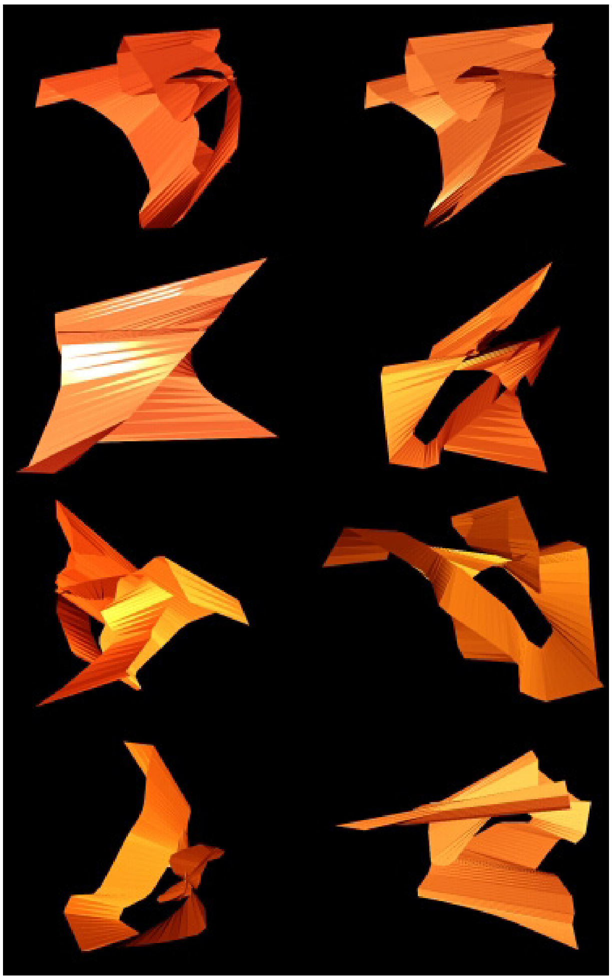

Figure 41: Curling ribbon from eight different viewpoints. Created by César Branco

The user with most experience using the 3D digital design program sketched this curling ribbon under good conditions: bright LED's in a dark room with the Sony video camera and the wide lens.

6.2.2. Interface

The users liked the feeling of freely moving the two LED "pens" trough space, and almost immediately grasped the interface concept. They also enjoyed the fact that the pens were so light and wireless. But the adaptation to the technological limitations was disappointing to them. Mainly the field of view of the cameras and the speed of the system (the response speed was considered by one user as being too fast).

These problems have been reduced by increasing the smoothing factor in the surface rendered, and by using another (more expensive) camera with a wider field of view in the Phase 2 of the testing

6.2.3. User Interface Feedback

The survey conducted after the first testing session showed that the users found the system to have an unnatural feedback, too fast and a limited space to work in. These problems led the users to concentrate more on maintaining the lights visible by the cameras than on the sketch itself.
The users also said the system was fun and they like the shapes generated. They liked especially the export feature because it allowed for more complete exploration of the generated shapes and further editing in 3D Studio or Auto CAD.
Different exploratory tools are also required to derive a better understanding of the objects that are being created.
A possible conclusion from the testers' behaviour and reactions is that a designer develops a personal relationship with a design tool, leading to an individual belief in her experience with the tool. However, a designer's "fluency" with a preferred design tool or method is usually not vocalized. With reference made to this approach, and its possible place in the design process, it was commented that when a designer becomes "fluent" in using a particular tool she is able to better consider all the possibilities available to her. So, training ends up as being essential.

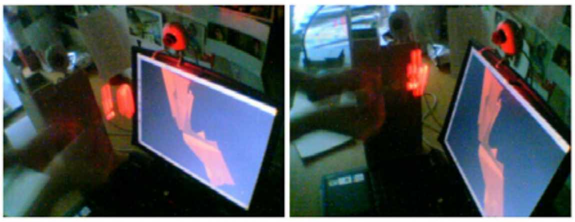

Figure 42: Testing the user interface design. Phase 1

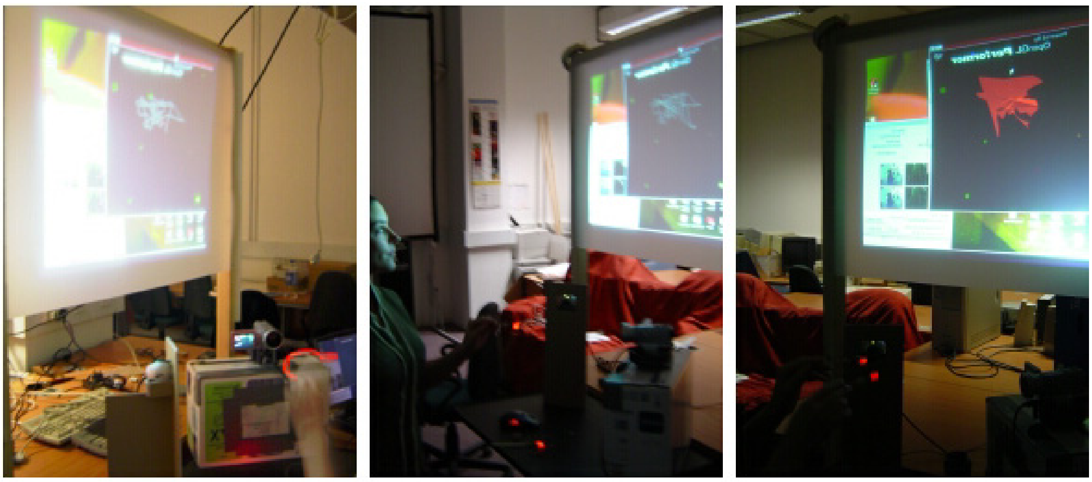

Figure 43: Testing the user interface design. Phase 2

6.3. Problems Encountered

6.3.1. Web Cameras Field of View

The main problem with this system is the limited field of view of the web cameras. This problem restricts the working space for digital design and distracts the user from the shapes being drawn to the tracker window indicating how far from exiting the cameras range the lights are.
This problem was partially overcome by using a Sony video camera fitted with a wide conversion lens X 0.6. The field of view for the x and y coordinates doubled.

6.3.2. Software Development Problems

The usage of two simultaneous cameras with Direct X was especially difficult to program, but was essential to achieve the desired performance, as having two separate programs for each camera was overloading the laptop.
The tracking system is such an important part of the configuration needed to 3D digital design, that the setting up of the two cameras/two light tracker consumed more the half the development time. But it is vital and must be further developed.

6.3.3. Light Tracking and the "Controlled Environment"

Light detection and tracking, even in a controlled environment, was also difficult. The constant web camera self calibration made it hard to implement. But a light was the only choice at this moment, as printed markings (like Artoolkit) were not visible from every angle and other technologies (infra red) required more expensive cameras and other hardware.
The fact that the system needs a controlled environment: in semi-darkness is problematic. Firstly because it is not a natural condition to work in a studio where several people work with normal light conditions. Secondly because it gets interferences and reflections all the time destroying the concept of natural interface since you have to set the light conditions beforehand.

6.3.4. Interface Calibration

The speed of the surface generation should be recalibrated for a different computer, because of the varying frame rates. The dimensions of each camera view port are hard coded in the tracker; this is a problem because it has to be changed when changing camera types.

part VII. Future work

During the course of this work, a few improvements and future uses were identified. Most of them require mainly changes in hardware.

7.1. Video Cameras

The web cameras should be fitted with wide angle lens or substitute with some kind of surveillance cameras with wider field of view.

7.2. Tracking

The tracking algorithm can be upgraded using different algorithms: differential based light searching and colour matching would make the system more robust under poor lighting conditions. For a similar approach see [Jordão, L. et al 1999].

7.3. Plug in for 3D CAD applications

This system can be merged with an application such as 3D Studio, as a sketch plug in, for fast sketch and edit drawing cycles.
This would significantly increase its credibility and enabling wider acceptance by the designer's community. It would enlarge its user-friendliness given that it would be built-in in the CAD system and therefore it would avoid moving between hardware and software systems, making it a part of the creative process.

7.4. Adding Graphic Primitives and Viewing Capabilities

The software, for more advanced modelling, should include extra primitives and functions:

- Gesture based interface to activate different primitives and functions;
- Parametric surfaces deformed by the movement of the 2 LED's in space (no mathematics required);
- Regular objects as spheres, boxes and straight lines;
- Rotating the shapes;
- Rotating the user;
- Boolean operations;
- Undo/redo capabilities be "rewinding" or "forwarding" the rendering of the surfaces using the 3D points stored in the program.

7.5. Extending Towards an Augmented Reality Configuration

The natural extension after changing the hardware as described before, will be adding a head mounted display to implement an augmented reality configuration for the system. This new layout will allow for realistic visualization and manipulation of the generated shapes, while maintaining the original sketch concept. This framework would allow visualising the object in full scale in the real world. Here the inspecting function would be performed by simply moving your head and body around the object at the same time as it is created like a sculptor with a clay model in front of her (see Figure 43).

There are already augmented reality systems that permit interaction with physical models, using tangible interfaces like paddle to manipulate and edit virtual objects overlaid into the physical models (see Figure 42) [Dias, 2002].

Figure 44: User modelling with tangible interfaces (paddles) overlaying virtual objects onto a physical model. On left visualising in Reality and on the right visualised in Augmented Reality [Dias, 2002]

For a less cumbersome set up the user should wear a wireless head mounted display.

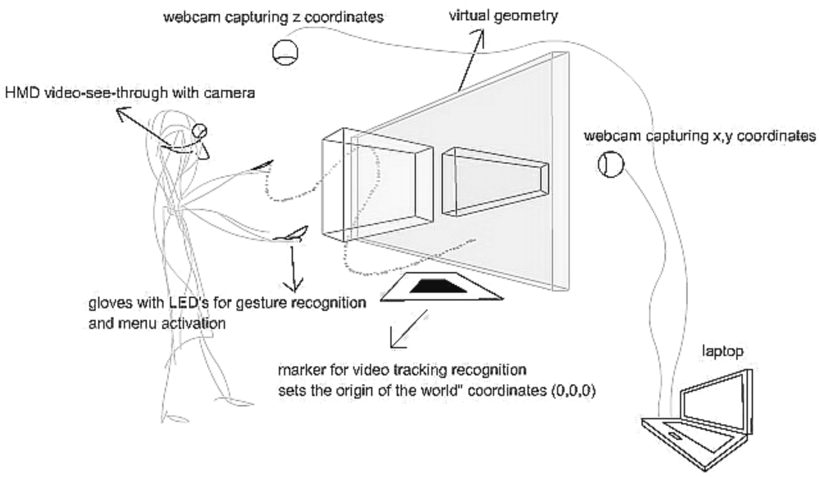

Figure 45: Hypothetical Augmented reality configuration.

7.6. Applications

Several possible applications are envisioned for the future development of this kind of system:

- Industrial and Product Concept Design
- Urban and Architecture Concept Design
- Rapid Virtual Environment Prototyping
- Education, Entertainment, Children Interaction
- Video Games

part VIII. Discussion and Conclusions

8.1. Discussion

8.1.1. Remembering the Hypothesis

The thesis hypothesizes that architects employ tangible interactions to assist design-thinking tasks in early design phases. In doing so, architects can lessen visual overload and exploit under utilized motor skills and hand-eye coordination lacking in most CAD systems. With tangible input, CAD systems not only retain functionality and accuracy, they also benefit from ambiguous freehand input directly from users. This thesis discusses the possibility of building an interface for 3D complex form generation. By using two hands moving independently in space the user will be able to create complex forms in an spontaneous manner.

8.1.2. Remembering the Research Objectives

Are there new ways of translating the shapes and concepts in the mind of the designer or architect other then paper sketching? How can computers help in the creative process without disrupting it?

This thesis argues that by using both hands freely, the designer will be able to convey his ideas more naturally, freely, in a quicker way, without thinking very much about the tools she is using. Such tools being more complex programs like CAD or 3D studio, which have elaborate grammars and command sequences, that take too much time to master. Additionally using a 3D cad system for organic shape - "nurbs" is far too difficult because as they're mathematical based, you have to set an amount of parameters which destroys the spontaneous creative thought. This usually ends up on a time consuming process, where usually a form is achieved after several and tedious attempts.

8.2. The Proposed Framework Features

8.2.1. Creation of 3D Form Using a Two-Hand Input

The two hand approach allows for two independent movements, not like usual 3D sketching applications, opening new exploration paths for shape generation.

The main difference to other freehand shape generations is the usage of two hands; this thesis argues that by using 2 hands the generated forms are more flexible because the position and orientation of the profile is constantly changing. This method creates non symmetric shapes, irregular surfaces, like ribbons with varying widths and that can be bent on them selves.

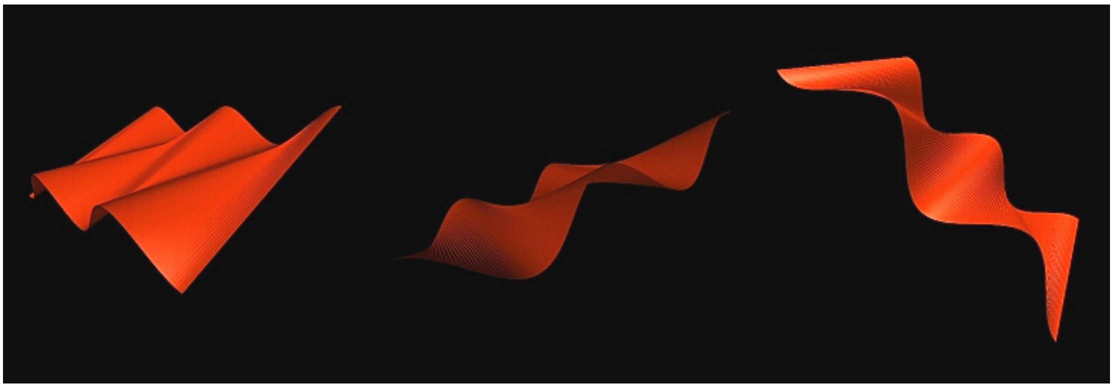

Figure 46: Images showing the asymmetrical shape versatility (This picture was made by sending 3D computer generated hand paths to the program, to clearly show the possible forms)

As the picture shows, the two sides of the surface are not symmetrical, one side moving up, and the other moving down. This gives the modelling paradigm used in the program the possibility to create complex shapes.

Figure 47: Spiral surface on with varying width along its 3D path. (This picture was made by sending 3D computer generated hand paths to the program, to clearly show the possible forms)

The picture shows a ribbon with varying width along its 3D path. One of the sides also varies in a wave like movement, as the ribbon describes a spiral movement.

8.2.2. Instinctive Tool not Replacing Sketching

Sometimes when designing, a user will just start scribbling in a piece of paper, trying to visualize her idea, seeing how it takes form. The same thing happens in CAD, as the designer tries to give tri dimensional meaning to an idea, even without a previous paper sketch. The user eventually adapts his mind and repeats the drawing attempts depending how the shapes are resulting in CAD. While developing the program focusing on a free hand drawing tool in 3D, the main test user noticed it did require planning, thus giving the application the usage of a form generator according to an idea. A kind of creative assistant, on exploring shapes: complicate, regular, edgy or smooth, always organic.

8.2.3. Non Parametric Shape Generation

One main difference to other systems is that the resulting shapes don't look like computer generated geometries, parametric, like smooth blobs or fractal like surfaces endlessly repeated. They are of more of an organic nature because they are created by the user hand movement, rather then by the user pre settings.

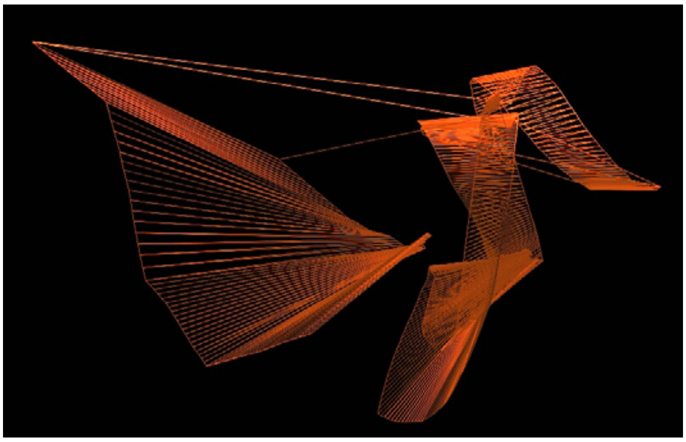

Figure 48: This picture was hand generated in the program. Notice the smooth but natural flow of the second ribbon, floating over the wider, more regular surface on the left

8.2.4. Training as an Important Factor

While developing this system one of the features in the methodology was using a test user following all the steps of the development giving his constant feedback. Obviously his results are much more affective, which leads to the conclusion that training is a crucial factor as the user adapts to the new paradigm. The test user that accompanied the complete development of the program increasingly adapted him self to the interface, and succeeded in doing the best shapes. He, nevertheless complained about the lack of inspection capabilities during design time, as much as the missing undo function.

8.3. Conclusions

The focus of this project is on the input interface. The goal is the development and testing of an easy and natural 3D two hands interface. This system is more natural to work with than using the mouse, less difficult than learning complex software packages and less abstract than manipulating two dimensional entities on orthogonal projections.

This project has developed one prototype for non intrusive, inexpensive, free hand based 3D sketching system to be used in the earliest phases of the design process. The approach this thesis suggests is based on the independent free movement of both hands in space, providing architects and other designers involved in object conception, with a highly flexible 3D shape generation instrument that takes advantages of mixed reality concepts. That is to say using real world paradigms with virtual objects.

The software was conceived (and tested along its development with that aim) to assist or enhance the first 2D drawings steps in the design process by using both hands to draw organic, non parametric, surfaces. This method produces rough 3D sketches that can be refined latter using any 3D modelling software package (as it was shown in 3D Studio and CAD examples). It is, in essence, a 3D modelling system directed to free hand sketching in a mixed reality environment.

8.3.1. Non-Intrusive, Spontaneous 3D Digital design

The testing phase and all the research made for the development of this system leads to the conclusion that a non-intrusive and insightful 3D digital design system is possible. All the problems encountered (and some solved) were technical, not fundamental to the configuration.

8.3.2. Simple, Low-cost Interfaces Based on Non Intrusive Devices

The hardware used is not expensive and the hand held input device is not cumbersome. The test users immediately grasped the concept and liked the freedom the un-connected LED light sticks allowed.

The (expensive) video camera used in the last tested configuration can be substituted by low-cost cameras with wide lens (common camera phones already have them).

8.3.3. Real World Applications: Concept Design

The export module demonstrates the applicability of such systems as a plug in for 3D design systems such as 3D Studio or Auto CAD. This will permit faster experimenting for designers and architects, without physical models and digitising.

8.3.4. Shape Generation

The system generates organic, complex, fractal like shapes from the free, creative hand of the digital artist, seeking new worlds inside the computer.

Figure 49: The Weatherhead School of Management's Peter B. Lewis, Frank O. Gehry. http://images.google.com/

This kind of sketch system can also be seen as a creative tool, a conceptual tool in computer design and architecture. The arbitrariness derived from the non precise movements of the hand is also a feature of the resulting 3D design, thus giving it a natural (in the sense of nature generated) quality. The 3D sketch program gives the ability to be new in every design.

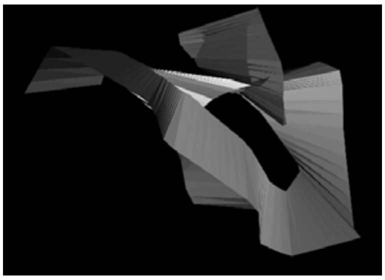

Figure 50: Trying to get the most of the program. Creating organic shape with strip-surfaces using the program. Created by the author

The fundamental difference from other design generating programs is that no explicit mathematic knowledge is required by the designer. No parameters need to be set. The objective is to achieve new form through hand movement. Not by a generative function that is left to work on it's own after the parameters are set.

The main obstacle between a working, marketable, 3D digital design system and the current prototype is technology. Advanced displays, better video cameras, brighter LED's and more accurate tracking systems. These are not real constraints, but more a matter of time and financial resources.

Three dimensional, direct, digital design systems are possible and will be a common technology available to concept design. The barrier between 2D paper representations of 3D concepts is bound to fall and it will be possible to translate a concept directly from mind to a geometric entity stored in computer memory. This digital design is ready to be edited, modified into something powered be the endless possibilities of a computer.

It will be a digital model that has had one less stage of translation where possibly some information would be lost.

The testing sessions led to the conclusion that the system provides 3D instinctive design capabilities, its strengths residing in:

- Natural CAD paradigm.
- It is implicit, i.e. describes form without a particular sequential structure real 3D design, with direct 3D input.
- It is inexact and abstract, avoiding the need to provide unnecessary details. It requires minimal commitment it is easy to discard and start a new one just like paper sketching
- Export module that allows further editing and precise vertex editing.

Even so, it proved the call for technological improvement and further time to develop some tools:

- Wider field of view for the cameras to have a broader working space.
- Better tracking under poor light conditions.
- The possibility to rotate the shape while drawing.
- An Undo/Redo function is crucial to an effective sketching as it allow the user to change is mind while drawing

To what its usability is concerned, like in any other paradigm, the designer will develop her own criteria for using the system, which could include convenience and how that environment relates to the particular stage reached in the design process. This program, and 3D digital input as a whole, provides one particular answer, or technical domain, for design exploration. During every stage of the design process, certain constraints guide — these allow the designer to explore certain aspects of the design. A question was raised which motivates further research: how do you try to explore and what it can contribute to the creative process?

In conclusion this work argues that 3D design, based on free hand form generation, allows for an enhancement of the traditional creative process through spontaneous and immediate translation of a concept into 3D digital shape.

part IX. References & Bibliography

References and Notes

[1] http://www.fingerworks.com/igesture.html

[2] http://www.inition.co.uk/inition/InitionPriceList.htm

[3] http://www.vr.ucl.ac.uk/projects/arthur/

[4] Pratini, E., [2001] "**The 3D Sketchmaker Project**", University of Brasília, Brazil, http://www.usp.br/nutau/pratini/sketchmaker.htm

Papers and Articles

Schieck, A. F. gen. [2001] "**Interactive Form Creation**", Thesis MSc in Virtual Environments, UCL, London.

Jenkins, D. L. and Martin, R. R. [1993] "**The importance of free-hand sketching in conceptual design: Automatic sketch input**", In: ASME Design Automation Conference in Albuquerque.

Pugh, D. [1992] "**Designing solid objects using interactive sketch interpretation**", Computer Graphics Symposium on Interactive 3D Graphics), 25(2):117-126.

Dias, J. M. S., et al, [2002], "**Tangible Interaction for Conceptual Architectural Design**","ART02", First IEEE International Augmented Reality Toolkit Workshop", ISMAR 2002, IGD, Darmstad,Germany.

Forsberg, A. S., LaViola Jr., J. J., Markosian, L. and Zeleznik, R. C. [1997] "**Seamless Interaction in Virtual Reality**", Computer Graphics & Applications, IEEE, Vol. 17, No. 6, pp. 6 – 9.

Gross, M. D. and Do, E. Y-L. [2000] "**Drawing on the Back of an Envelope: a framework for interacting with application programs by freehand drawing**", Computers & Graphics, Vol. 24, No. 6, pp. 835 – 849, Elsevier.

Lipson, H. and Shpitalni, M. [1997]. "**Conceptual design and analysis by sketching**", In AIDAM-97.

Hwang, T. and Ullman, D. [1990] "**The design capture system: Capturing back-of-the envelope sketches**", Journal for Engineering Design 1, 4.

Hwang, T. and Ullman, D. [1994] "**Recognizing features from freehand Sketches**", Computers in Engineering- 1994 Vol. 1, ASME.

Igarashi, T., Matsuoka, S. and Tanaka, H. [1999] "**Teddy: "A sketching interface for 3D freeform design**", In Proceedings of SIGGRAPH 99, pp. 409– 416. 1, 2, 5, 9

Jordão, J. A. and Glinert, E. P. [2000] "**Calligraphic Interfaces: towards a new generation of interactive systems**", Jorge J A, Glinert E P (guest editors), Computers & Graphics, Vol. 24, No. 6, pp. 817.

Kato, O., Iwase, H., Yoshida, M. and Tanahshi, J. [1982], "**Interactive Hand-Drawn Diagram Input System**", Proc. IEEE Conference on Pattern Recognition and Image Processing (PRIP 82), Las Vegas, Nevada, pp. 544-549.

Jordão, L., Perrone, M., Costeira, J. and Santos-Victor, J. [1999] "**Active Face and Feature Tracking**", VisLab-TR 08/99, International Conference on Image Analysis and Processing, Venice, Italy.

Nielsen, M., Störring, M., Moeslund, T. B. and Granum, E. [2003] "**A Procedure For Developing Intuitive And Ergonomic Gesture Interfaces For Man-Machine Interaction**", Aalborg University, Laboratory of Computer Vision and Media Technology, Denmark.

Karpenko, O., Hughes, J. F. and Raskar, R. [2002] "**Free-form sketching with variational implicit surfaces**", Eurographics, Saarbrucken, Germany.

Schkolne, S. [1999], "**Surface Drawing: The Perceptual Construction of Aesthetic Form**", M.S. thesis, Computer Science, Caltech, USA.

Schkolne, S., Pruett, M. and Schröder, P. [2002] "**Drawing with the Hand in Free Space - Creating Organic 3D Shapes with Gesture in a Semi-Immersive Environment**", Computer Science Department, Caltech.

Igarashi, T., Matsuoka, S. and Tanaka, H. [1999]. "**Teddy: A sketching interface for 3D freeform design**", SIGGRAPH 99 Conference Proceedings, pages 409–416.

Turner, A., Chapman, D. and Penn, A. [2000] " **Sketching space**", Computers & Graphics, Vol. 24, No. 6, pp. 869 – 879, Elsevier.

Sutherland van E. [1963] "**Sketchpad: A man-machine graphical communication system**", In AFIPS Spring Joint Computer Conference, pages 329--346, 1963.

Zeleznik, R. C., Herndon, K. P. and Hughes, J. F. [1996] "**Sketch: An Interface for Sketching 3D Scenes**", SIGGRAPH '96 Conference Proceedings, ACM, Vol. 30, No. 4, pp. 163 – 170.

Bibliography

A.D. Architectural Design Magazine [1998] "**Architects in Cyberspace II**", Vol 68 NO 11/12

Dix, A., Finlay, J., Abowd, G. and Beale, R. [1998] "**Human-Computer Interaction**", New York, London, Prentice Hall Europe.

Egerton, P. A. and Hall, W. S. [1999] "**Computer Graphics – Mathematical First Steps**", Prentice Hall.

Imperiale, A. [2000] "**New Flatness: Surface Tension in Digital Architecture**", Birkhauser.

Jacobs, S. P. [1991] "**The CAD Design Studio: 3D modelling as a fundamental design skill**", McGraw-Hill, New York.

Lindsey, B. [2001] "**Digital Gehry**", The IT Revolution in Architecture Antonino Saggio (Ed.), Birkhauser.

Lynn, G. [1999] "**Animate Form**", New York, Princeton Architectural Press.

Mitchell, W. J. [1993] "**A computational view of design creativity**", in J. S. Gero and M. L. Maher (eds), Modelling Creativity and Knowledge-Based Creative Design, Hillsdale, NJ: Lawrence Erlbaum, pp. 25-42.

Puglisi, L. P. [1999] "**HyperArchitecture Spaces in the Electronic Age**", The IT Revolution in Architecture Antonino Saggio (Ed.), Birkhauser.

Schmitt, G. [1999] "**Information Architecture – Basis and Future of CAAD**", Basel, Birkhauser.

Walker, J. [1990] "**Through the Looking Glass in Laurel, B., The Art of Human-Computer Interface Design**", New York, Addison-Wesley, pp. 439-447.

Yu-Tung, L. [2001] "**Defining Digital Architecture: FEIDAD award**", Birkhäuser.

Zellner, P. [1999] "**Hybrid Space – New Forms in Digital Architecture**", London, Thames & Hudson.

Web Documents [last accessed August 2003]

20th Century 3DUI Bib: Annotated Bibliography of 3D User Interfaces of the 20th Century http://www.mic.atr.co.jp/~poup/3dui/3duibib.pdf

Literature on 3D input for conceptual design (Last updated April 17, 2002) http://dutoce.io.tudelft.nl/~tjamme/literature-ica-a.html

Gesture Recognition Homepage: http://www.cybernet.com/~ccohen/

Whole-Hand and Speech Input in Virtual Environments by Joseph J. LaViola Jr., B.S., Computer Science, Florida Atlantic University, 1996 http://www.cs.brown.edu/people/jjl/pubs/mthesis.pdf

Jot: A Framework for Interface Research Joseph J LaViola Jr., Andrew S. Forsberg, and Robert C. Zeleznik http://www.cs.brown.edu/people/jjl/jotreview.html

Direct X: http://www.microsoft.com/directxDirectXHome

Space Mouse: http://www.3dconnexion.com/spacemouseplus.htm

Microscribe: http://www.immersion.com/digitizer/products/microscribe_g2.php

Inition: Innovative Graphics Solutions: http://www.inition.co.uk/inition/InitionPriceList.htm

Ascension Technology Corporation: http://www.ascension-tech.com/

Cyber Glove: http://www.vrsolutions.com.au/vrsproducts.htm

Appendix I

Survey

An approach on 3D Digital Design – Free Form Hand Generation

Study conducted by Nancy Diniz as part of the her master's thesis in Virtual Environments Bartlett School of Graduate Studies, UCL.

Description of Proposed Study

Increasingly, research is being done to investigate the use of computer applications to generate and explore form instead of just representing it.

This study analyses the use of a program in order to understand the interest of creating more natural and perceptive ways of conceptualising 3D virtual form. The purpose of the study is to ascertain whether 3D form can be created and understood without any previous experience with CAD computation.

Prior to the commencement of the study, the participants will be asked to read and sign consent forms that explicitly request permission for the use of comments and feedback by the testers.

The session will take approximately 20 minutes.

Consent Information

I understand that participation in this study is voluntary and that I am free to withdraw my consent and to discontinue participation in the project or activity at any time without prejudice to myself. During the survey, I understand that I may decline to answer any questions, again without prejudice.

I understand that after the study, the investigator will have control over this questionnaire.

I also understand that the investigator may ask to quote any comments I make in her research/publications, and that I will inform her if I wish to remain anonymous in such research /publications.

Signed

Date

An approach in 3D Digital Design - Survey

Thank you very much for taking part in this survey. Please take a few minutes to fill this in. I'd really like to know what you think!

1) Name:……………………………………………………………………………………

2) What is your field of interest and/or what degree program are you in?
…………………………………………………………………………………………………

3) How much experience do you have with computers?
Considerable………Some ………Little………None………

4) What computer software/applications have you used before? (underline please)
AutoCAD or Other programs (please describe) Microstation (7 responses), Lightscape, 3D Studio Max, VectorWorks, FormZ, Autocad, Bentley Microstation LT, MiniCAD. Alias Wavefront, Adobe Photoshop, Adobe Illustrator, Adobe Premier, Adobe After Effects, MacroMedia Flash, MacroMedia Dreamweaver,

5) How much do you know about CAD (computer aided design) systems?
Considerable ……. Some ………Little………None………

6) How do you find using this system as a possible tool for natural 3D form?
Fun…………The feedback was useful…………It was confusing…………
Too restrictive………… It generated surprising designs…………
Other……………………………………………………………………………………

7) Do you find it frustrating to use?
Yes…..….No……….Other…………………………………………………………………

8) How easy to use was it?
Very easy ….…….Somewhat easy ………Mildly tiring………Difficult………
Very annoying……………..Impossible…………

9) What is your comment on the speed of the program?

Very quick …………Quick…………Average………….Slow…………

10) How enjoyable was it to use?

Very enjoyable………Somewhat enjoyable…………Boring……………

Other……………………………………………………………………

11) How would you use it again?

For a modelling form use ………..For other design use…………For fun…………

Other ……………………………………………………………………………

12) Would you have preferred to sketch on paper before trying this system?

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13) During a conceptual design phase do you enjoy and/or find it more useful to do hand sketches on paper or using a computational design system?

By hand ……..…Using a CAD system……..…Both the same………..

14) Are there any comments/suggestions you'd like to make about this demo?

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