# An Approach to 3D Digital Design Free Hand Form Generation

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## Abstract

*This paper describes a method for direct freehand drawing of complex tri-dimensional surfaces, by moving 2 hands in space. The system tracks the movement of 2 lights in space using 2 web cams. The light's (LED's) are attached to the designer's finger who watches the surface being drawn on a monitor. The user can draw any surface that can be described by the movement in space of a line of varying length, in any direction. The shapes generated can be imported by 3D Studio and then AutoCAD for later precise editing. 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.*

## 1. Introduction

Traditional (non natural and spontaneous) interfaces force 3D modeling 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. An application was developed to track lights in 3D space and draw surfaces according to those movements.

**Figure 1. Setup**

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. 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. The next two diagrams 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 -> Digitized Model -> Cad Model -> Physical Prototype

**3D Virtual Sketching:**
3D Digital Sketch -> Cad Model -> Physical Prototype

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):

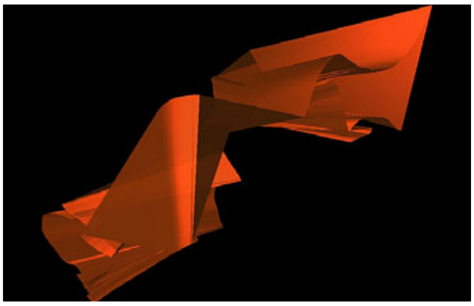

**Figure 2. 3D shape generated from the paths of 2 lights moving freely through 3D space.**

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.

## 2. Two Hands - Two Light Tracking

### 2.1. Hardware/Software Configuration

The system used 2 web cams, 2 LED's, 1 laptop, OpenGL Performer for 3D graphics and 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.
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.

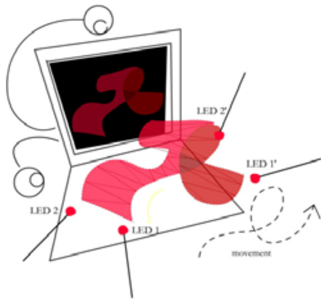


**Figure 3. Diagram of the form - generation system**

## 3. 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 paper 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 bignger 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 expensive 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).

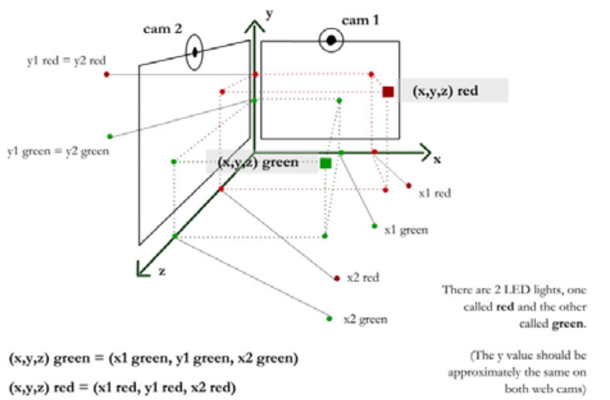


**Figure 4. Web cam layout to extract the LED's 3D coordinates**

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 6). The two cameras are connected to the computer and the images analyzed 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. 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. The shape is generated as the result of an imaginary line uniting the two lights as they move through space.

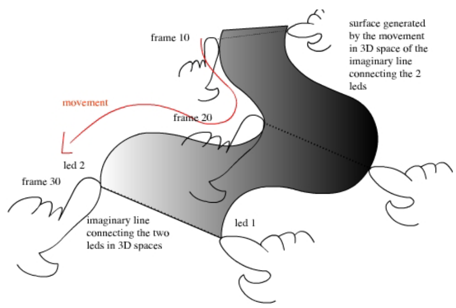


**Figure 5. Movement in 3D space as a surface generator**

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.

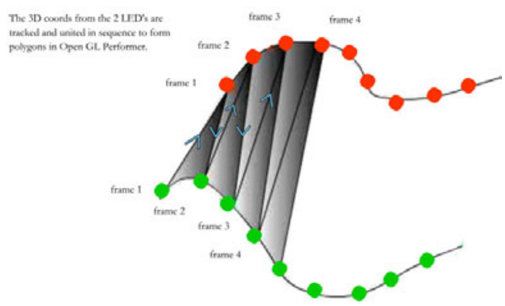


**Figure 6. Triangle creation sequence as LED positions are united in every frame**

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.

## 5. WRL and 3D Studio Export Module

In order to make the shapes available, 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.

# 6. Testing

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 and 3D Studio. As this user became increasingly trained using the software a test round with users unfamiliar with the system was needed for a non-biased feedback.

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/modeling 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, 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.

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

- Increase the field of view of the web cams.
- 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.

## 6.1. Results

**Figure 7. Simple surfaces.**

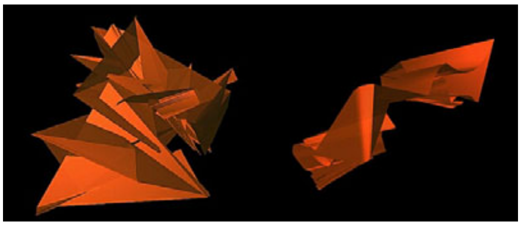

**Figure 8. Tests conducted before and after slowing the speed of the program and widening the field of view of the cameras.**

# 7. Conclusions

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 paper 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 modeling software package (as it was shown in 3D Studio and CAD examples).

### 7.1 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.

### 7.2. 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).

### 7.3. 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 digitizing.

### 7.4. 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.
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.
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. There's a real need to have better video cameras (wider field of view) and more accurate tracking systems before extensive use. Advanced displays and brighter LED's would be helpful but not determinant. 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.

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.

## 8. References


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