

# AN INNOVATIVE USER INTERFACE FOR INTUITIVE 3D-SKETCHING IN AN AUGMENTED REALITY ENVIRONMENT

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## 1. Objectives

Conventional tools for engineering design like CAD do not support creativity in the early design phases. Instead, paper based sketches are still the conceptual designer's first choice for fixing his ideas. Even during work with CAD, paper based sketching is widespread [Pache 1999]. New technologies like Virtual Reality (VR) or Augmented Reality (AR) offer new ways of visualization and interaction, but usually base on CAD data that is created in later phases of product development and thus do not support the creative phases.

Combining the intuitive use of paper based sketching, the easy manipulation of CAD data and the immersive visualization of AR/VR-technologies, a new computer based tool could be created that supports creativity in early conceptual phases of product development. Using such a tool should be intuitive so that the designer can concentrate on his principal task of making conceptual design. The ideas that the designer has in mind should be fixed very easily in order to free the mind for new ideas or to have a basis for discussion with other designers [Höhne 2003]. The designer using such a tool should not be distracted by the necessity to recode the thoughts to perspective 2D-drawings or different views and sections, but should be able to work intuitively.

## 2. Requirements

Most problems engineering designers work on are three-dimensional. In order to transfer ideas from the imagination in mind easily to a sketch, a three-dimensional working space is considered to be more appropriate than just a two-dimensional one. When working with paper or with a digital pen-display in 2D, there is no distance between action- and perception space. At the point where a line is drawn the result can be observed, which makes it much easier to sketch than with a setup where action- and perception space are separated, like computer mouse and screen. In consequence, also a three-dimensional perception space is needed. It should be coincident with the working space to provide a paper-like 3D-tool. The technology to achieve this is already existent – Virtual and Augmented Reality. This is different to existing solutions of mapping 2D-input to a 3D-model [Zeleznik 1998, Min 2002].

Indeed, this constellation requires an innovative user interface that provides intuitive usage similar to dealing with paper and pencil but nevertheless makes available the broad functionality of today's graphic- and CAD-software. The core requirements for such a user interface are real-time interaction, quick access to functions, quick and easy turning and moving of the working space and the provision of broad functionality by just a small number of commands.

### 3. Results

The user interface we developed based on the requirements mentioned above features a consistent and coherent structure. Importance was attached to not disturbing the creative process of sketching by unexpected reactions of the system. The development of the user interface did also include the hardware used for interaction with the system.

#### 3.1 Augmented Reality Environment

In order to achieve the aim of providing a coincident action- and perception space three-dimensional sketching, Augmented Reality is a promising technology. An Augmented Reality Environment adds computer generated visual information to the view of the reality. A quite simple and cheap way to realize an Augmented Reality Environment is the usage of a semitransparent mirror. Positioned in the right angle to a computer screen, the computer generated image and objects underneath the mirror can be seen at the same time. Assuming an input device that is correctly calibrated, it is possible to display a line that is coming out of the moving input device, just like a line appears when a pencil is moved on paper. With the help of stereo visualization, a technology that is known from Virtual Reality, a three-dimensional “sketchpad” below the semitransparent mirror is realized. One great advantage of working under the mirror compared to working with paper is that with the AR system there is no occlusion of any parts of the sketch by the users hand or arm. Figure 1 shows the setup of such an Augmented Reality supported 3D-sketching system.

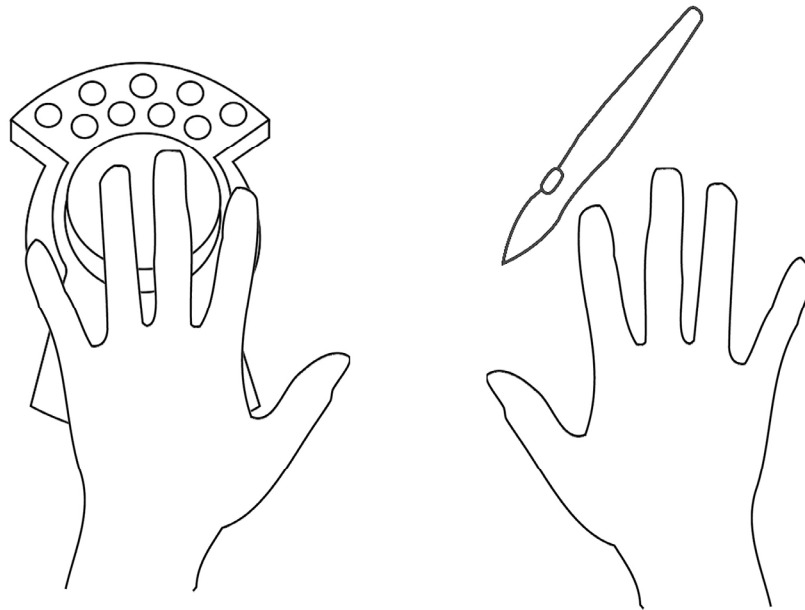


**Figure 1. Prototype of a 3D-sketching tool using Augmented Reality**

#### 3.2 Two-handed interaction

A 3D-sketchpad in an Augmented Reality Environment needs a new approach for user interaction. As the input device has an additional degree of freedom and as there is no real medium where the sketch is made on, common 2D user interfaces are not sufficient. Experiments with the prototype described in [Müller 2003], which is controlled only by keyboard, showed the need to develop an innovative interaction concept that offers intuitive creation, manipulation and navigation.

In order not to overload one single input device with a multitude of functions we decided for a two-handed interface. In difference to the setup of [Gribnau 1999] two different input devices are used. The primary input device is a pencil-like tool like the Phantom Desktop from Senseable. It is used for the creation and manipulation of 3D-graphic data and for working with the graphical user interface (GUI). The secondary input device provides a quick and easy navigation in the virtual 3D-world. In our system we use a SpaceMouse for this purpose (Figure 2). Similar to the rapid positioning and re-positioning of the paper during conventional 2D-sketching the passive hand is doing this task in 3D, too. This setup is in our opinion the basis for intuitive sketching in 3D, because basic elements of paper based sketching can be retrieved.

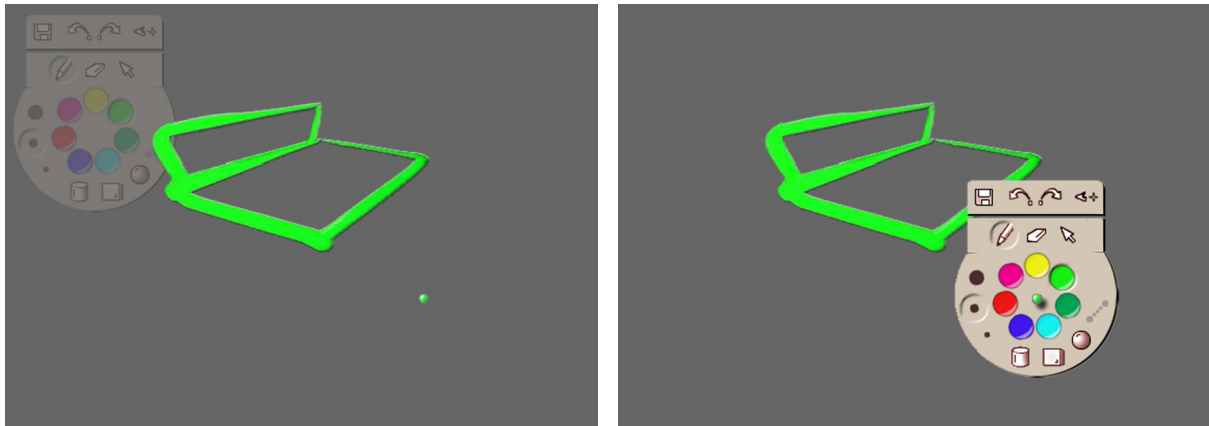


**Figure 2. Two-handed user interface with SpaceMouse (Navigation) and pen (Creation, Manipulation) for right-handed people**

### **3.3 Graphical User Interface (GUI)**

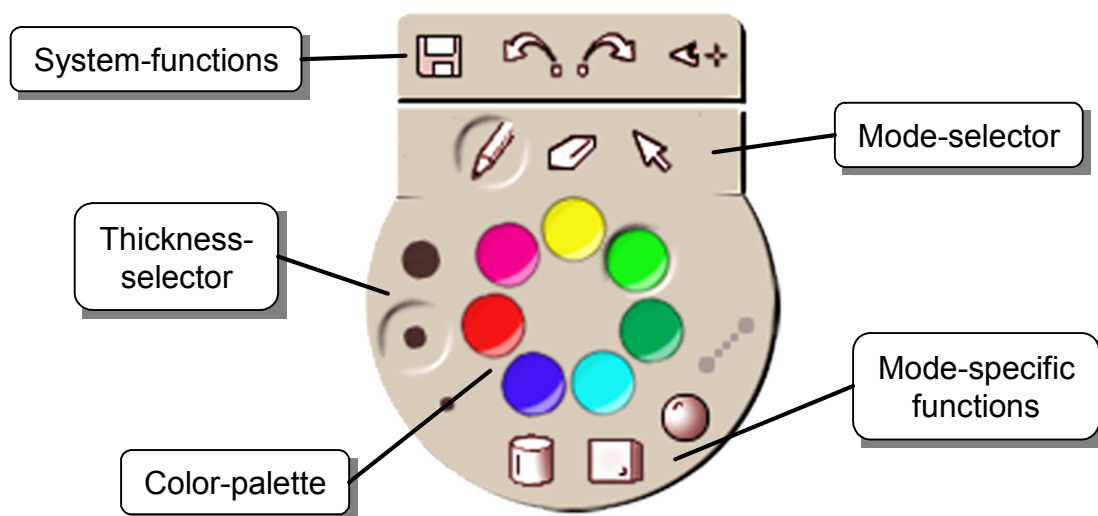
Compared to keyboard controlled software, graphical user interfaces offer a much more intuitive access to the functionality of the software, because the several functions are offered instead of being hidden in cryptic commands that the user actively has to know. Graphical user interfaces in 2D are standard for nowadays computer applications and usually do not differ significantly from each other, whereas real 3D-GUIs (for software that supports stereo visualization) are very rare and heterogeneous. The challenge was to develop a GUI for an AR-supported 3D-sketching tool that makes use of the additional degree of freedom without getting ornate.

The GUI for the 3D-sketching tool is a dynamic, semitransparent 2D-menu (like a palette) that has its default position in the left-upper-back corner of the “working-cube”. In distinction to the Personal Interaction Panel of [Szalavári 1999] the menu must not be “held” with the left hand. In order to provide quick access to the functions of the menu, it can be switched to the current 3D-cursor position by pressing a button on the SpaceMouse. The cursor then is in the middle of the menu so that all functions can be reached without moving the cursor far away from the starting position (Figure 3). A function is selected by tipping with the pen of the primary input device onto the correspondent icon. After the activation of the function the menu returns to its default position and work can be continued close to the point where the last action ended. This reduces the distances that have to be covered with the cursor (resp. the input device) and helps to keep the concentration on the object to be sketched and not on the usage of the tool.



**Figure 3. The graphical user interface: default position (left) and activated at the cursor position (right)**

The menu is divided into five sections that are showed in Figure 4. Functions that are related with the sketching process are arranged in two circles around the center of the menu. The inner circle consists of the color-palette that enables the user to change the color of the lines very quickly. In the outer circle there are three different areas: With the thickness-selector the user rapidly can change the diameter of the 3D-line. For switching from the drawing mode to the erasing or selecting mode the user just points to the correspondent icons of the mode-selector. Depending on the selected mode, specific icons appear in the down right area of the outer circle. Basic system functions like file-saving or the undo-function are located in a bar above the two concentric circles. As they are not that often used during the sketching process than the basic drawing function, the distance to move the cursor is bigger, but, compared to static icons on top of the screen, still relatively small.



**Figure 4. Structure of the menu**

### 3.4 Primary modes: drawing, erasing and selecting

The interaction concept is based on three primary modes: Drawing, erasing and selecting. Depending on which mode is selected, the GUI menu offers different functions. Figure 5 shows the appearance of the GUI menu in the different modes.

In the drawing mode the user primarily can produce line-based three-dimensional sketches using different line thicknesses and colors. With the lines representing the edges of an object, 3D wire-frame sketches can easily be made. The user can choose whether he wants do work with free-hand lines or

with point-to-point lines. Some 3D-geometries however are difficult to sketch just by lines because they have curved surfaces without edges. In order not to disturb the user from his creative design process because of considering how for example a cylinder can be drawn in 3D just by lines, there are functions to draw simple geometries like spheres and cylinders. Also cuboids can be drawn in this way easier than drawing 12 lines. As the system's purpose is to support creative design in early conceptual stages and not to replace a CAD system, there is no functionality for example to define exact dimensions.



**Figure 5. The menu in the primary modes drawing (left), erasing (middle) and selecting (right)**

Sometimes users make mistakes or want to change existing sketches. The erasing mode turns the ball-shaped cursor into a 3D-eraser. Every object in the working space that collides with the cursor will be deleted. With the thickness-selector the size of the eraser can be adjusted. But not only deletion of all collision objects is possible, there is also a conditional erasing mode. Depending on the selected properties for example only thin red lines or only cylinders will be de erased.

Generally the user can always perform navigation operations with the SpaceMouse. This is useful to view the 3D-sketch from different points of view and makes it possible to continue a sketch from another perspective. In the drawing and the erasing mode the navigation operations affect the whole sketch, similar to positioning the paper on the table. In the selecting mode it is possible to reposition single elements of the 3D-sketch. To achieve this, these elements have to be selected by spanning a semi-transparent cuboid. After finishing this operation, all elements inside the cuboid are selected. It is possible to group these objects in order to memorize this selection. A selected object can be moved, rotated, positioned and scaled independently from other objects in the working space. The navigation of the objects is very simple: no special icons or keys have to be selected and the objects can be moved intuitively to the position where the user wants them to be using the six degrees of freedom of the SpaceMouse. There is no differentiation of translation or rotation as it uses to be in 2D-interfaces for 3D-data.

First tests made with a prototype implementation on an Augmented Reality 3D-sketching tool were promising. After finishing the implementation of the whole user interface concept a usability test is planned to verify the concept and to get inspiration for further improvement. These tests will be performed with both, professional designers and students of mechanical engineering, who have to solve a real design task.

#### **4. Key conclusions**

For better support of the conceptual phase of product development a new tool is suggested that combines the advantages of paper based sketching and 3D software tools – a “3D-sketcher”. Acting directly in a three-dimensional working space requires new user interaction concepts that are different to current 2D-WIMP (Windows-Icons-Menus-Pointer) interfaces and allow intuitive working. A two handed interface emulates the familiar usage of paper and pencil. The Graphical User Interface (GUI)

is based on a palette-like context menu that is displayed on demand directly at the actual cursor position. This enables the user to reach the core functions within short-distances.

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