INFORMATION SOCIETY TECHNOLOGIES
(IST)
PROGRAMME

SmartSketches

Technical Report

Project acronym: **SmartSketches**

Project full title: **SmartSketches: A Multimodal Approach to Improve Usability in the Early States of Product Design**

Contract no.: **IST-2000-28169**

DELIVERABLE: **D 18a SketchAR User Manual**

Deliverable

DELIVERABLE Nº	**18a**
NAME:	**SketchAR User Manual**
WORKPACKAGE:	**4**
LEAD PARTICIPANT:	**IG**
TYPE:	**Report**
DATE:	**2004 , 09 , 21**
CIRCULATION:	**Public**

Executive Summary

SketchAR is one of the first immersive design and modeling systems for early stages of product design. It combines precise optical tracking with interaction on an accurate CAD model, which is not just a triangle or subdivision surface model.

This document represents the SketchAR User Manual.

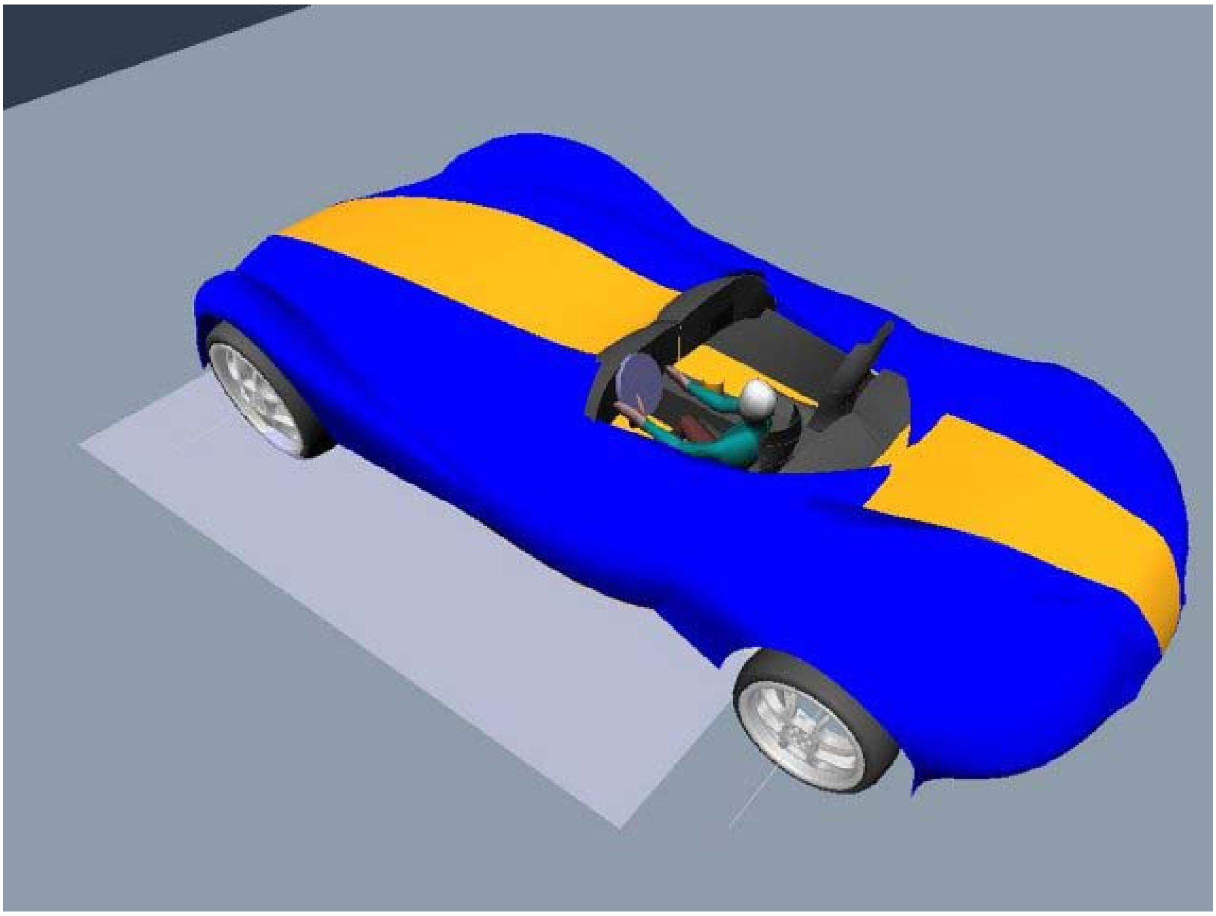

Figure 0: A car body sketched with SketchAR in a few minutes

The SketchAR User Manual is intended as a guide for the user to set-up a working SketchAR environment as well as getting to know how all available features work. It is split up as follows:

- Hard- and Software requirements
- CD content
- Hardware Setup
- Software Setup
- Multimodal Interaction Techniques
- Functionality:
    - File Operations
    - Package Model Editing
    - Editing Operations
    - Geometry Creation
    - Geometry Modification
    - Supporting Operations
    - Network Collaboration

Please note that additional information can be found on the installation DVD (D17).

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1 Introduction

The SketchAR User Manual (D18a) is intended as a guide for the user to set-up a working SketchAR environment as well as getting to know how all available features work. It is split up as follows:

- Hard- and Software requirements: This section specifies the minimum hardware requirements for SketchAR, the target operating systems as well as supporting software.

- CD content: This section describes the content of the Installation DVD (D17)

- Hardware Setup: SketchAR relies on tracking and rendering hardware to run. In this chapter the setup of the currently used optical tracking system is explained and the user is given information on which alternative tracking systems can be used. Furthermore the various scenarios in which SketchAR can be used are detailed, namely the back-projection, virtual table and augmented reality setup.

- Software Setup: The software setup section mainly deals with the configuration of SketchAR for the three above mentioned scenarios. The calibration of tracked artifacts and the many ways of editing and merging tracking input are explained in detail.

- Multimodal Interaction Techniques: This section introduces the user to the main interaction techniques used in SketchAR, which are usage of the tracked model artefact, the pen interaction, the two alternate menu forms (PIP and PIE menus) as well as speech I/O and gesture based interaction techniques, draggers, sliders, picking, snapping and the usage of the spacemouse while in four-view mode.

- Functionality: This section covers all currently available features, specifying which multimodal input techniques will invoke which functionality. The features are grouped according to the following feature areas:
    - File Operations
    - Package Model Editing
    - Editing Operations
    - Geometry Creation
    - Geometry Modification
    - Supporting Operations
    - Network Collaboration

The SketchAR Technical Report (D18b) elaborates on the user manual to describe SketchAR from a technical point-of-view focussing on the specific details of the hardware used and the implementation of the software.

2 Hard- and Software Requirements

SketchAR, the immersive design and modelling application has the following hard- and software requirements to run properly:

Minimum Hardware Requirements:

- > Pentium 4, 1.6 Ghz
- 512 MB RAM
- 300 MB Disk Memory
- Nvidia Quadro Graphics Board [1] or ATI FireGL (active 120Hz output / passive stereo 60Hz output) [2]
- Opentracker Supported Trackingsystem such as AR-Tracking Optical Tracking System [3] or others.
- Spacemouse (to use four view drawing) [4]
- Tracked artifacts: Model, Cyberstilo [5], PIP
- Active Stereo: CrystalEyes Active stereo shutter glasses [6]
- Passive Stereo: Circular Pole filter glasses and filters for beamers
- Active Stereo Beamer (120Hz) [7] or two regular beamers (60Hz) for passive stereo [8]
- Desktop: Autostereo Display [9]
- Augmented Reality: Trivisio Optical See-through glasses [10]
- In case of beamer usage: Back Projection Plexiglas which keeps polarization.

Software Requirements:

- Windows 2000/XP Operating System [11]
- TGS Open Inventor License >3.1.1 (Scenegraph functionality) [12]
- ACIS 8 Modeling Kernel License (modeling kernel) [13]
- TAO CORBA and ACE Distribution (distributed communication) [14]
- Magic Software distribution (utils libs) [15]
- Studierstube distribution (immersive interaction framework) [16]
- Opentracker distribution (unified tracking system interface) [17]
- Xerces distribution (XML Parser) [18]
- MS Speech SDK (Speech I/O) [19]
- Spacemouse drivers (four view support) [4]

Please see Annex A for references to all described hard- and software.

3 DVD Content

The content on the DVD (D17) is presented in more detail. The main directory contains a general README file and three directories.

- Docs
- SketchAR
- Stb

DOCS:
In the "Docs" directory the user finds documentation on SketchAR such as this handbook as well as the SketchAR Technical Report.

STB:
In the "Stb" directory the user finds all supporting software (in general runtime DLLs) that does not have to be installed and will run from this directory, once SketchAR is started. The only exception here is TGS Open Inventor which has to be downloaded and installed for the machine where SketchAR will run and the Microsoft Speech SDK, if a user wants to use Speech I/O functionality in SketchAR.

SKETCHAR:
In the "SketchAR" directory the user will find all necessary files to execute SketchAR as well as the binary itself in decompressed form.
Batch files have been created as well as sample configurations for the different setup types, as there are: Passive Stereo Back-Projection, Active Stereo Table Projection and Desktop usage as well as Augmented Reality usage.
More information is available in the README files in each directory.

4 SketchAR Hardware Setup

In this chapter we present the SketchAR hardware and software setup. We describe the rendering systems, tracking systems and input devices. Figure 1 shows a schematic diagram of our sample setup with an active stereo display and optical tracking system.

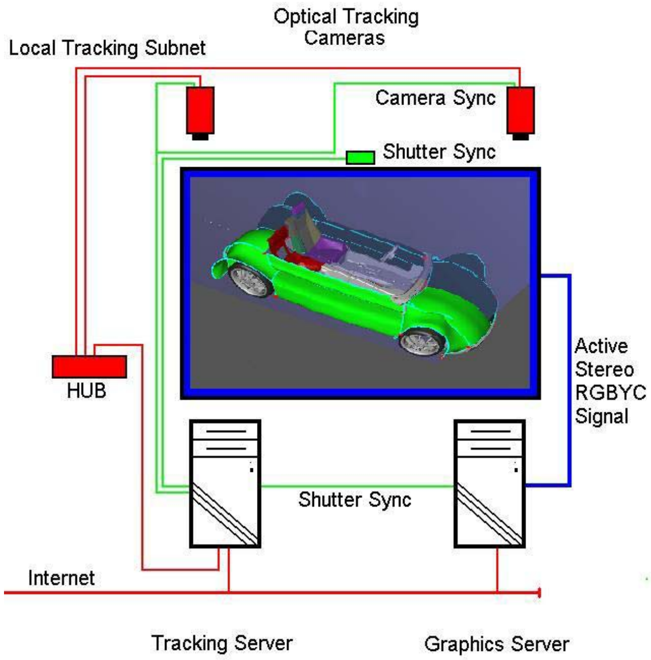


Figure 1: Hardware Setup Overview

4.1 Rendering Systems

Rendering in SketchAR can be done in a number of scenarios as there are the back-projection display, the virtual table or the augmented reality setup allowing to design on a physical mock-up of a car.

4.1.1 Stereovision (active / passive stereo)

Stereovision means that scenes created with immersive SketchAR applications will have to be rendered simultaneously for the left and right eye of a user and then be displayed on a screen, back-projection system or an HMD.

This poses additional challenges to system hardware, such as graphic accelerators, projectors and HMDs, which need to be able to support it.

Graphics boards like the 3D Labs Wildcat 4 or ATI Fire GL powered by Radeon 8800 GPU are able to provide the required output for active stereo vision by supporting the necessary update frequencies around 120Hz or passive stereo vision requiring two separate independent graphic outputs.

Active Stereo Displays:
In this case frames for right and left eye are multiplexed on one output port of the graphics board. This requires the board and the display to support high refresh frequencies which should be around 120Hz , so each eye will be able to visualize its content with 60 Hz. Generally active stereo displays require users to wear shutter glasses, because they have to actively switch between left and right frames. The display types may be monitors or projectors.

Passive Stereo Displays:
Here graphics boards will render left and right frames in parallel, thus in general sending their output to two regular mono projectors, which will then overlay their projection images as to provide a stereo view, using pol-filters in front of their objectives and requiring the user to use pol-filter glasses as well.

4.1.2 Virtual Reality Setup

For styling, the output device should provide high quality images, presence in the virtual workspace, and immersion. We decided to use a semi-immersive, table-like display with a diagonal of 1.7 meters, which allows creating e.g. parts of a car body in scale by appropriate hand gestures and arm movements.
In stereoscopic mode the user wears a tracked pair of shutter glasses, and the scene is rendered according to the user's point of view. In this way the virtual objects appear floating in the space above the table (Figure 2).

A second scenario uses an upright projection wall to display the picture. In this case the tracked artefacts are placed on a table and the user operates with the pen in front of the wall. As an advantage to the immersive table this setup is portable. The disadvantage is that the tracked artefacts cannot be put somewhere conveniently. Therefore a portable table-like stereo display would be the best solution. Figure 3 shows the setup at the review in Brussels 2003.

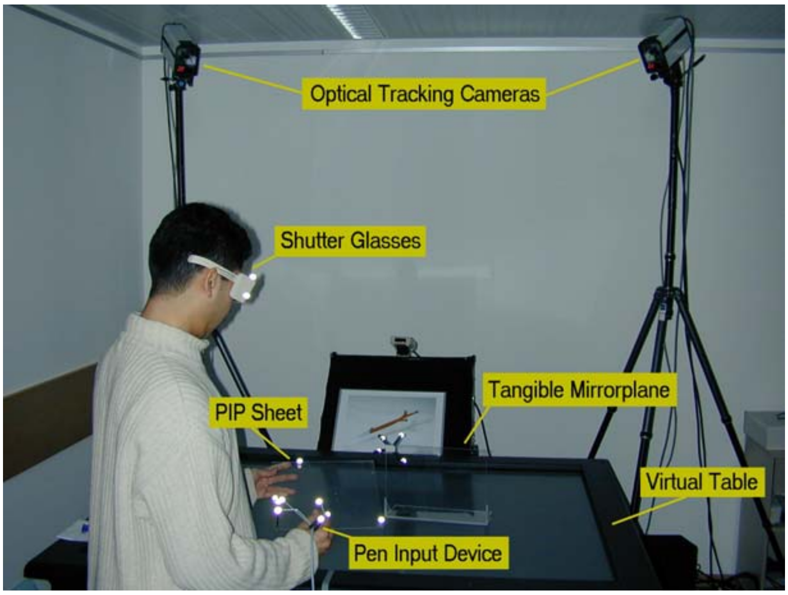


Figure 2: VR- Setup, active stereo scenario

Figure 3: VR- Setup, passive stereo scenario

4.1.3 Augmented Reality Setup

Besides sketching in virtual reality SketchAR also supports sketching in mixed reality. For this purpose the user wears a video or optical see-through head mounted display. The video HMD is equipped with two cameras at the position of the users' eyes. They capture the real environment in front of the user. The camera picture is then mixed with the virtual image, so the virtual elements appear embedded in the real world. The optical HMD has semi-transparent glasses on which the augmented content is projected so the user sees both, the virtual parts and the real scene. As demonstration of this technology we use a small, tracked, physical model of a car. The user can then augment the physical model with virtual elements, for example drawing a new roof. This scenario can for example be used for design reviews on physical mock-ups. In this way design changes are recorded in a digital way and the created CAD geometries can be merged with the virtual model the physical mock-up was created from.

Figure 4: AR- Setup

Figure 4 shows a “fake image” to render the effect obvious: An outside observer sees both: The user with the HMD plus the physical car with the virtual overlay.

4.2 Tracking System

Optical tracking systems use a variety of detectors, from ordinary video cameras to LEDs, to detect either ambient light or light emitted under control of the position tracker. Infrared light is often used to prevent interferences with other activities.
Main advantages of optical tracking systems are their high availability, large area tracking capacity, their high accuracy and their immunity against magnetic interferences.

Their weaknesses are the need for a clear line of sight, light source interferences and their need for processing power. Also they are more expensive than other tracking solutions.

ART – Advanced Real-Time Tracking:

The ART [22] optical tracking system is composed of two or more (theoretically extendable to N) CCD infrared tracking cameras, which contain Linux Embedded PC systems performing a two step calculation on marker recognition and position calculation.

The body to be tracked (e.g. a human body or an object) is equipped with markers that are often covered with retro-reflective surfaces. Tracking cameras, scanning a certain volume, recognize these markers. The data of the tracking cameras are handed over to a central PC for final processing. The result of each measurement are coordinates that describe the position of the markers, and hence the position of the body carrying the markers.

The results are then broadcasted onto a local tracking network (Ethernet) to which a tracking PC is attached, which will perform the final calculation of object positions merging data from all attached tracking cameras.

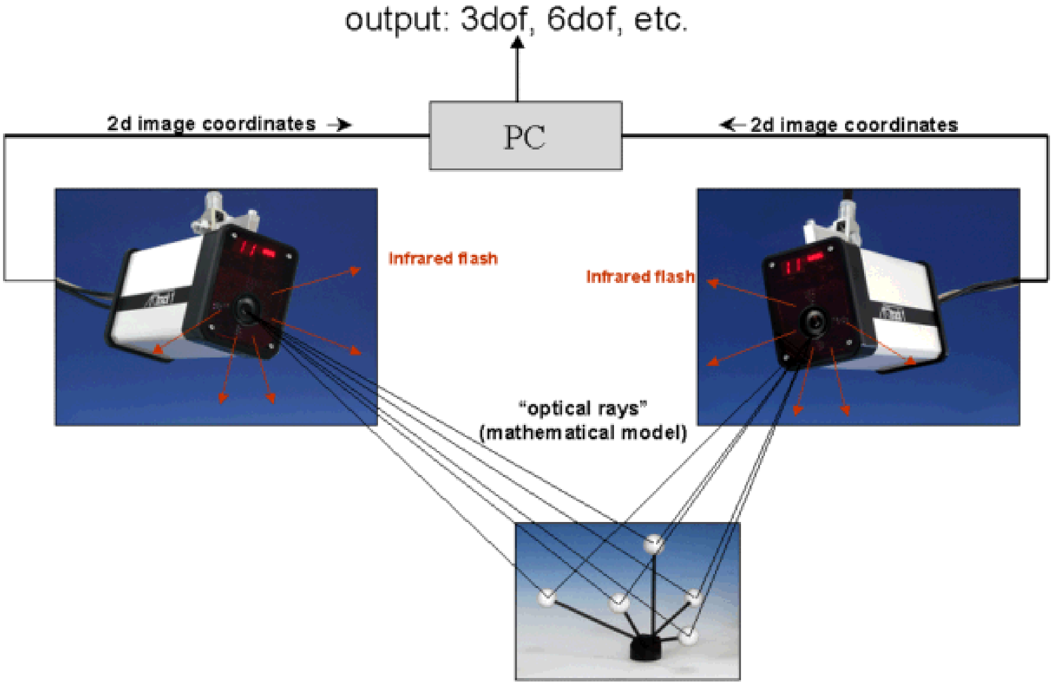


Figure 5: Optical Tracking - ART Tracking System with ARTtrack1 cameras

The system is highly stackable so tracking volumes only depend on the number of cameras used. The final computed data by tracking PCs is broadcasted onto the network for further processing by one or more applications.

Technical Data:

Tracking System	Range	Accuracy	Latency /Update Rate	Max Bodies	Cost	Remarks
ARTtrack1 **http://www.ar-tracking.de/**	300cm x 300cm (using 4 cameras) range is only limited by the amount of cameras used (max supported at the moment 256)	Position 0.4mm Orientation 0.12 degrees Standard deviation Position 0.06mm Standard Deviation Orientation 0.03 degrees	Latency: no details Update rate: Max 60Hz	Up to 20 target bodies (10 in accurate mode)	EUR 30000 (including 2 cameras and one DTrack server machine)	The camera CCD chip is 658x496 pixel Cameras are available for different Field of Views: horizontal up to 60 degrees, vertical up to 45 degrees Camera weight is 2,5 KG

Range of a single camera up to 10 meters depending on marker size

Pros:

- Un-tethered tracking system
- Many tracked bodies possible
- Unlimited extension of tracked area using more cameras (max 256)

Cons:

- Line of sight occlusion problem
- Expensive compared to other systems

Conclusion:

ART offers a tracking system that is not susceptible to electro-magnetic interferences, However there is an inherent line of sight problem, which can be solved by using more cameras. Nevertheless certain scenarios require a user to go into a physical mockup and in such places this technology will not work as well as others. Very good about optical tracking systems is the fact, that interaction devices are un-tethered and quite a large tracking area can in principle be achieved by adding more cameras.

4.3 Interaction Devices

Different kind of tracked objects can be used as input devices (Figure 6):

- **Pair of glasses**
  According to the setup, the glasses are shutter glasses, pole filter glasses or a head mounted display. These devices are tracked so that the virtual picture can be calculated according to the head position / user point of view.

- **Pen**
  A pen-like device with 3 buttons is used as main input device (Cyberstilo).

- **PIP-sheet (Personal Interaction Panel)**
  A transparent Plexiglas panel on which the application menu is projected. The menu on the sheet is operated with the pen.

- **Navigator axis (L shape, cube shape)**
  The navigator axis is used to navigate the model in 3DOF. You can choose between a device in the shape of an “L” and a cube.

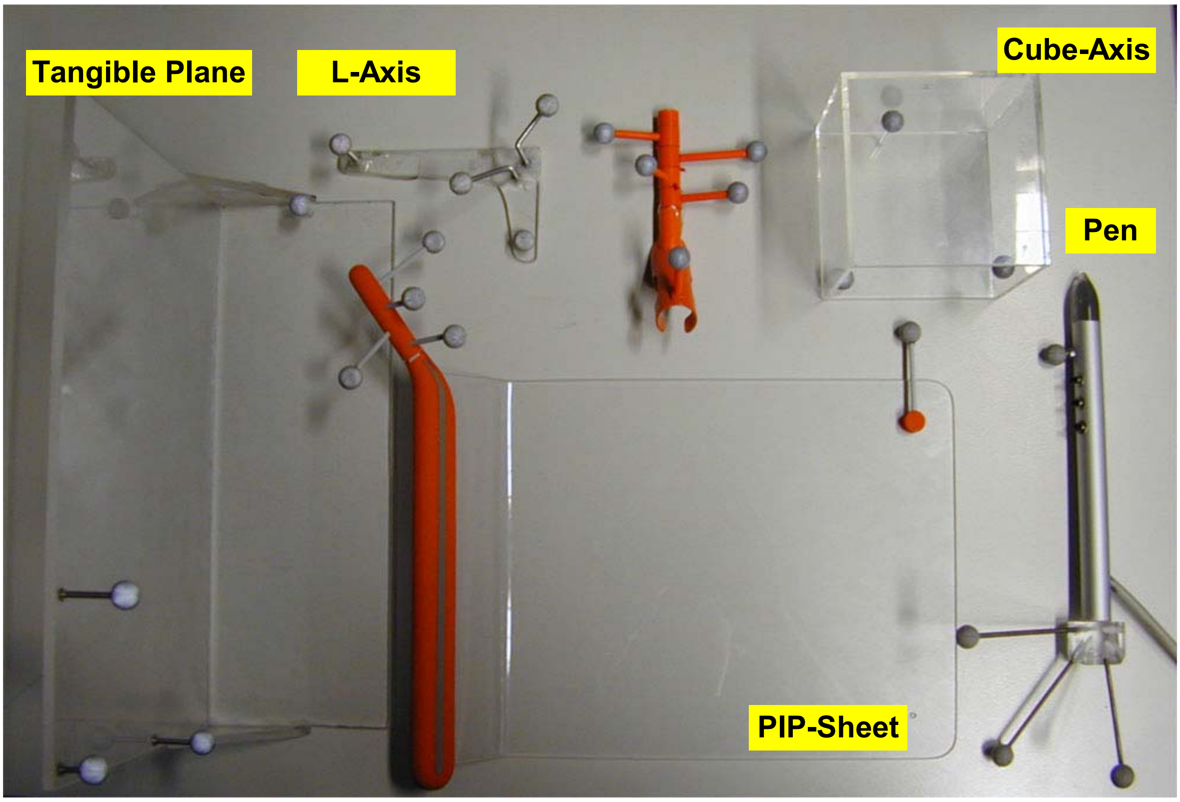


Figure 6: Interaction Devices

- **Tangible planes (mirror plane/work plane)**
  These tracked artifacts are used by the mirror and work plane function. Both functions operate on a virtual plane, which are moved according to the artifacts.

- **Tape fingers**
  These devices are only used for the virtual taping function. That function operates with two input devices.

- **SpaceMouse**
  The SpaceMouse is used in four-view mode to control the projection plane in analogy to a sheet of paper which can be panned, rotated and zoomed.

5 Software Setup

This chapter shows how to configure the SketchAR software by showing how to edit the two SketchAR configuration files. Three setups are discussed in this chapter: the active stereo-, the passive stereo- and the desktop configuration. You find sample configuration files in Annex B.

5.1 SketchAR Software Architecture

SketchAR consists of three layers (Figure 7). In the first layer the visualisation takes place. Operations related to the visualization library (OpenInventor) are implemented there. The main layer contains the actual intelligence of the functions. Here the user input is processed to create and modify geometries. The lower layer is the connection to the CAD library (ACIS Modeling Kernel).

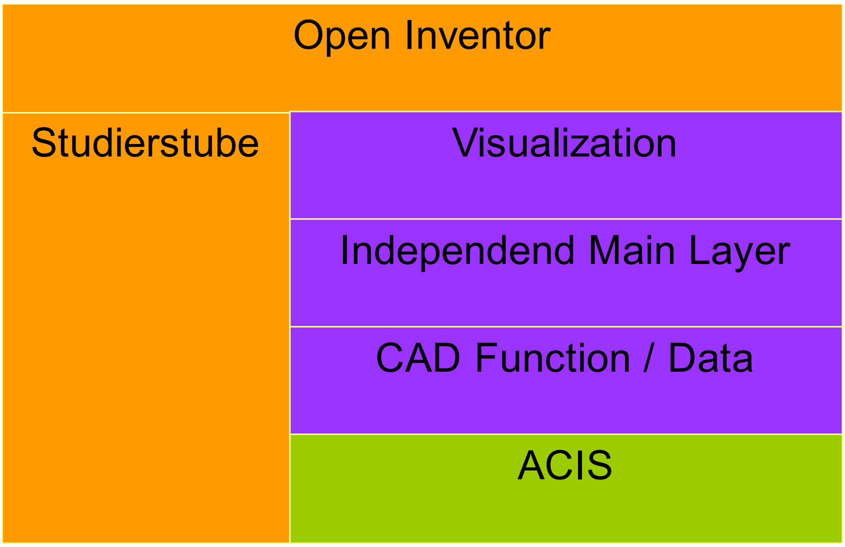


Figure 7: SketchAR Architecture

Due to the strict separation of the layers the visualization and CAD library can be exchanged by other products with reasonable low effort.

Following an OO approach using UML diagrams we wanted to ensure that all functions fit into a comprehensive framework.

The system's conceptual key entities are:

- Users
- Shapes
- Operations

Each instance of the user class represents one user currently using the system. The system is designed to support multiple users working together at one place or spatially distributed.

Shape is a super class of all shapes being created with the system. Different types of shapes such as curves and surfaces are represented as sub-classes.

Operations represent the actions preformed to create or change a shape. For instance the creation of surfaces, or mirroring a curve with a mirror plane are operations. Note that the operations are user-specific, so each user can have activated a different operation.

To create geometries the operations follow a strict pattern regarding the communication between the layers. When the user starts an operation the operation is initialized. Then while operating a preview of the operation result is displayed.
To achieve high speed preview the CAD kernel is not invoked at that time. After the user finished the operation the operation data is processed and the CAD kernel is called to create the accurate geometries. Finally the preview is exchanged by a visualization of the CAD kernel result.

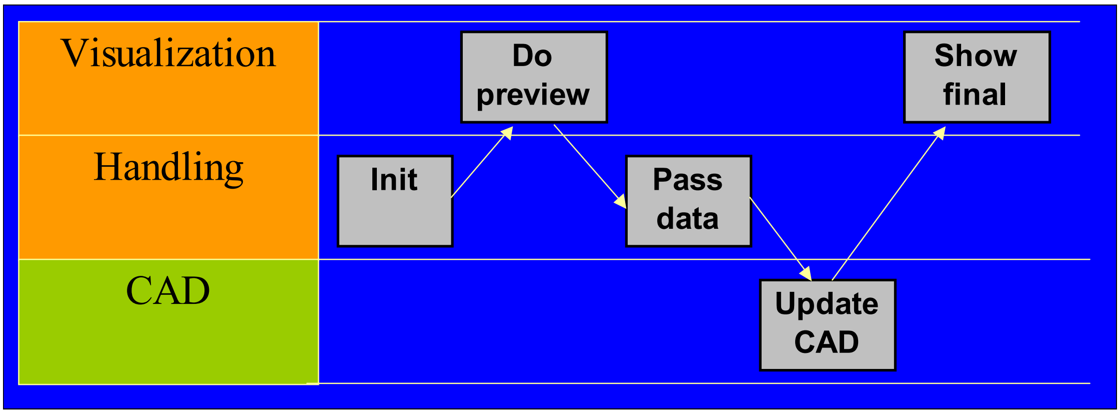


Figure 8: Abstract execution flow of operations

5.2 XML Configuration File

Here an XML-Fragment from the *SketchARActiveStereo.xml* is shown to explain the XML sections:

```
<StbSink station="7">
        <Merge>
            <MergeDefault>

                <!-- Pen -->
                    <EventVirtualTransform rotation="0 1 0 1.57"
                    translation="0.053 0.261 -0.058">
                    <EventTransform scale="0.001 0.001 0.001"
                    translation="-0.055 -0.515 -0.01">
                        <ARTDataTrackerSource number="6"/>
                    </EventTransform>
                </EventVirtualTransform>
            </MergeDefault>
            <MergeButton>
                <NetworkSource number="2" multicast-
                address="224.100.200.101" port="6667"/>
            </MergeButton>
```

```
        </Merge>
    </StbSink>
<StbSink station="7">
```

A node like this, transfers and eventually manipulates tracking information on a tracked artefact from a specific tracking system into a SketchAR data structure for this artefact. It has the following attributes:

- Station integer starting from 0 giving the station number to use in Stb
- Event on|off whether this station should emit events or not, default is off

<Merge>
A Merge node is an EventGenerator node that listens to several other EventGenerator nodes and merges data from these. It has several inputs that are marked with different wrapper tags. It stores an internal state and updates it with parts of the data depending on the type of input. Then it generates an event of its own. Timestamps are treated in a special way. If no child node is connected to the MergeTime input, then the timestamp of the new event equals the timestamp of the last received event. Otherwise it behaves like other inputs.
MergeDefault any data that is not set by a child of another wrapper element is used.

<ARTDataTrackerSource number="8"/>

The **ARTDataTrackerSource** node is a simple EventGenerator that inputs the data from the ART Data Tracker. The attribute number the body number of the specific source, starting with 0.

<EventVirtualTransform rotation="0 1 0 1.57" translation="0.053 0.261 -0.058">
<EventTransform scale="0.001 0.001 0.001">

With this tags you can calibrate the virtual objects to fit with there physical representation (tracked artifacts). In the following a calibration of the pen and the PIP is shown exemplarily. All the other artifacts have to be calibrated in the same way.

5.2.1 Calibrating the pen

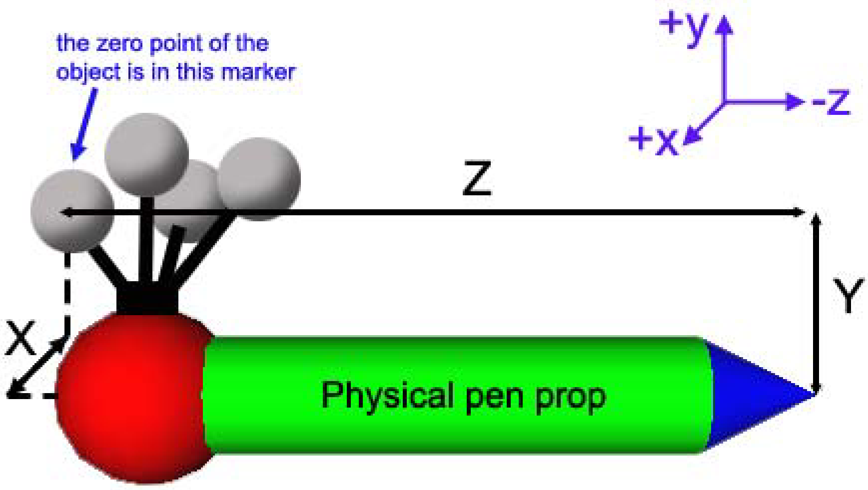


Figure 9: Pen Calibration

- The point of rotation of the pen artifact in SKetchAR is the tip (the tip of the blue cone in the picture above).
- If the orientation at calibration was different from the one suggested above in the initial Studierstube artifact arrangement picture, let the rotational offset be **(p q r s)**. Let the position offset between the zero marker and the tip of the pen be **(x,y,z)**. We need to shift the coordinate system first from the zero-marker to the tip using a translation. We translate the coordinate system within the pen's **LOCAL** coordinate system (**<EventVirtualTransformation translation>**), then we rotate the pen (**<EventVirtualTransformation rotation>**) into the desired SketchAR initial orientation. We need to perform the following sequence for the transformation:
- <EventVirtualTransform translation="-x -y -z" rotation="-p -q -r s">
- <NetworkSource number="1" multicast-address="224.100.200.101" port="12346" DEF="pen0"/>
- </EventVirtualTransform>
- You can add **<EventTransform>** tags if necessary for the post fine tuning.

5.2.2 Calibrating the PIP

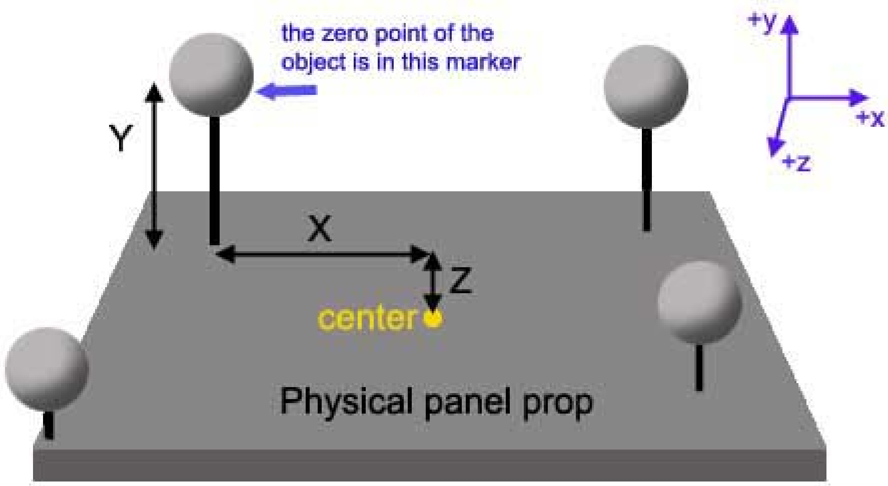


Figure 10: PIP Calibration

- The point of rotation of the PIP is the centre point of the panel.
- If the orientation at calibration was different from the one suggested above in the initial SketchAR artifact arrangement picture, let the rotational offset be **(p q r s)**. Let the position offset between the zero-marker and the centre of the panel be **(x,y,z)**. We need to shift the coordinate system first from the marker to the centre of rotation. We translate the coordinate system within the panel's **LOCAL** coordinate system (**<EventVirtualTransformation translation>**), then we rotate the panel (**<EventVirtualTransformation rotation>**) into the desired SketchAR initial orientation. We need the following script for the transformation:

  <EventVirtualTransform rotation="-p -q -r s" translation="-x -y -z">
  <NetworkSource number="2" multicast-address="224.100.200.101" port="12346" DEF="pip0"/>
  </EventVirtualTransform>

- You can add **<EventTransform>** tags if necessary for the post fine tuning.

5.2.3 Speech Recognition

An additional part of the XML-configuration is the configuration of Speech Recognition.

```
<SpeechRecoConfig language="english">
            <CommandSet id="TapeD">
                  <Command id="1" name="line" weight="1.0" />
                  <Command id="2" name="stop" weight="1.0" />
                  <Command id="3" name="red" weight="1.0" />
                  <Command id="4" name="green" weight="1.0" />
                  <!-- Command id="5" name="blue" weight="0.5" / -->
                  <Command id="6" name="black" weight="1.0" />
                  <Command id="7" name="white" weight="1.0" />
                  <Command id="8" name="yellow" weight="1.0" />
                  <Command id="9" name="undo operation" weight="1.0" />
                  <Command id="10" name="redo operation" weight="1.0" />
                  <!-- Command id="11" name="damn"_u119 ?eight="1.0" / -->
                  <Command id="12" name="open menu" weight="1.0" />
                  <Command id="13" name="go" weight="1.0" />
                  <!-- Command id="14" name="shaaesa" weight="1.0" / -->
                  <Command id="15" name="speech activate" weight="1.0" />
                  <Command id="16" name="speech deactivate" weight="1.0" />
                  <Command id="17" name="connect joe" weight="1.0" />
                  <Command id="18" name="connect jack" weight="1.0" />
                  <Command id="19" name="network disconnect" weight="1.0"/>
                  <Command id="20" name="userlist" weight="1.0" />
            </CommandSet>
</SpeechRecoConfig>
```

Explanation of speech specific tags:

- <SpeechRecoConfig> select the speech of the SR component.
- <CommandSet> define a set of speech command.
- <Command> define a single speech command.
- <SpeechRecoSource> build a speech event firing source node with a specific command set

5.3 User Kit Configuration

The userKit is a config file in OpenInventor format. In this file you are able to configure Input devices of all users (pen & PIP) and set the configuration of rendering output (like stereo, Camera model, Video background).

The Devices are the same in all our configurations (active-, passive stereo and desktop). Only the DisplayKit settings vary from configuration to configuration.

5.3.1 Devices

All tangible user devices have a virtual match which can be configured in the following "UserKit.iv" file:

```
UserKit {
  # userID 8 in Desktop and 10 in Stereo Mode
  userID 8
  pen PenKit{
    station 7
    geometry File {name "./graphix/smartPen3.iv"}
  }
  pip PipKit{
    station 1
    pipSize 0.3 0.2 0.01
    sheetAreaUpperLeft  0.05 0.05
    sheetAreaLowerRight 0.95 0.95
    offset Transform {translation 0 0 0
                rotation 1 0 0 -1.57
    }
    geometry File {name "DefaultPip.iv"}
  }
```

5.3.2 Display

The DisplayKit settings vary according to the rendering configuration that the user chooses, be it a desktop configuration a passive stereo or active stereo.

5.3.2.1 Desktop

For autostereo displays, the desktop configuration file is used to configure SketchAR:

```
display DisplayKit {
     stereoCameraKit  File { name "defaultCameraKit.iv"}
     station 2
          headlight TRUE
     headlightIntensity 1.0
     backgroundColor 0 0 0
                 transparencyType SORTED_OBJECT_BLEND
  }
```

The desktop configuration uses a Studierstube- Viewer- Widget to render the scene to the desktop. Additionally a 2D- PIP is offered, which can be used with the mouse.

5.3.2.2 Active Stereo

The active stereo configigiration is meant for devices that support active stereo, such as BARCO Virtual Reality Tables:

```
display DisplayKit {
        station 2
    stereoCameraKit  File { name "VTStereoKit.iv"}
        display FieldSequentialDisplayMode {stereoMode QUAD_BUFFER}
        cameraControl TrackedViewpointControlMode {}
    headlight TRUE
    headlightIntensity 1.0
        backgroundColor 0.2 0.3 0.4
        xoffset 0
    yoffset 0
#    Size of the viewer-window (in pixels)
        width 1024
        height 768
        transparencyType SORTED_OBJECT_BLEND
  }
```

5.3.2.3 Passive Stereo

The passive stereo setup can be used for passive stereo back-projection systems using pol filters for both beamers:

```
display DisplayKit {
        station 2
    stereoCameraKit  File { name "VTStereoKit.iv"}
    display DualChannelDisplayMode {splitMode VERTICAL}
        cameraControl TrackedViewpointControlMode {}
    headlight TRUE
    headlightIntensity 1.0
        backgroundColor 0.2 0.3 0.4
        xoffset 0
    yoffset 0
#    Size of the viewer-window (in pixels)
        width 2048
        height 768
        transparencyType SORTED_OBJECT_BLEND
   }
```

6 Multimodal Input Methods

This chapter describes all existing interaction methods, which range from pen input to draw in 3D as well as in 2D table-top projection to short-cut gestures for editing commands to Speech I/O and two alternative menu types to choose functionality from.

In contrast to much work done in this area, SketchAR not only features a few input methods but tries to combine different forms of interaction in a seamless and user friendly way.

6.1 Pen Interaction

The pen is the most important input device. It is used for:

- Sketching, geometry creation in space
- Menu interaction
- Performing gestures
- Picking and Dragging
- Editing

Figure 11: Cyberstilo

The wireless CyberStilo has three buttons:

- The first button is the one closest to the tip of the pen. It is for interacting with widgets on the PIP and starting line and surface creation operations for example.
- The second button (in the middle) is used for certain two-state operations, which require an explicit finishing action like implicit spline extrusion for example.
- The third button is used to activate the pie menu.

6.2 Tracked Artifact

Tracked artifacts are the real world representation of virtual objects. One can move the virtual objects, e.g. the mirror-plane or the car by moving around the corresponding tracked artifacts in the tracked space.

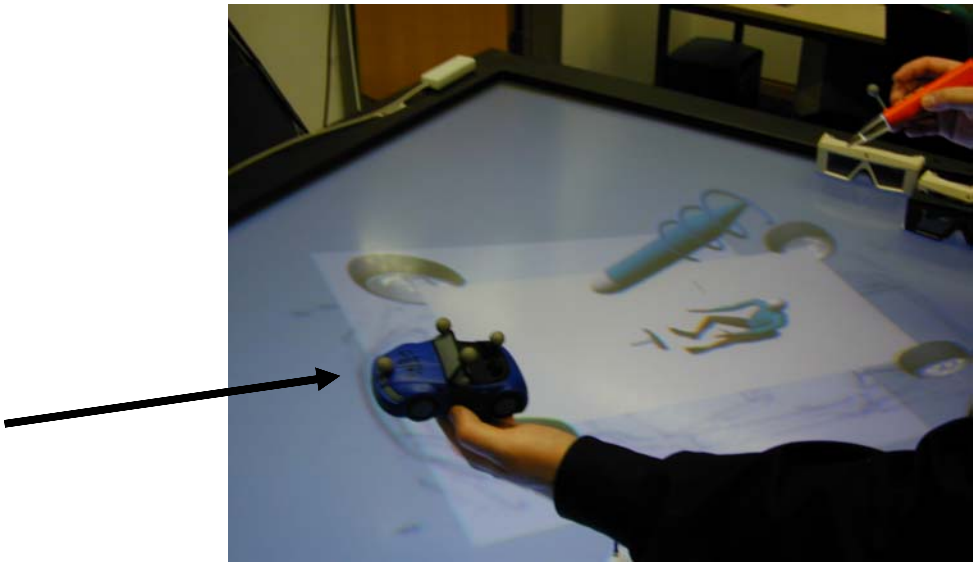


Figure 12: Tracked Model Artifact

6.3 PIP – Personal Interaction Panel

The PIP (Personal Interaction Panel) sheet is a virtual menu, from which the user is able to choose SketchAR functionality from. It has its match in the real world in form of a tracked Plexiglas artifact. The PIP-sheet is operated by the Pen (Cyberstilo). As a result of the second round of usability tests (D11) the PIP has consequently been supplemented by a pie menu methodology, which is described further below. However it remains active for users who prefer it.

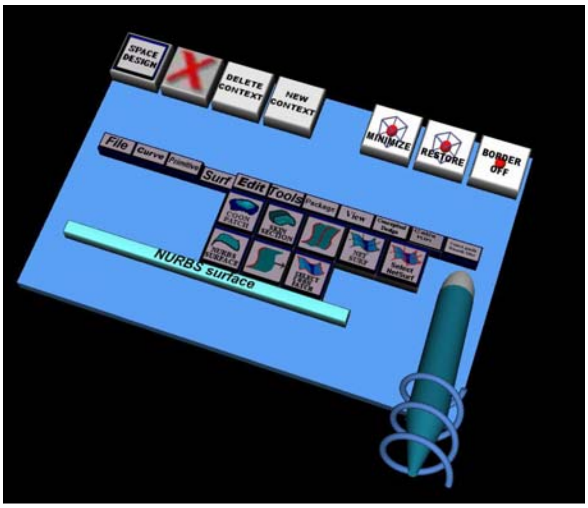


Figure 13: PIP & Pen

6.4 Pie Menu / Ring Menu

The ultimate aim of any good user interface design for immersive environments is to reduce the number of interaction devices to as few as necessary. For this reason we have developed and implemented dynamically configurable pie/ring menus to reduce interaction with the PIP and allow selection of operations with the pen only.

Pie/ring menus operate as follows: Each section of the menu may be an operation or another pie/ring sub-menu. The user selects a specific section by implicitly moving from the center of the pie/ring menu to that section. If the section is another pie/ring sub-menu this menu will appear subsequently, otherwise an operation is triggered.

Pie/ring menus are implemented in two flavors:

- Static pie/ring menus: They display a texture reflecting the pie section's operation or sub-menu
- Animated pie/ring menus: They display an animated OpenInventor file reflecting the pie section's operation outcome.

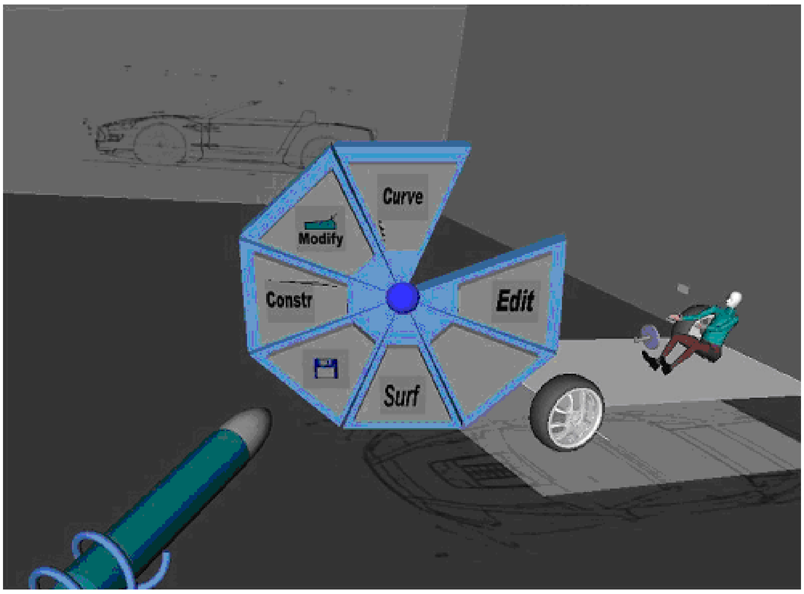


Figure 14: Pie Menu

<u>Animated Pie / Ring Menus:</u>

To render pie menus even less obtrusive and more self explaining, animated pie menus have been introduced. This basically means that in the configuration file of a pie menu a user can specify an open inventor file representing the visual outcome of an operation. Note that the shapes displayed in the pie menu were actually created with SketchAR. When moving the 3D into such a piece of the pie, the 3D iconic model starts to spin.

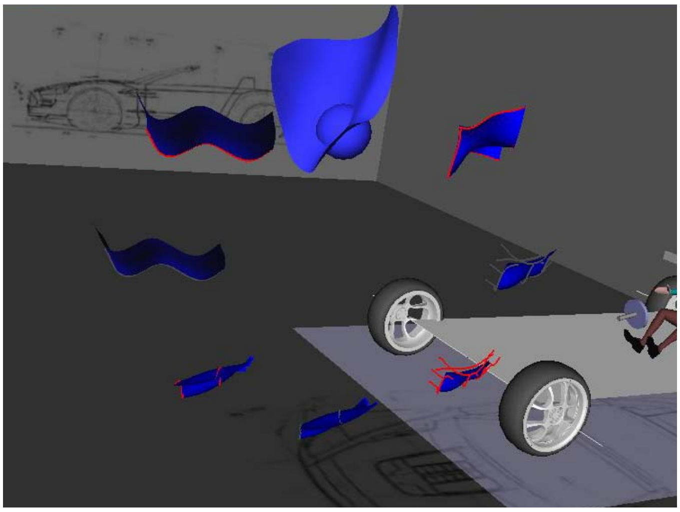


Figure 15: Pie sub-menu "SURF" animated pie menu

Context-Sensitive Pie / Ring Menus:

Extending our pie menu implementation, context-sensitive pie menus have been implemented. When the 3D pen is close to an activated projection plane, the context-sensitive pie menu allows translation, rotation or free positioning of the plane. In SketchAR the pie menu is activated by pressing the third button of the Cyberstilo. However, if the projection plane is activated and the pen is close to it and the user presses the third button, the user will see a context menu allowing him to perform a translation, rotation or free movement of the projection plane along dragger axis or in space. Support for this feature was implemented in a class named "SoArtifactPlaneWidget".

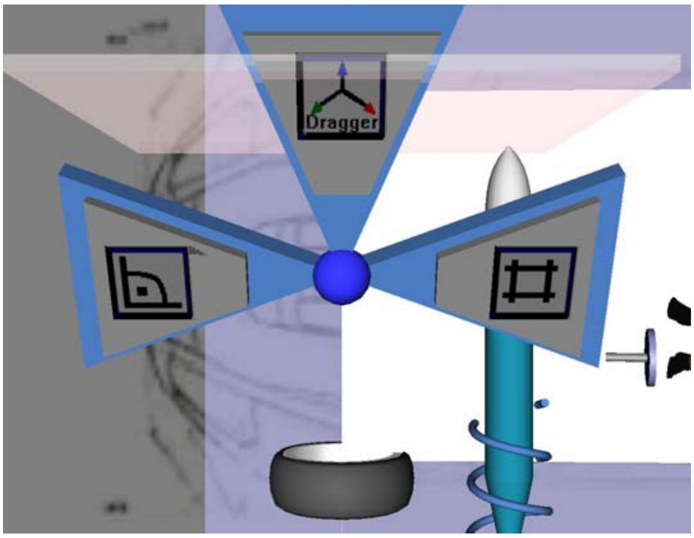


Figure 16: Context-sensitive pie menu

6.5 Speech Recognition / Synthesis

The Microsoft Speech SDK [51] is freely distributable and represents an interesting choice, because it enables applications to respond to spoken commands and includes a text-to-speech engine in its distribution. In this way, commands will not only be recognized but the user may be informed about application status and operation results by synthesized speech which helps him not to become distracted from its original task at hand by obtrusive status displays or similar information conveyers. In addition the fact, that Microsoft Speech SDK does not come with a dictionary and grammar, but instead relies on the developer to specify a grammar for his specific purpose, allows for not too much overhead in the application if the main goal is simply being able to input speech commands and returning synthesized speech output.

Speech is to be used to support the following functionality:

- Speech Commands in Virtual Taping
- Implementation of multiple UNDO/REDO
- Color selection
- Pie menu activation and operation choice
- Activate and deactivate speech

For available speech commands see annex B.

6.6 Implicit Gesture Recognition

As direct consequence of the second round of usability tests, we have observed that users would perform gestures much faster than stroke input. Subsequently we implemented an implicit approach that analyses the user's movement for potential gestures. As a side effect of that implementation, the third button originally used to trigger gesture recognition could now be used to activate the pie menus.

To offer implicit gesture support, the Studierstube event-loop had to be intercepted, so gesture recognition would be active with any operation anytime and react to gestures when it made sense.

The decision when to start and stop the Cyberstilo positional information capture is done based on the average speed of the movement of the pen. A gesture is in general initiated with a rapid movement and ends with a total halt of the pen. Therefore automatic capture of pen positions is triggered when exceeding a certain threshold speed and stopped when going below another threshold speed. The resulting list of pen positions is then sent to the 3D extended CALI Gesture recognition engine, which analyzes the sequence and outputs the gesture found.

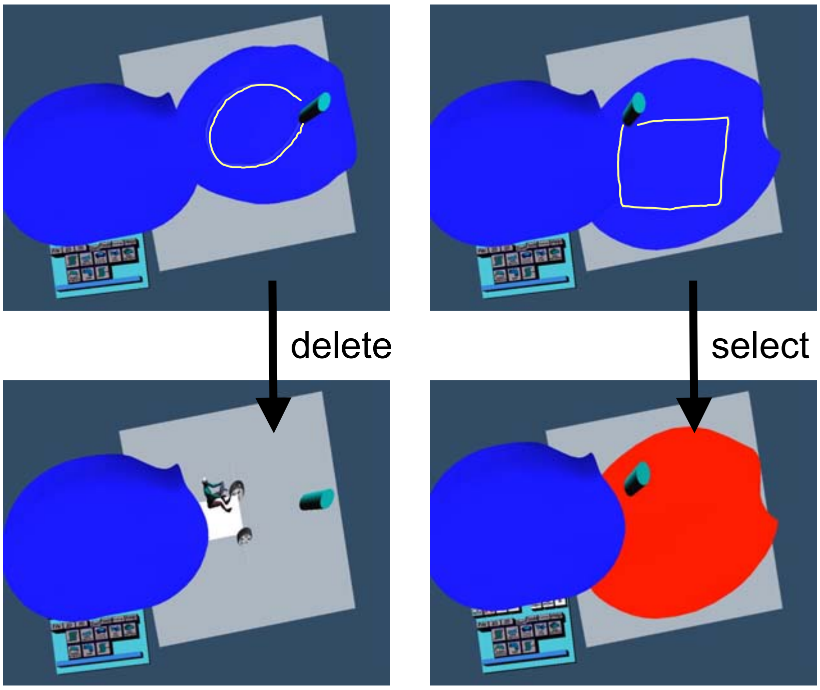


Figure 17: Gesture based Input

6.7 Draggers & Sliders

In some cases the 6 DOF of 3D input devices provide too much freedom to the user. 3D Widgets have proven useful to enable 3D interaction with 2D input devices. Following the idea of 3D widgets, we have extended OpenInventor by 3D event-enabled 3D widgets that map 3D events to lower degrees of freedom.

Our dragger can be moved arbitrarily in space by picking the centre sphere or it can be moved along one axis by just picking the arrow at the tip of the axis.
The dragger handles 3D events from the pen and maps them to the according axis.
A rotation can be performed by picking the rotator of one axis and by using the pen just like a screwdriver (rotating it around its main axis). Only the rotation around the main axis is mapped. The other rotations are not considered. The rotation will be performed on the dragger and the related object.

Our slider to adjust parameters can be adjusted continuously or incrementally by using the arrows at both ends of the slider.
When using the slider to adjust the parameter, the slider maps the 3D events of the pen to the axis. The arrows at both ends of the slider body increment or decrement the current value by a predefined step.

Draggers and sliders are widgets, which can be placed in free space. They can be used to manipulate for example control points or parameters fast and intuitively.

They are especially useful in package creation, where the user can control package parameter like overall car dimensions, chassis length and width, dimensions or encumbrances and other package constraints.

In addition they are also used to position mirror- and work planes accurately in 3D space.

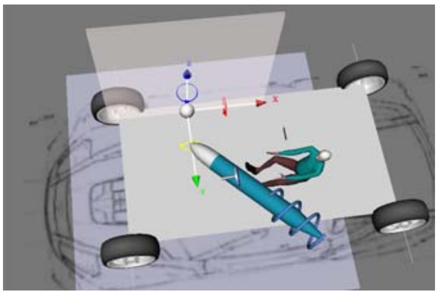


Figure 18: Dragger

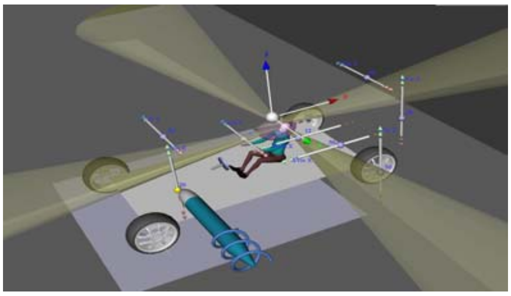


Figure 19: Slider

6.8 3D Picking & Snapping

Picking and Snapping is a feature used throughout most of the available geometric operations to select or draw next to existing objects.

3D Picking:

To select and move objects in free space they can be picked. In contrast to other VR-CAD systems, SketchAR did not simply use ray picking for selecting objects because it is an indirect, distant interaction. Instead a fast 3D picking on the precise topological element's geometry was implemented using a two step procedure which first checks for bounding boxes and then calculates the nearest distance of the topological elements' geometry to the current pen position.

3D Snapping:

When operating in free space it is difficult to sketch a new surface close to an existing one. But obviously it is crucial for a car model that all parts match without any gaps. To avoid those gaps we extended our 3D picking approach toward snapping. Snapping is performed by successively doing 3D pick actions. When snapping is active, the virtual 3D pen snaps automatically to faces, edges or vertices in its proximity. The user can define its pick / snap radius in 3D. A corresponding visual feed-back is generated on the fly.

Intelligent 3D Picking and Snapping:

We have extended our picking and snapping algorithm to a more intelligent behaviour that prioritizes lower dimensional, topological elements, when they are inside the picking and snapping radius of the tip of the pen.

Let a curve be on a surface. A regular picking algorithm would in general return the surface object since most of the times it is nearer to the tip of the pen than the curve. On the other hand most of the times the user does not want to pick the surface, but the curve. The problem is, that a curve is more difficult to pick than a surface. Therefore our algorithm prioritizes lower dimensional, topological elements when picking and snapping according to the following order so the user picks the curve and not the surface:

- Vertices
- Curves (Edges)
- Surfaces (Faces)

6.9 Virtual Paper Metaphor

We have implemented a virtual paper metaphor using the SpaceMouse. In a four-view the position, size and orientation of the background image (the model), can be controlled with the SpaceMouse in the same manner as paper can be rotated on a table-top.

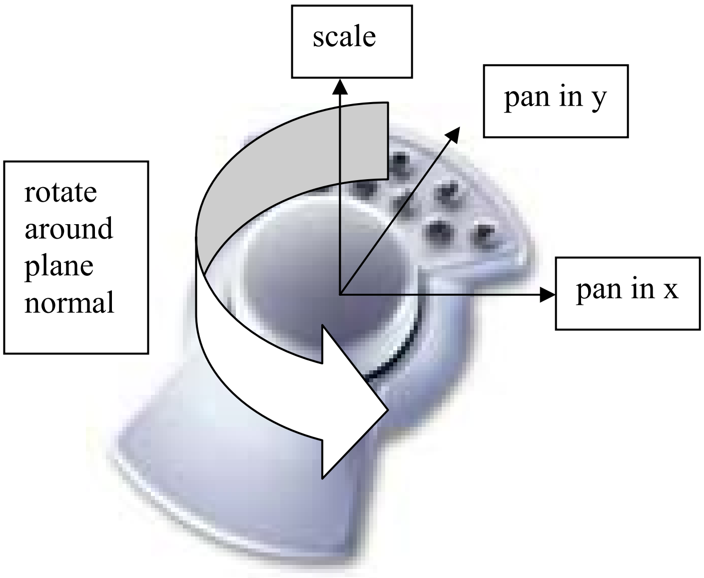


Figure 20: SpaceMouse supporting the virtual paper metaphor

7 System Functionality

In the following the functionality of the SketchAR prototype is presented from a technical point-of-view.

7.1 File Operations

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
File	File ->Load /Save	File- ->Load /Save				Pen

For file I/O we are using the ACIS reader and writer. The model created within SketchAR and represented in the ACIS modeling kernel can be exported into the following formats:

- ACIS *.sat
- ProEngineer *.proE
- CATIA V5 *.model

When reading such a file the ACIS tessellation functionality is used to generate a displayable version.

Please click on the

7.2 Package Model Editing

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Wheel Adjustment	Package-> Wheels	Package-> Wheels				Pen
Dimensions Adjustment	Package-> Overall	Package-> Dimensions				Pen
Ergonomic Adjustment	Package-> Human	Package-> Ergomomic				Pen
Encumbrance Adjustment	Package-> Tech Free	Package-> Enc.				Pen
Package On/Off	Package-> On/Off					Pen

A package model defines a set of constraints, which have to be left untouched by the stylists. These constraints may be imposed by car parts, such as the engine, wheelbase or overall dimensions and generally also involve security constraints, such as size of bumpers, head clearance and visibility angles. The constraints may vary according to the car model developed (sports car, sedan, etc.).

Usually the package model is given to the stylists by the costumer or by the planning department. The package model constraints the freedom of the stylists and give hints which dimensions to respect.
Instead of importing package drawings into our system (or in addition to this), the system provides the possibility to configure a default 3D package model. Using draggers or sliders on the pip or alternatively in 3D space the package model parameters can be changed.

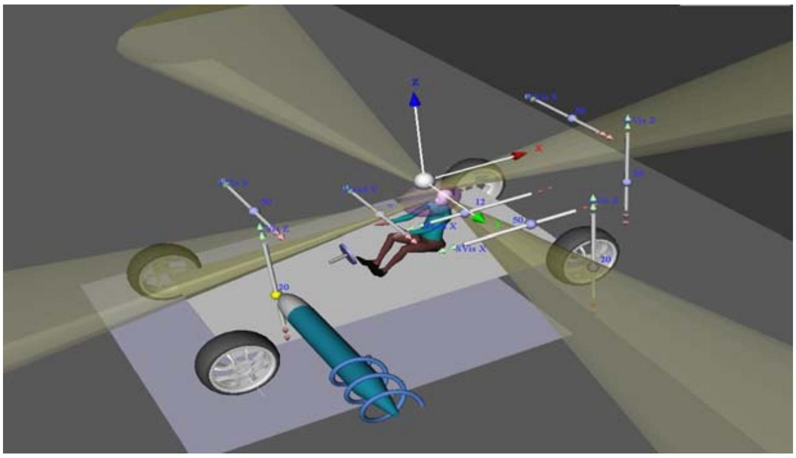


Figure 21: Package Model

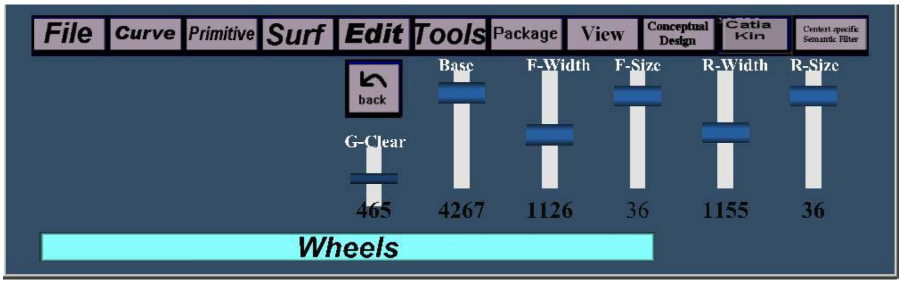


Figure 22: Package Model Constraints – Wheels

7.2.1 Package Model Parameters

In the following we show a list of configurable package parameters which can be accessed through the package menu:

- Wheels
  - Wheelbase
  - Front Axis Width
  - Front Wheel Size
  - Rear Axis Width
  - Rear Wheel Size
- Dimension
  - Front Overhang
  - Length
  - Width
  - Height
- Ergonomic
  - Dummy Position
  - Steering Wheel Position
- Encumbrance
  - Wheel envelope Size
  - Engine Encumbrance

- Head Clearance
- Front Visibility Angle
- Rear Visibility Angle
- Side Visibility Angle
- Heater Encumbrance

7.2.2 Package Model Constraint Check

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Collision Detection	Package-> Collision Detect	Package-> Collision Detect				Pen

To support monitoring of whether package constraints are being respected by the stylist, a check functionality has been implemented.

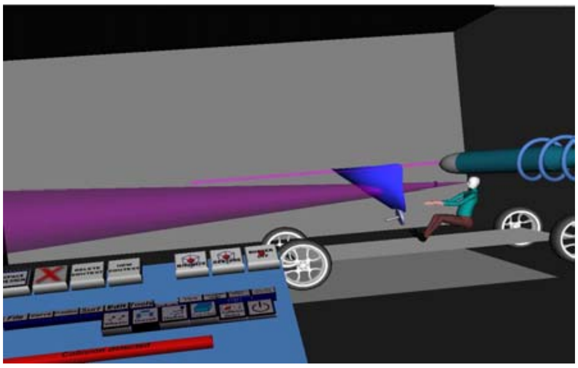


Figure 23: Package Constraint Check

The constraint checking in SketchAR uses the ACIS CAD kernel. Every shape that is created with ACIS is checked against the parameters of the package model in a post-process function, which can be triggered by the user after a geometric operation. For this reason the geometries imposed by the package are represented in ACIS. If a collision occurs, SketchAR shows the involved parts in red to signal the collision.

To activate/deactivate the *Collision Detection* use the *Collision Detect* button in the *Package* menu on the PIP sheet or in the Pie menu.

After activating the *Collision Detection* start creating geometry. Every conflict of the created geometry with the package model will be displayed.

7.3 Geometry Creation

There are two ways to create geometry in SketchAR:

- Implicitly: Create curves and surfaces in a single interaction process.
- Explicitly: Select existing curves to create surfaces.

The following section explains geometry creation in SketchAR.

7.3.1 Curve Creation

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Free Sketch	Curve ->Free Sketch	Curve ->Free Sketch				Pen
Closed Sketch	Curve ->Closed Sketch					Pen
Line	Curve ->Line					Pen
NURBS Curve	Curve ->NURBS Curve	Curve ->NURBS				Pen
Freehand Spline	Curve-> Freehand Spline	Curve-> Freehand Spline				Pen
Poly Line	Curve-> Polyline					Pen

SketchAR supports the creation of free-form curves, lines and polylines. Free-form curves are easily created by pressing the pen button and move the pen in free space. The created curve is internally converted into a spline curve.
The user can choose two kinds of free-form input:

- **Polyline:** The first draws a polyline in the preview and creates the spline curve after button release
- **NURBS-curve:** The second calculates the spline in real-time and also displays the control polygon while drawing.

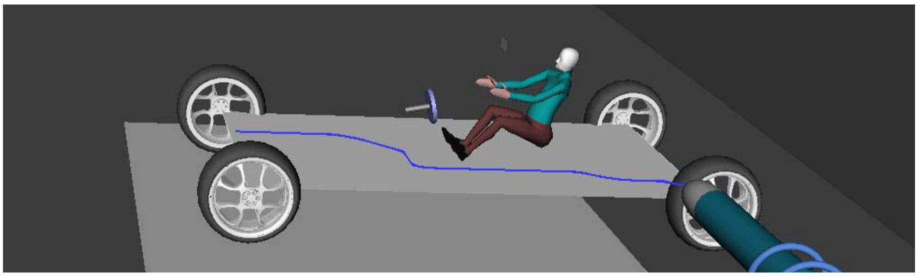


Figure 24: Curve Creation

To create curves in SketchAR select one of the *Curve*- operations pressing the according button in the *Curve* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Curve*, select the according button and release the third button. To start the *curve*- operation press and hold the first button of the pen and draw the curve. Release the first button to complete the *Curve*-operation.

7.3.2 Eraser Pen

During the styling process, the designer usually makes different sketches until the shape has the desired appearance. In traditional CAD systems and in general in 2D design environments, the user takes a rubber tool to correct his drawings or he may change the position of control points to modify a curve. Also an *undo* function is commonly used to correct errors or retry an operation.

This means that in traditional tools the user has to change modes between drawing and deleting. The idea of the new interaction metaphor "eraser pen" is to combine the creation and deletion process in just one tool. Moving "forward" the user creates a stroke by just reversing the direction he is deleting the stroke partially, reverting again, automatically bring him back into the drawing mode (Figure 25). So drawing and deleting is seamlessly integrated. See also tape drawing where a similar approach has been taken.

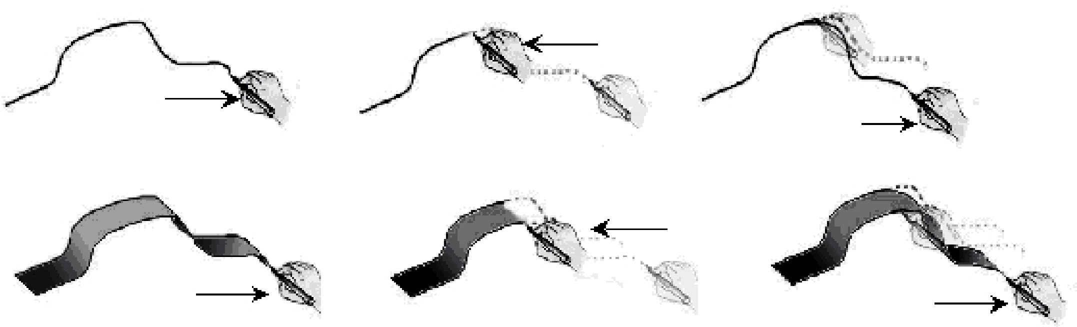


Figure 25: Eraser Pen

In that way we have combined the creation and deletion process, rewriting the rubber and pencil metaphor in just one tool.

The correction is done in real-time, if the pen inverts its direction for a second time the drawing process restarts. In this manner it is very simple to correct an error or to go back to follow a different path. The advantage respectively the common use of a rubber tool is that the user can correct the curve instantaneously, and the user may try and retry many times until the desired shape takes the form the user had mind.

7.3.3 Automatic Curve Splitting

Curves of high quality should have as few control points as possible. But one problem with curves build from few control points is, that it is not possible to have high curvature points (HCP). We therefore developed a function, which analyses the drawn curve according to its curvature. It detects points of high curvature and cuts the curve at these points. The resulting curve consists of partial curves with few control points and possible sharp edges at the junctions.

In Figure 26 three curves are shown:

1. Input stroke
2. Approximation with one low-degree spline (tip rounded)
3. Approximation with two low-degree splines (HCP maintained)

The upper curve is drawn with the conventional freehand spline function. It can be clearly seen that the curve's tip is smoothened. The lower curve is automatic tiled using our function, therefore the tip is as sharp as you draw it.

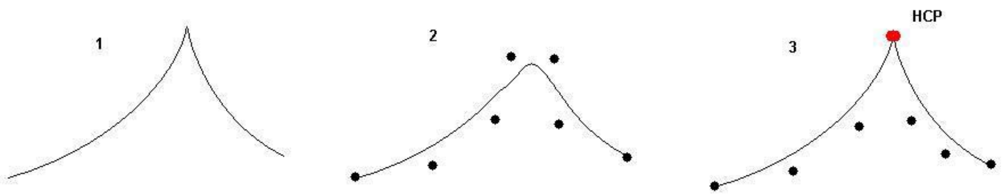


Figure 26: Automatic Curve Splitting

7.3.4 Virtual Tape Drawing

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Tape Draw	Curve ->Tape Draw	Curve ->Tape Draw		({"<color>" }; "line") to start taping "stop" to stop taping	Confirmation of actions	Fingers

Taping is a well-known technique designers use to create and modify characteristic lines of a model on a white board. In SketchAR this technique has been translated into a virtual taping feature and been improved by adding a new finger-tracking module to OpenTracker enhancing the realistic behavior of virtual tape drawing.

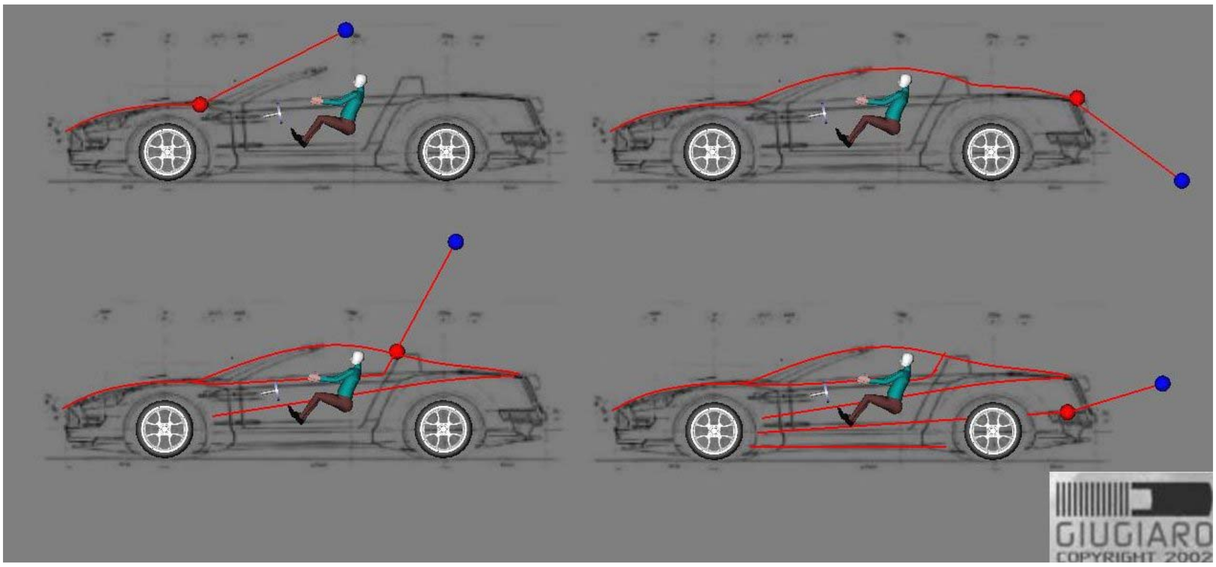


Figure 27: Virtual Tape Drawing

While taping, the user is in an eyes-busy, hands-busy situation, since he uses both hands for his task. Therefore speech input and output is used to switch between drawing and not drawing as well as choosing a color for the line and optionally its thickness. The advantage again is that the user can focus entirely on his task and his view is not obstructed by pop up menus or interaction devices**.**

Speech in-/output for *Tape Drawing*

Virtual tape drawing is activated by pressing the *Tape Draw* button in the *Curve* menu on the PIP sheet. Each of the users' tracked forefingers is matched by a small virtual sphere / 3D cross. Between the spheres there is the virtual tape.

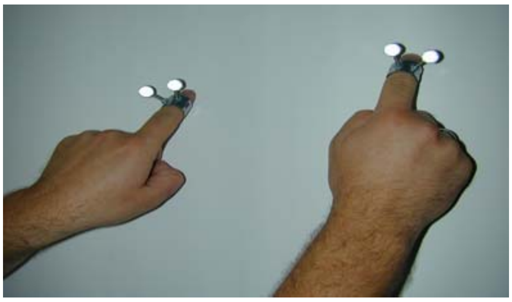


Figure 28: Virtual Tape Drawing – Finger Tracking

The left forefinger is used to glue the tape on the imaginary wall and the right forefinger is used to control the tangent. Now the user may start by saying the colour he wants to use, e.g.: "black", "white" and then the user says: "line" to start taping. Going forward with the left forefinger will glue the tape to the wall, going back with the left forefinger will detach the tape from the imaginary wall such as with a real tape.

To end the taped line, the user says: "stop". For each command the user receives synthesized speech feedback to know it has been recognized.

7.3.5 Surface Creation

In SketchAR surfaces can be generated using two different paradigms. The first is to explicitly select already drawn curves and perform surface creation operations on them. The second is to implicitly create surfaces, by sketching necessary curves during the surface creation operation.

Spline Extrusion:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Spline Extrude	Surface-> Spline Extrude	Surface-> Spline Extrude				Pen
NURBS Surface	Surface-> NURBS Surface	Surface-> NURBS Surface				Pen

SketchAR supports explicit and implicit spline extrusion. In the first case, a previously drawn curve is selected and extruded to build a surface. In the latter case a curve is drawn and extruded in one single interactive step.

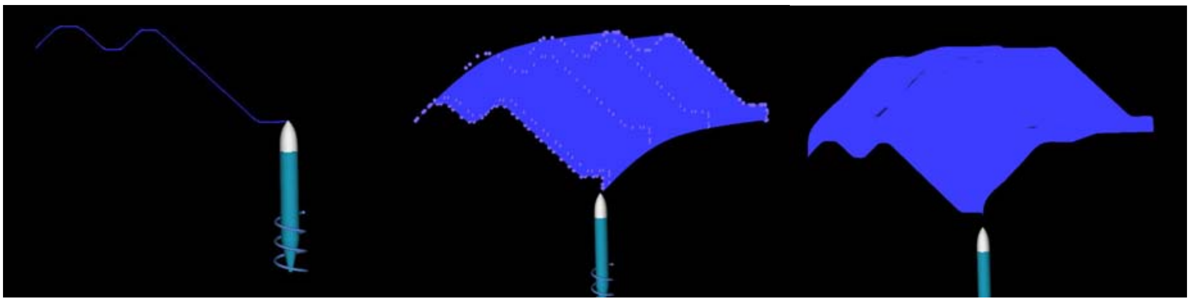


Figure 29: Spline Extrusion

To use the *Spline Extrude*- operation and to create a surface of an existing NURBS curve, you have to press the *Spline Extrude* button in the *Surface* menu on the PIP sheet or to activate the pie menu using the third button, go to the submenu *Surface*, select the *Spline Extrude* surface and release the third button.

To create the surface pick the NURBS curve with the pen, press the first button and extrude the curve along the path of the pen movement to get the surface. Release the first button to complete the *Spline Extrude*- operation.

To use the *NURBS Surface*- operation and create a surface of an on the fly created NURBS curve, press the *NURBS Surface* button in the *Surface* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Surface*, select the *NURBS Surface* and release the third button.

To create the surface, press and hold the first button to create a new curve. Release the first button to complete the curve creation. After creating the curve you can extrude the curve along the path of the pen movement (without pressing a button) to get the surface. Press the first button one more time to complete the *NURBS Surface* - operation.

Skinning:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Skin Surface	Surface-> Skin Section	Surface-> Skin Section				Pen
Skin Select Surface	Surface-> Skin Select	Surface-> Skin Select				Pen

If curves are created within the skinning operation, a real-time preview of the surface to be expected is shown during the operation (Figure 30). For this purpose an algorithm has been developed which generates a triangle mesh between the curves.

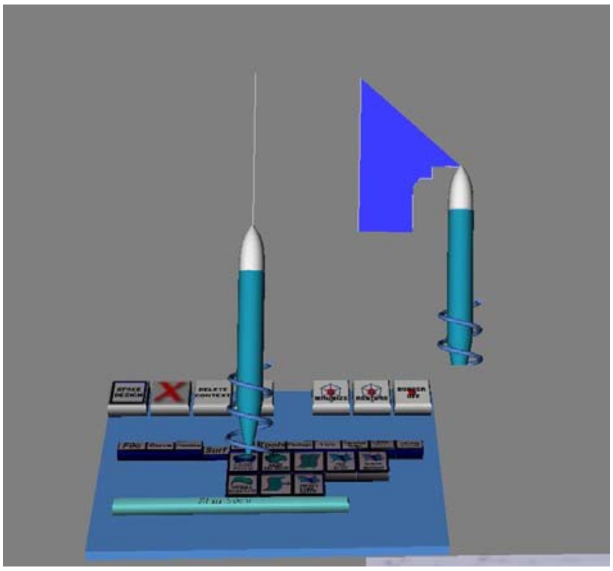


Figure 30: Skinning

Net Surface:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Net Surface	Surface-> Net Surface	Surface-> Net Surface				Pen
Net Select	Surface->	Surface-> Net				Pen

Surface	Net Select	Select				

Net surfaces are surfaces created from a net of four or more not necessarily intersecting curves.
ACIS supports net surfaces but requires the curves to be input in a certain order to process them correctly. To relieve the user from fulfilling these ACIS requirements we have implemented an intelligent mapping algorithm that sorts the selected curves, so ACIS can generate the corresponding surface.

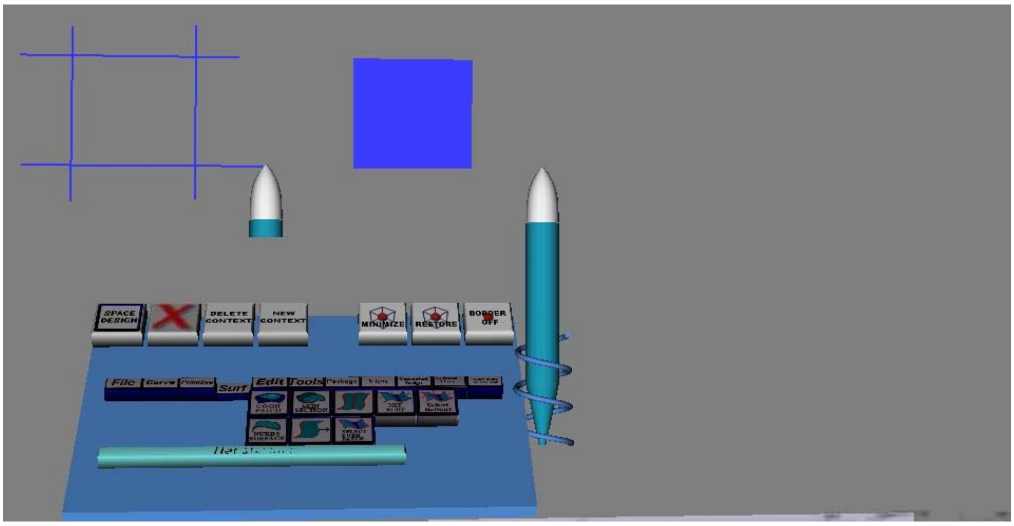


Figure 31: Net Surface

To use the *Net Select Surface* -operation and to create a surface of existing NURBS curves, press the *Net Select* button in the *Surface* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Surface*, select the *Net Select* Surface and release the third button.

To create the surface pick the NURBS curves with the pen, press the first button to select them one after another press the second button to create the surface and complete the *Net Select Surface-* operation.

To use the *Net Surface-* operation and create a surface of on the fly created NURBS curves, press the *Net Surface* button in the *Surface* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Surface*, select the *Net Surface* and release the third button.

To create the surface, press and hold the first button to create as many curves as you like. Release the first button to complete the current curve and press and hold it again to create the next curve. After creating all the curves press the second button to create the surface and complete the *Net Surface-* operation.

Coons Patch from one 3D stroke:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Coon Patch	Surface-> Coon Patch	Surface-> Coon Patch				Pen
Select Coon Patch	Surface-> Coon Select	Surface-> Coon Select				Pen

Coons patches from one 3D stroke is a way for creating complex free form shapes in a intuitive way: a closed non self-intersecting contour is covered using a Coons patch. The mathematical concepts behind the surface generation, which requires four oriented curves for the interpolation, are completely handled by SketchAR in a transparent way. The intuitiveness of the interaction method is reached by performing some reasoning on the input data: the outline of the 3D stroke is automatically splitted into two pairs of oriented curves. The resulting shape of the Coons patch heavily depends on the position of the split points. This function has been improved in SkectchAR to provide surfaces that better conform to the user's expectations. Starting form the splitting points using a simplified bounding box method, the algorithm searches the respective neighborhoods relative maximum values of the first derivative along the curve. Using such points avoids undesired wrinkles, which appeared in the previous implementation. In addition, SketchAR visualizes an approximate preview of the created surface during the sketching phase.

To use the *Coon Patch Select* -operation and create a surface of existing NURBS curves, press the *Coon Select* button in the *Surface* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Surface*, select the *Coon Patch Select* Surface and release the third button.

To create the surface pick the NURBS curves with the pen, press the first button to select them one after another press the second button to create the surface and complete the *Coon Patch Select-* operation.

To use the *Coon Patch-* operation press the *Coon Patch* button in the *Surface* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Surface*, select the *Coon Patch* and release the third button.

To create the surface, press and hold the first button to create the surface. Release the first button to complete the *Coon Patch -* operation.

7.3.6 Primitive Creation

SketchAR supports the creation of many different primitives. To create primitives select the Primitive menu on the PIP sheet. Then you can choose between two sub menus: Shape1 and Shape2

Shape1 consists the following primitives:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Sphere	Primitive ->Shape1 ->Sphere					Pen
Quad	Primitive ->Shape1 ->Quad					Pen
Cylinder	Primitive ->Shape1 ->Cylinder					Pen
Cirular Cone	Primitive ->Shape1 ->CircCone					Pen
Cirular Prism	Primitive ->Shape1 ->CircPrism					Pen
Cirular Pyramide	Primitive ->Shape1 ->CircPyr					Pen
Ellipse Cone	Primitive ->Shape1 ->EllipCone					Pen

Shape2 consists the following primitives:

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Ellipse Cone	Primitive ->Shape2 ->EllipCone					Pen
Ellipse Prism	Primitive ->Shape2 ->Ellip Prism					Pen
Ellipse Pyramide	Primitive ->Shape2 ->EllipPyr					Pen
Circular Trunc Cone	Primitive ->Shape2 ->CircTrunc Cone					Pen
Circular Trunc Cone	Primitive ->Shape2 ->Circ Trunc Cone					Pen
Circular Trunc Pyramide	Primitive ->Shape2 ->Circ					Pen

	Trunc Pyr					
Ellipse Trunc Cone	Primitive ->Shape2 ->Ellip Trunc Cone					Pen
Ellipse Trunc Pyramide	Primitive ->Shape2 ->Ellip Trunc Pyr					Pen

To create primitives in SketchAR select one of the *Primitive* operations pressing the according button in the *Primitive* menu on the PIP sheet.

To start the *Primitive* operation press and hold the first button of the pen and draw the primitive moving the pen. Release the first button to complete the *Primitive*-operation.

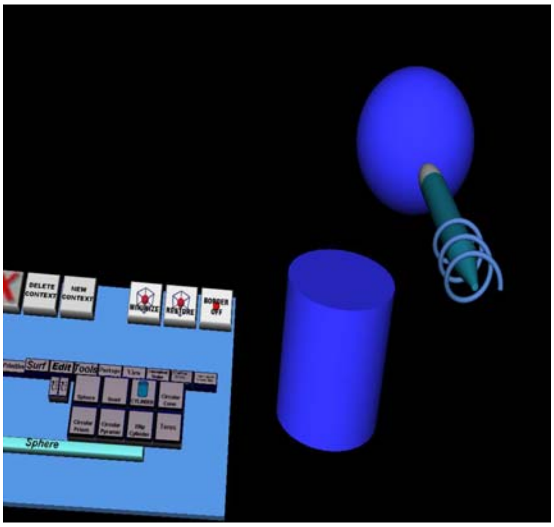


Figure 32: Primitive Creation

Primitives can be moved and copied. In addition the following Boolean operations can be performed on primitives which can be found under the BOOL menu:

- Intersection
- Subtraction
- Addition

7.3.7 Scene Modelling and Assembly

In SketchAR constraints can be applied to the entities (edges, faces) of two shapes.

In detail SketchAR provides the following constraints:

- Coincidence
- Concentric center-points / axis for cylinders and spheres

- Parallelism
- Tangential
- Perpendicular
- Fixation in world space

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Coincident	Primitive -> Constr. -> coincident					Pen
Parallel	Primitive -> Constr. -> parallel					Pen
Perpendicular	Primitive -> Constr. -> perpen-dicular					Pen
Tangent	Primitive -> Constr. -> tangent					Pen
Concentric	Primitive -> Constr. -> concentric					Pen
Dimensioning	Primitive -> Constr. -> dimension					Pen
Fix/ Unfix	Primitive -> Constr. -> (un)fix					Pen
Show / Free	Primitive -> Constr. -> show/free					Pen

To use Constraint operations, press one of the according buttons in the Primitive -> Constraints- menu on the PIP sheet.

To apply a constraint to geometries, first select the geometries by picking them with the pen and pressing the first button, then press the second button to apply the constraint and complete the operation.

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Sliding Joint	Conc. Design-> Sliding Joint					Pen
Block with Hole	Conc. Design-> Block with Hole					Pen
Block with Bolt	Conc. Design-> Block with Bolt					Pen
Disc	Conc. Design-> Disc					Pen
Pivor Lever	Conc. Design-> Pivot Lever					Pen
Upright Bar	Conc. Design-> Upright Bar					Pen
Simple Block	Conc. Design-> Simple Block					Pen
Drilled Lever Bar	Conc. Design-> Drilled Lever Bar					Pen
Bolted Lever Bar	Conc. Design-> Bolted Lever Bar					Pen

To create a component in SketchAR select one of the *scene modeling and assembly* operations, pressing the according button in the *Conceptual Design* menu on the PIP sheet.
To start the *scene modeling* operation press and hold the first button of the pen and position the component moving the pen. Release the first button to complete the *Scene Modeling*- operation. Constraint operations may help you to create assemblies in VR or AR.

An additional operation is the resize operation for the components. Just select the *Resize* – operation in the *Scene Modeling* menu.
To use the *Resize*- operation pick an existing component with the pen, press and hold the first button and resize it moving the pen. Release the first button to complete the *Resize*-operation.

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Resize	Conc. Design-> Resize					Pen

With the feature-based approach users are supported to define the parametric interdependencies between the parts of an assembly. For this, features and parameters are mapped into a net of geometric constraints that are solved whenever the user interacts with the model by either inserting or modifying parts or constraints.

The semantic filter is to restrict the view on the product information according to the actual modelling context, which is defined by the current user operation. The realised model contexts are a part view during the modelling of parts and an assembly view for assembling operations and kinematics validating of obtained mechanisms.

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Semantic Filter On/Off	Context Specific Semantic Filter-> On/Off					Pen

In the following an excerpt of an assembly sequence is presented.

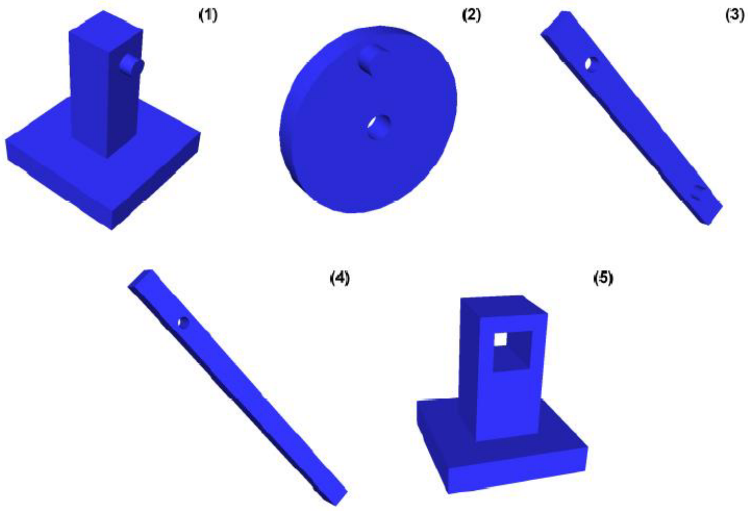


Figure 33: Assembly Parts

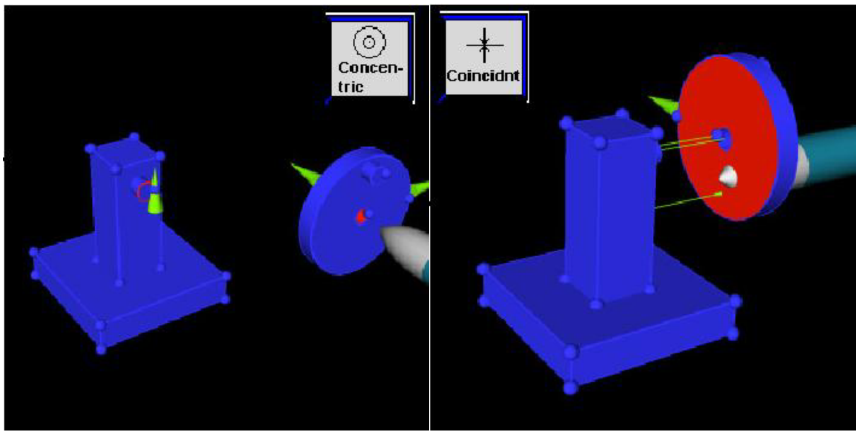


Figure 34: Assembly I

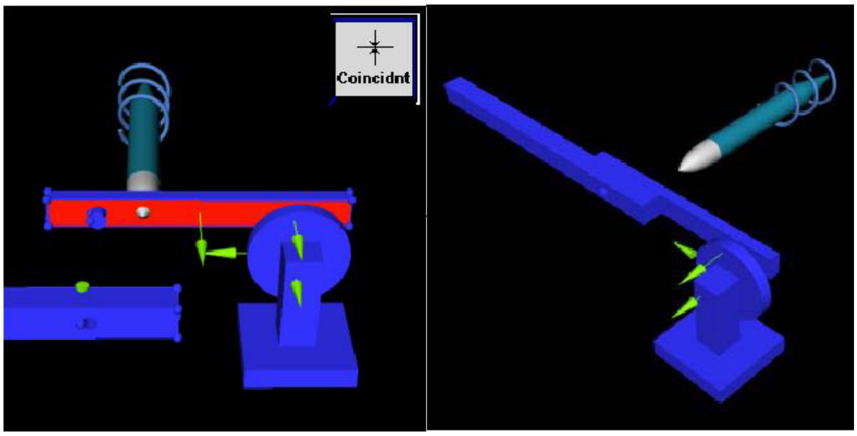


Figure 35: Assembly II

7.4 Geometry Modification

In SketchAR several ways for modifying and refining geometry exist. This section will introduce them.

7.4.1 3D Oversketching

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Over-sketching	Edit-> Oversketch					Pen

A common technique to create a desired curve is to repetitively draw over a curve – this technique is called oversketching. To mimic this curve modification method we developed a virtual oversketching technique. With this function a curve can be changed with sketching a new curve *over* the existing one. The user can control the influence of the new curve to the resulting curve with two sliders.

In Figure 45 two examples of oversketching are shown. In a) the influence parameter of the oversketched curve is 0.5. Therefore the resulting curve lies between the original and the oversketched one. In b) the influence parameter is 1.0, therefore the result follows the oversketched curve exactly.

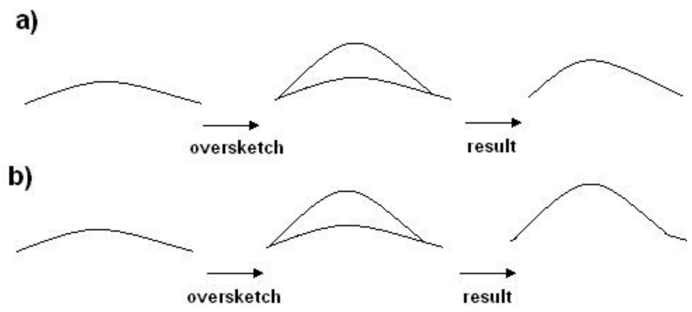


Figure 36: Curve Oversketching

7.4.2 Constrained Oversketching

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Over-sketching	Edit-> Oversketch See additional buttons for influence: "Vertical" "Horizontal"					Pen

The oversketching method described in the previous section allows oversketching the curve in all three dimensions directly, when applied in an immersive environment using direct 3D input devices. The following modification to the idea of oversketching adds the possibility to constrain the changes to two coordinates. To perform a constrained oversketch the user has to choose a 2d orthographic view of the curve he intends to change. For example in figure 37 the oversketch is done on the xy-plane. The modification of the curve is now constrained in a way that the original profile from the xz-plane is not changed.

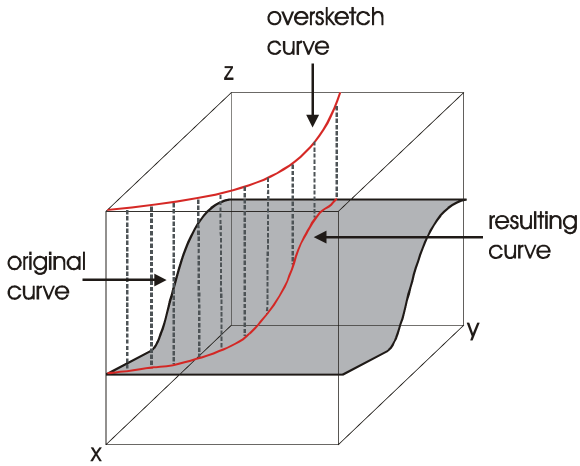


Figure 37: Constraint oversketching principle

The implementation of the constrained oversketching makes use of the CAD library ACIS. In contrast to the technique presented before, the curves need to be represented as splines. Conversion from point sets to splines is also achieved using the ACIS library. To combine the oversketch curve with the destination curve the destination curve is extruded to a surface. The extrude path has to be parallel to the constraint plane and can either be vertical or horizontal as shown in Figure 38.

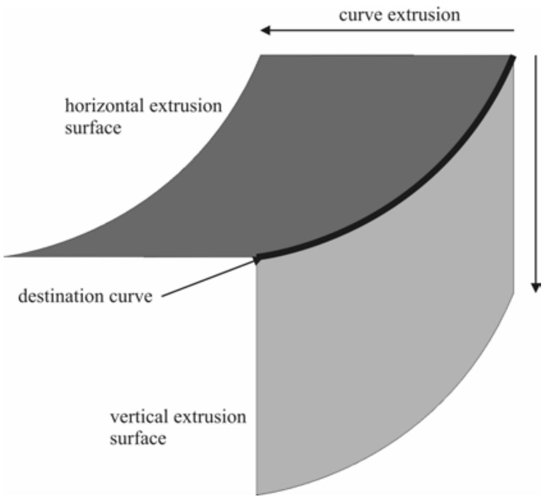


Figure 38: Two possible curve extrusions

The selection between vertical and horizontal influence is done by the user. In this way he selects which side profile stays unchanged.
Then the oversketch curve is projected onto the surface of extrusion. The result of this projection is the oversketched curve.

The sequence in Figure 51 explains the steps from the user's point-of-view:

1. The user starts with sketching a curve of the hood in side view.
2. He switches to top view.
3. He makes an oversketch defining the side part of the hood.
4. The resulting oversketched curve is created.
5. The user switches back to 3D view to see the result.

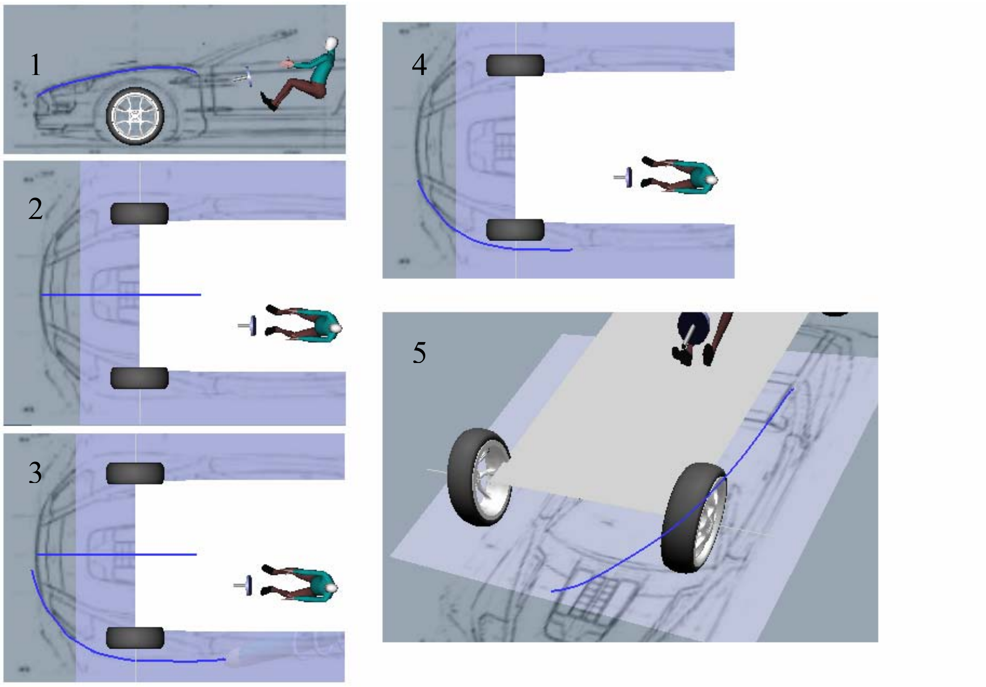


Figure 39: Constrained Oversketching

7.4.3 Editing Control Points

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Edit Control Points	Edit-> EditCPs					Pen

Nowadays a vastly used tool for curve and surface modification in CAD / CAS software is control point modification. Although controlpoint modification is known to be not very intuitive from the scientific literature, the users in SmartSketches demanded this functionality. We implemented two ways of control point modification:

a) The user selects a curve and can freely manipulate each control point
b) The user can use a dragger to constrain the movement of a control point

To edit the control points of a curve or a surface choose the *Edit Control Points* button in the *Edit*- menu of the PIP sheet.

To start editing the control points pick a curve or surface with the pen and press the first button to select it. The control points are displayed now. You can manipulate the control points in two ways(Figure 40): the first (a) is to pick them with the pen, press and hold the first button and move them free in space. The second way (b) is to pick a control point and press the second button. The control point turns into a dragger, which can be moved either free in space or only in one axis and can be rotated. Pick the centre of the dragger and press the second button again to make it disappear.

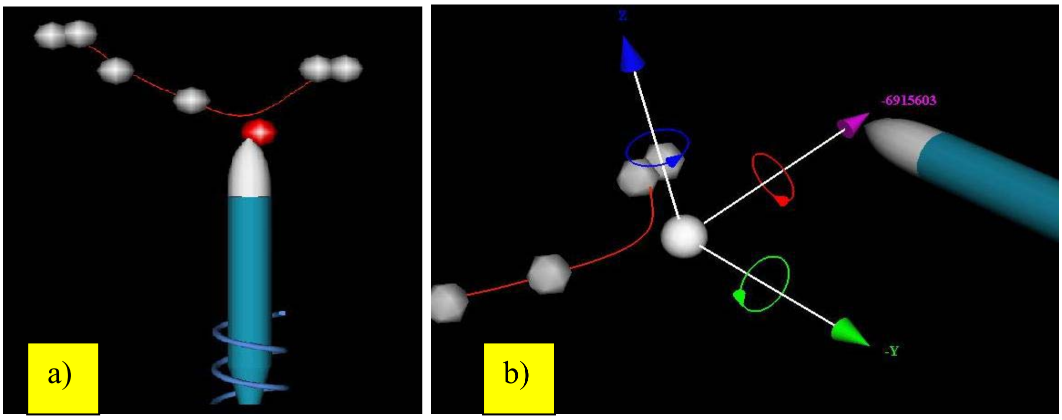


Figure 40: Editing Control Points

7.4.4 Net Surface Oversketching

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Over-sketching	Edit-> Oversketch					Pen

Control points modification might be very useful for an accurate modification in a small area of interest. But imagine changing the character of a complete patch - then fiddling around with lots of control points becomes a difficult and maybe frustrating task. The idea of oversketching is to change the shape of a surface according to a curve sketched on top of it. In SketchAR a surface created by a Net Surface operation can be modified by sketching additional lines over and over the surface again (Figure 41).

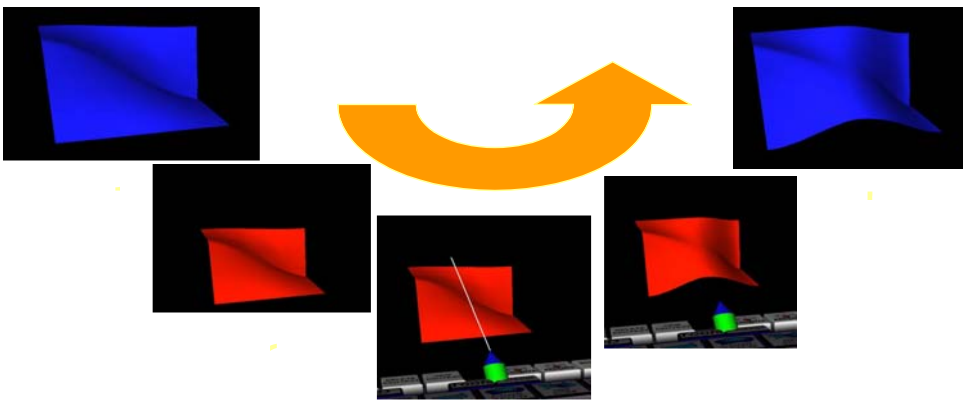


Figure 41: Net Surface Oversketching

Net surface oversketching is implemented by successively using our mapping and sorting algorithm for input strokes to feed the ACIS net-surface functionality.

7.4.5 History based surface modification

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Implicitly supported functional ity						Pen

In SketchAR each shape object stores all operations that were applied to it. In addition each shape object knows all its descendant shapes that were created by duplication etc. Any modification applied to the original shapes will be propagated to their descendants, which causes re-computation of the operations that led to them. Let a surface be generated explicitly from previously drawn curves. If subsequently one of the sections is edited, for example by oversketching or control point manipulation, then this change will also be reflected in the surface and the surface changes accordingly.

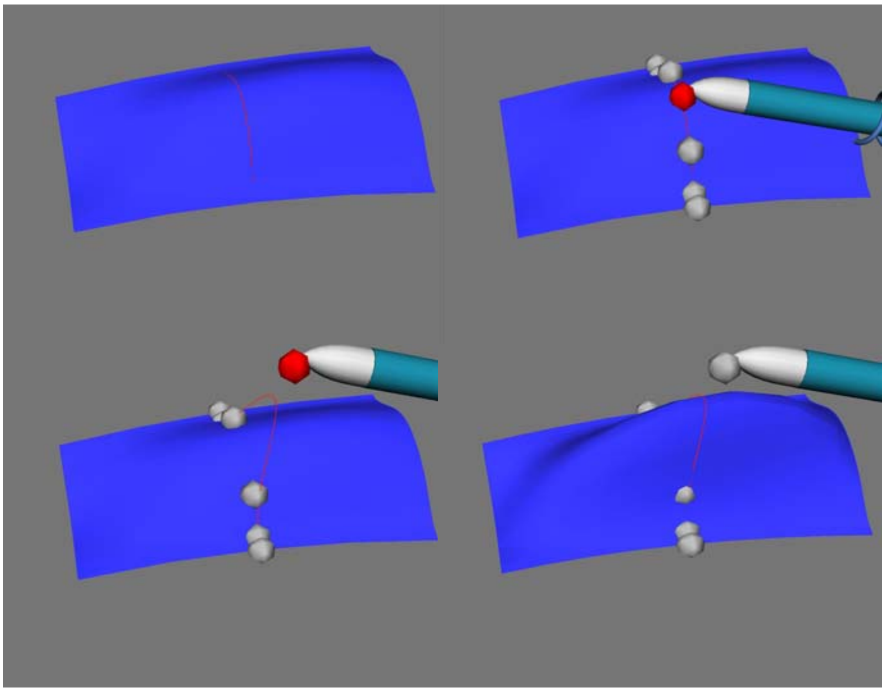


Figure 42: History based surface modification

7.4.6 Boolean Operations

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Boolean +	Primitive ->Bool -> Bool+					Pen
Boolean -	Primitive ->Bool -> Bool-					Pen
Boolean Intersect	Primitive ->Bool-> Bool int					Pen

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Realtime Boolean +	Primitive ->Bool -> Real+					Pen
Realtime Boolean -	Primitive ->Bool -> Real-					Pen
Realtime Boolean Intersect	Primitive ->Bool-> Real int					Pen

Boolean operations can be applied to all geometries in SketchAR. Additional *Real-time Boolean* operations are supported, that let the user move one geometry into another one while seeing the boolean result in real-time.

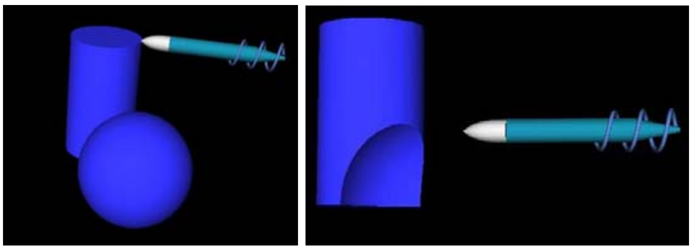


Figure 43: Boolean Intersection

To activate a *Boolean* operation in SketchAR select one of the *Bool* operations pressing the according button in the *Bool* submenu in the *Primitive* menu on the PIP sheet.

To apply a *Boolean* operation to geometries, select two geometries by picking them with the pen one after another and pressing the first button. After selecting the geometries press the second button to apply the operation.

To activate a *Realtime Boolean* operation in SketchAR select one of the *Realtime Boolean* operations pressing the according button in the *Bool* submenu in the *Primitive* menu on the PIP sheet.

To apply a *Realtime Boolean* operation to geometries, select one of the geometries by picking them with the pen and pressing the first button. Hold the first button and move the geometry into the other one. A preview is displayed while moving. Release the first button to apply the operation.

7.5 Editing Operations

Editing operations let you move, copy, select or delete a curve, surface or primitive. Additional SketchAR provides multiple undo / redo functionality.

7.5.1 Select / Multiple Select

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Select	Edit ->Select	Edit ->Select	Ellipse		"(un-) selecting shape"	Pen

One or more shapes in the scene can be selected with the virtual 3D pen.

To activate the *Select*-operation, press the *Select* button in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Select* button and release the third button.

To use the *Select* operation pick a shape with the top of the pen and press the first button. To deselect the shape just do this once again.

However the easiest way to *select/deselect* a Shape is to use gesture recognition. Just make an *ellipse* gesture near the shape to *select/deselect* it. The synthetic speech output confirms the *select/ deselect* operation with *"selecting/deselecting shape"*

7.5.2 Move / Copy

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Move	Edit ->Move	Edit ->Move				Pen
Copy	Edit ->Copy	Edit ->Copy				Pen

The selected shapes can be moved or copied in the scene. A copy-move operation allows to copy and move selected objects in one step, thus reducing the number of pen interactions.

To activate the *Move*-operation, press the *Move* button in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Move* button and release the third button.

To use the *Move* operation pick a shape with the top of the pen, press and hold the first button and move the pen. Release the pen to complete the *Move*-operation.

To activate the *Copy*-operation, press the *Copy* button in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Copy* button and release the third button.

To use the *Copy* operation pick a shape with the top of the pen, press and hold the first button. You can copy and position the duplicated shape by moving the pen. Release the first button to complete the *Copy*-operation

7.5.3 Delete

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Delete All	Edit ->Erase	Edit-> delete All				
Delete Select	Edit-> Clear Select	Edit-> Delete Select	Rectangle		"deleting shape"	Pen

Selected objects can be deleted from the scene.

To delete all shapes in the application use the button *Erase* in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Delete All* button and release the third button.

To delete only several shapes use the *Delete Select* operation. To activate the *Delete Select* operation press the *Delete Select* button in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Delete Select* button and release the third button.

To use the *Delete Select* operation pick a shape with the top of the pen and press the first button. The shape is deleted.

To delete a shape using gesture recognition, just make a *rectangle* gesture near the shape. The synthetic speech output confirms the *Delete* operation with *"deleting shape"*

7.5.4 Multiple UNDO / REDO

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Undo	Edit->Undo	Edit->Undo	Bold Rectangle	"undo operation"	"undoing operation"	Pen
Redo	Edit->Redo	Edit-> Redo	Bold Triangle	"redo operation"	"redoing operation"	Pen

Multiple Undo/Redo has been implemented, which allows going back N operations and forward N operations. Multiple Undo/Redo also takes into account if an operation was performed while a mirror or projection plane was activated and stores the generated or manipulated shapes accordingly by storing the associated operations that lead to their creation or manipulation.

Multiple Undo/Redo is a model centered global operation and not a user centred operation, which means, that each user can go back and forward again through all modifications made by all users according to the chronological sequence of a session. If two users are working at the same model, then the first user can undo the operation the second user just performed. This is useful in collaborative scenarios, where both discuss on the same model.

To use *Undo* or *Redo*, press the *Undo* or *Redo* button in the *Edit* menu on the PIP sheet or activate the pie menu using the third button, go to the submenu *Edit*, select the *Undo* or *Redo* button and release the third button.

The gestures used for multiple Undo/Redo are respectively a bold triangle for Redo and a bold rectangle for Undo recognized by CALI. The Synthetic Speech Output confirms the *Undo* or *Redo* operation with *"undoing operation"* or *"redoing operation"*

7.5.5 Material Editor

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Color Selection	Edit-> Material Editor			"black", "white", etc (7 colors)	"black", "white", etc (7 colors)	

Stylists use different colors and materials to emphasize the character of the concept drawing. We implemented a small material editor to assign arbitrary colors as well as material properties like transparency to shapes.

There are two ways of working with the Material Editor:

- Selection of a new material which entails that newly created shapes get the selected material
- First select a shape and then change its material properties by selecting a new material

To change the default material, just use one of the buttons in the *Material Editor* submenu in the *Edit* menu on the PIP sheet.

To change the Material of one geometry select the geometry using the select operation, use one of the buttons in the Material Editor submenu and deselect the geometry.

While drawing any shape, you are able to choose one of the material properties of a shape namely the color, by simply saying using speech recognition and receiving synthesized speech feed-back for each command.

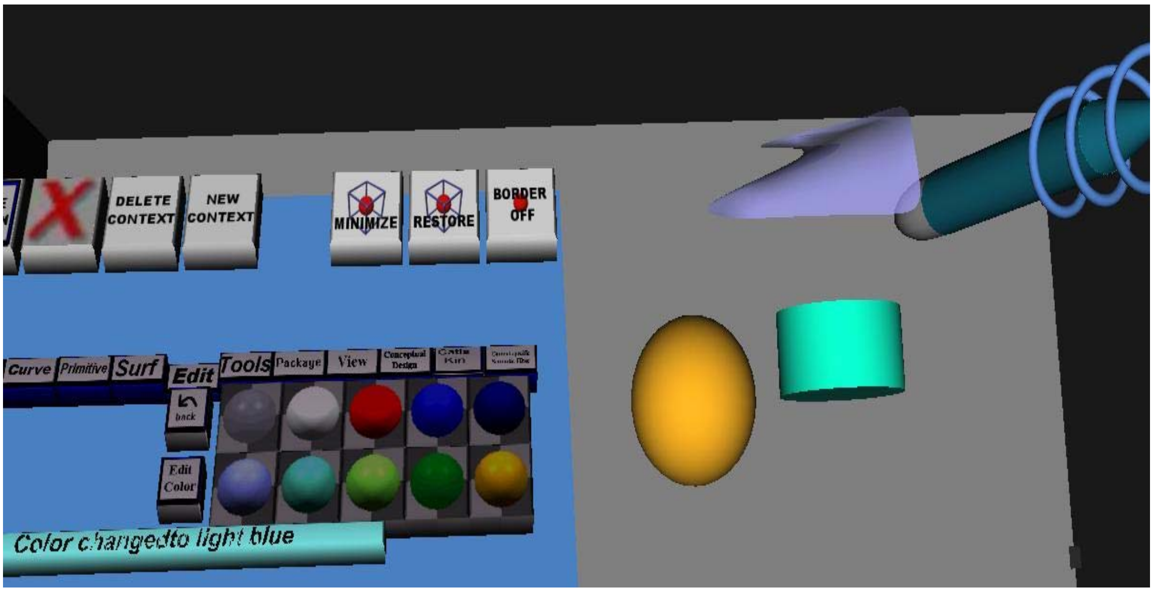


Figure 44: Material Editor

If you would like to define your own material, SketchAR defines the *Color Editor*. You find it in the *Material Editor* menu, pressing the *ColorEdit* button. Use the sliders to define red, blue, green, transparency and shininess of your material. In the lower left corner of the PIP you find a preview of the material. Use the *Apply* button to apply the material to your geometry.

7.6 Supporting Operations

In this section we present a number of useful tools and operations that help users to accurately draw and position shapes.

7.6.1 Picking

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Implicitly supported feature						Pen

As stated in the chapter on input techniques, SketchAR uses an intelligent picking that privileges objects with lower topological priority first: vertices, curves, faces.

To pick a geometry part in SketchAR just move the pen near the part. How near you have to move it depends on the pick radius. You can adjust the *pick radius* using the slider in the *Tools-> Pick Radius* submenu on the PIP sheet. The *Pick Radius* is represented as a sphere, which can be shown and hidden using the *show/ hide* button next to the slider.

7.6.2 Snapping

Activate *Snapping* using the *Snap-* button in the *Tools* menu on the PIP sheet.

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Snap	Tools-> Snap					Pen

7.6.3 Workplane

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Workplane	Tools-> Workplan e	Tools-> Workplane				Pen, Plane

To allow the stylist to create a car silhouette line as a curve on a plane we introduced the work plane concept which constraints the input to a plane by projecting the pen tip to the nearest point of the work plane. The plane can be positioned arbitrarily in space using a tracked artifact or a dedicated dragger.

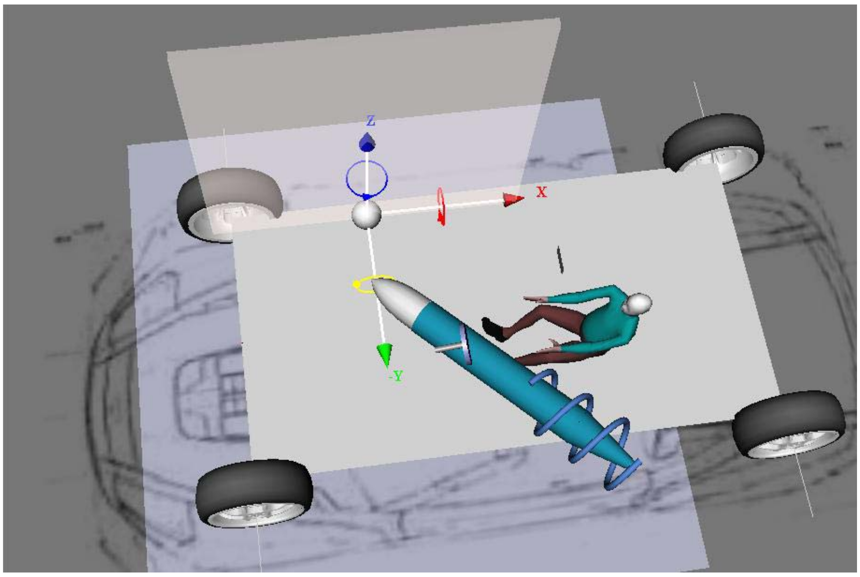


Figure 45: Workplane positioned by dragger

In addition, the work plane can be linked to a tangible physical element and positioned arbitrarily, in discrete angles or moved along a pre-defined grid.

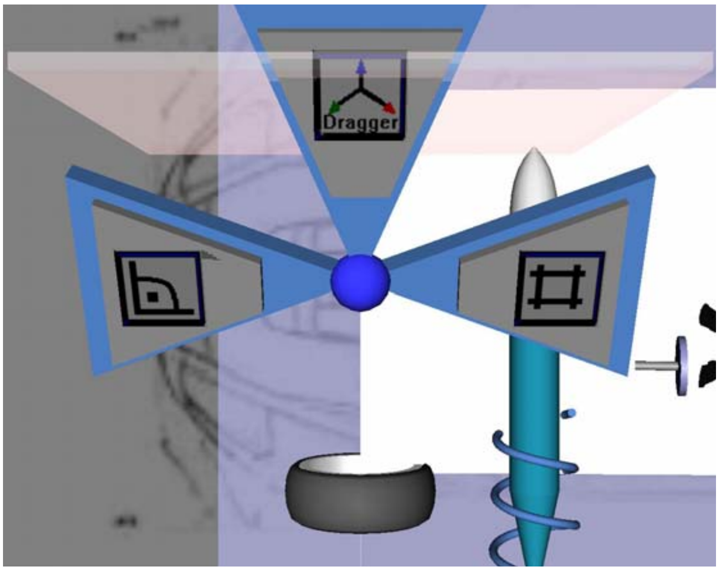


Figure 46: Context pie menu allowing the work plane to be positioned in different ways

Use the *Workplane* button in the *Tools* menu on the PIP sheet to activate the *Work Plane* operation.

- First press: free positioning mode.
- Second press: Workplane in car mode.
- Third press: Workplane off.

Alternatively use the pie context menu, clicking the third button of the pen once you are close to the *Workplane*.

7.6.4 Workplane to table

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Workplane to Table	Tools-> Table Projection					Plane, Pen

Stylists are used to have physical feedback while drawing. In free space this kind of feedback is not available unless you use special haptic input devices. Today haptic devices that cover an area as big as a virtual table working space are hardly affordable. With this new function we provide a way to draw a curve on a plane, which is arbitrarily positioned in 3D space, using the table itself as drawing surface.
Using a tangible, physical plane a projection plane is arbitrarily positioned in space. When activating the “pp2table”-function the projection plane is rotated to the table surface, so that the designer can directly draw on the table. Furthermore all geometry between the work plane and the user’s head position is clipped away. On the left Figure 59 you see the projection plane positioned in the scene. On the right side you see the rotated view clipped at the plane position in orthographic view mode.

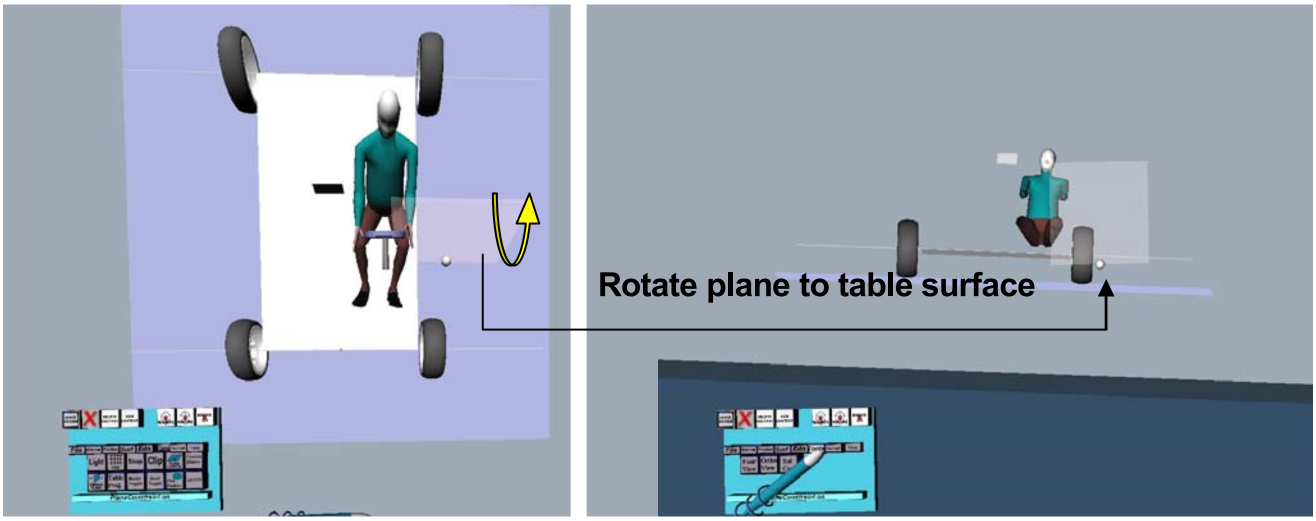


Figure 47: Work Plane to Table

7.6.5 Mirrorplane

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Mirrorplane	Tools-> Mirrorplane	Tools-> Mirror-plane				Plane, Pen

To create symmetric shapes, we introduced a mirror plane concept. The mirror plane can be used in two modes:

- Free positioning using a tangible physical plane or a dragger
- Positioning it contrained to the center axis of the car

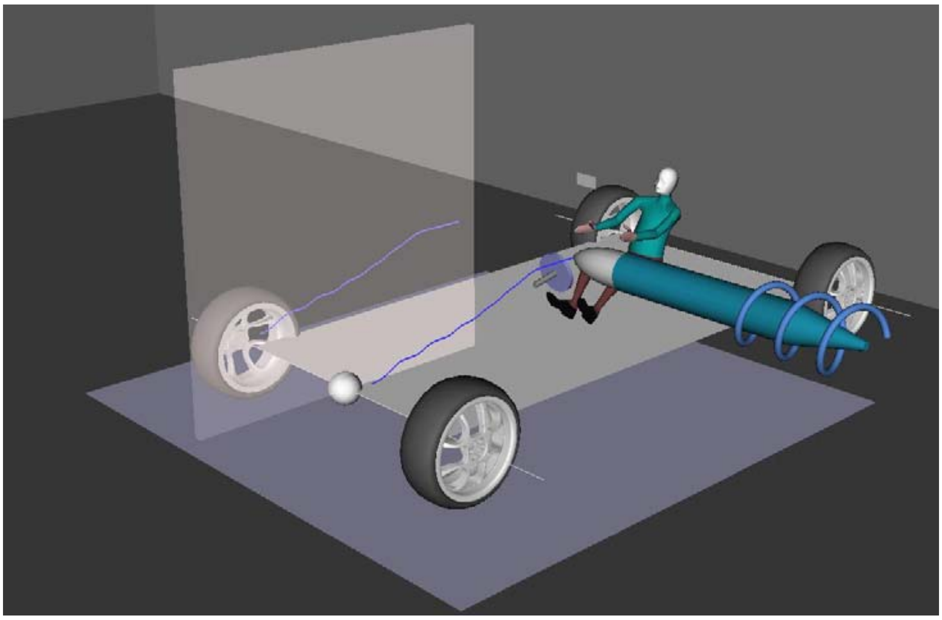


Figure 48: Drawing in mirrored mode

Shapes are immediately mirrored while creation time if the mirror is active. This is implemented by activating a second creation operation that processes the mirrored pen positions (events).

The *Mirrorplane* operation in SketchAR has two different modes. The first is a *free positioning mode*: Position the *Mirrorplane* using the *tracked Tangible Plane Artefact* (chapter 1.1.1 and 3.1). The second mode is the *Mirrorplane in car mode*. In this mode the Mirrorplane is fixed in the centre of the car.

Use the *Mirrorplane b*utton in the *Tools* menu on the PIP sheet to activate the *Mirrorplane* operation.

- First press: free positioning mode.
- Second press: Mirrorplane in car mode.
- Third press: Mirrorplane off.

7.6.6 Clipping Plane

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Clipping Plane	Tools-> Clipping Plane	Constraint ->Clip				Plane, Pen

To investigate the shape of a model we added a clipping plane to our immersive modeler. The clipping plane clips away one side of a plane and presents a cut through the model. The plane can be arbitrarily positioned in the scene using the tracked tangible plane.

7.6.7 Freeze Scene and View

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Freeze Scene	Tools-> Model Toggle					Pen
Freeze View	Tools-> Head Toggle					Pen

One characteristic of an immersive environment is that the scene changes when you move your head. This feature was very well accepted by stylists able to view the model while styling it. However sometimes while drawing, the continuous movement of the scene irritated them and prevented them to sketch with precision. Therefore we developed the possibility to freeze the view and the scene, so they can draw accurately without distraction.

To freeze/unfreeze the scene press the *Model Toggle* button in the *Tools* menu on the PIP sheet. While the scene is frozen, you are able to move the scene with a dragger.

To freeze/unfreeze the view press the *Head Toggle* button in the *Tools* menu on the PIP sheet.

7.6.8 Camera Zoom / Move

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Camera Zoom / Move	Tools-> Camera Sliders					Pen

In the immersive modeler the virtual camera is attached to the user's viewpoint. That way the user can examine the model from all sides and can go nearer and farer away to zoom in and out. However, sometimes the stylist may need to change the view without moving the head, for example an interior designer wants to have a view from the inside of the car. Therefore we added support to pan the camera and zoom in/out.

7.6.9 Ortho View

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Ortho View	View-> OrthoView	View-> OrthoView				Pen

For curve input stylists often prefer to have an orthographic or mono view of the scene. In SketchAR you can simply switch between those views.

Use the *OrthoView* button in the *View* menu to switch between mono- and stereo view.

7.6.10 Four-View

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
4 Side View	View-> FourView	View-> FourView				Space mouse, Pen

Stylists usually create four side drawings of selected concepts. These drawings are used as a basis for the CAD modeler to create a 3D model. Therefore we added a function that switches into a 2D, orthographic viewing mode and displays the car from each side, top, front or back view. With this feature we support the stylist to draw e.g. characteristic curves from a certain point of view.

While working in the four-side view, the user is able to control the camera, move and zoom using the SpaceMouse. This feature lets him work as on a virtual piece of paper, which he can pan, rotate and zoom in any position to do his sketches in the most comfortable way.

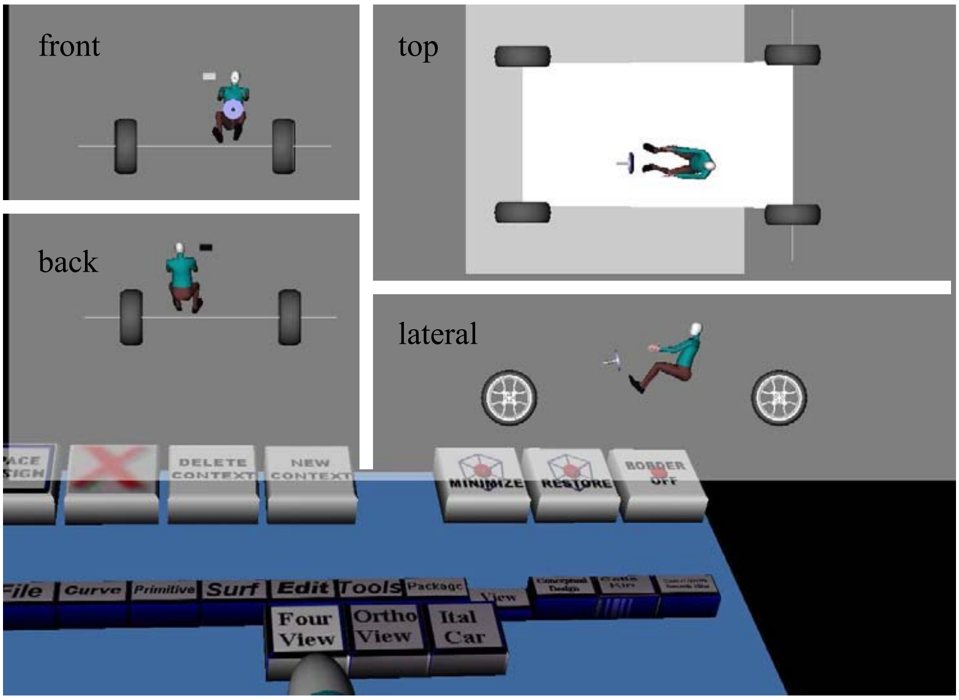


Figure 49: Four-View

Use the *FourView* button in the *View* menu to switch between the four side views:

- First press: Left
- Second press: Front
- Third press: Back
- Fourth press: Top
- Fifth press: Fourview off

In the *FourView* mode you can move and zoom the scene using the space mouse.

7.6.11 3D Layers

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthesis	Inter-action Device
Layer	Tools-> Layer					Pen

To hide and show parts of the model we integrated 4 drawing layers. The current drawing is always made on the selected one. The user can then choose which layer is visible and which is not. These layers may contain parts of the 3D model to compare alternatives.

7.7 Network Collaboration - SketchNET

SketchNET is a framework, which allows design and modeling applications to share and collaboratively generate shapes. The general term "shape" here means any objects, which their CAD modelling kernels can compute. The SketchNet framework uses a Web service approach with an SQL database back-end serving as shared memory. It allows for 1:N collaboration by implementing locking mechanisms on shape-by-shape basis. In fact in its current version, SketchNET is a shape exchange repository. It can be accessed using the event-subscriber paradigm: Interested applications subscribe to certain events. Applications communicate events like login, logout of users or shape updates via notification to the Web service, which in turn connects to an SQL database and executes the necessary changes in the particular tables. Then, should the event description specify this, the Web service will broadcast the results to the event's subscribers.

7.7.1 SketchNET overview:

SketchNET is split in a client-side API that enables subscription to events and notification of events. Each participating design and modelling application has to include the SketchNET API to be able to subscribe to events and send them to SketchNET.
Furthermore it is required, that each application is extended to handle subscription to and arrival of events. In addition SketchNET is based on the principle, that each shape should be self-describing and that an application connected to SKETCHNET will decode shapes it understands and ignore all shapes it does not understand.

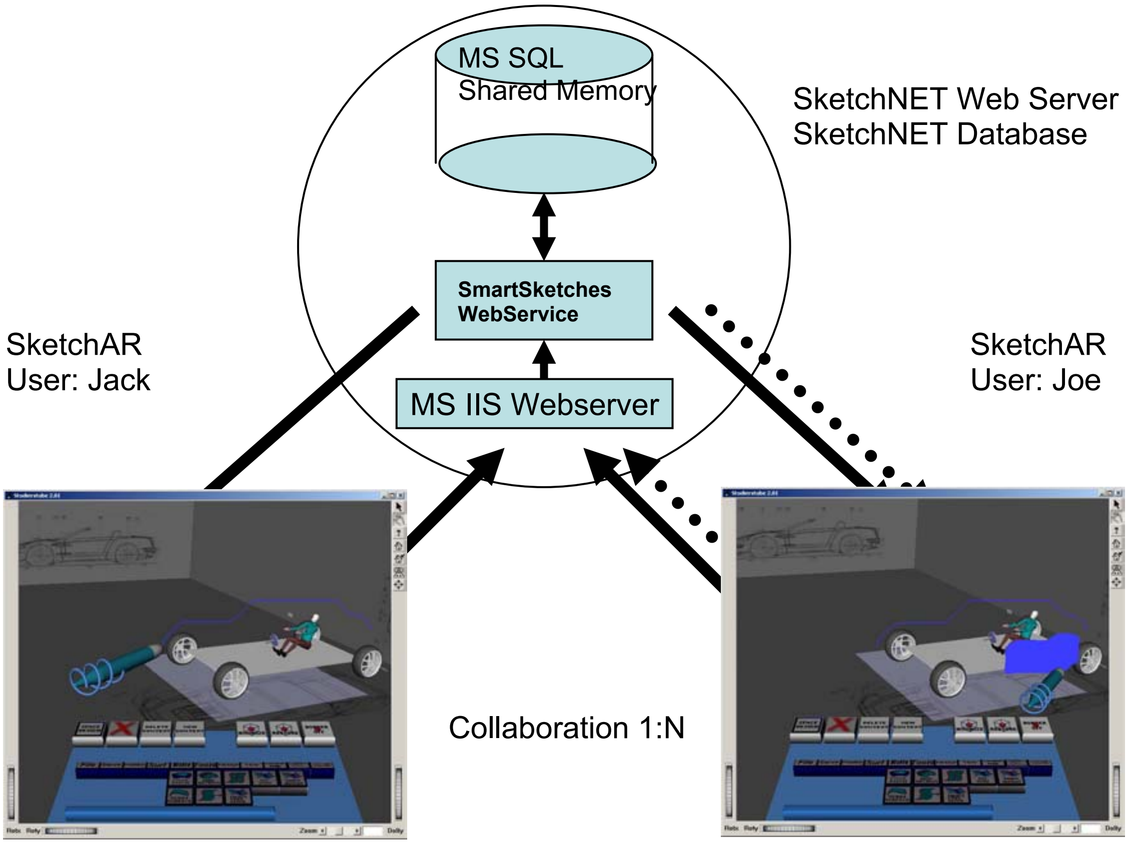
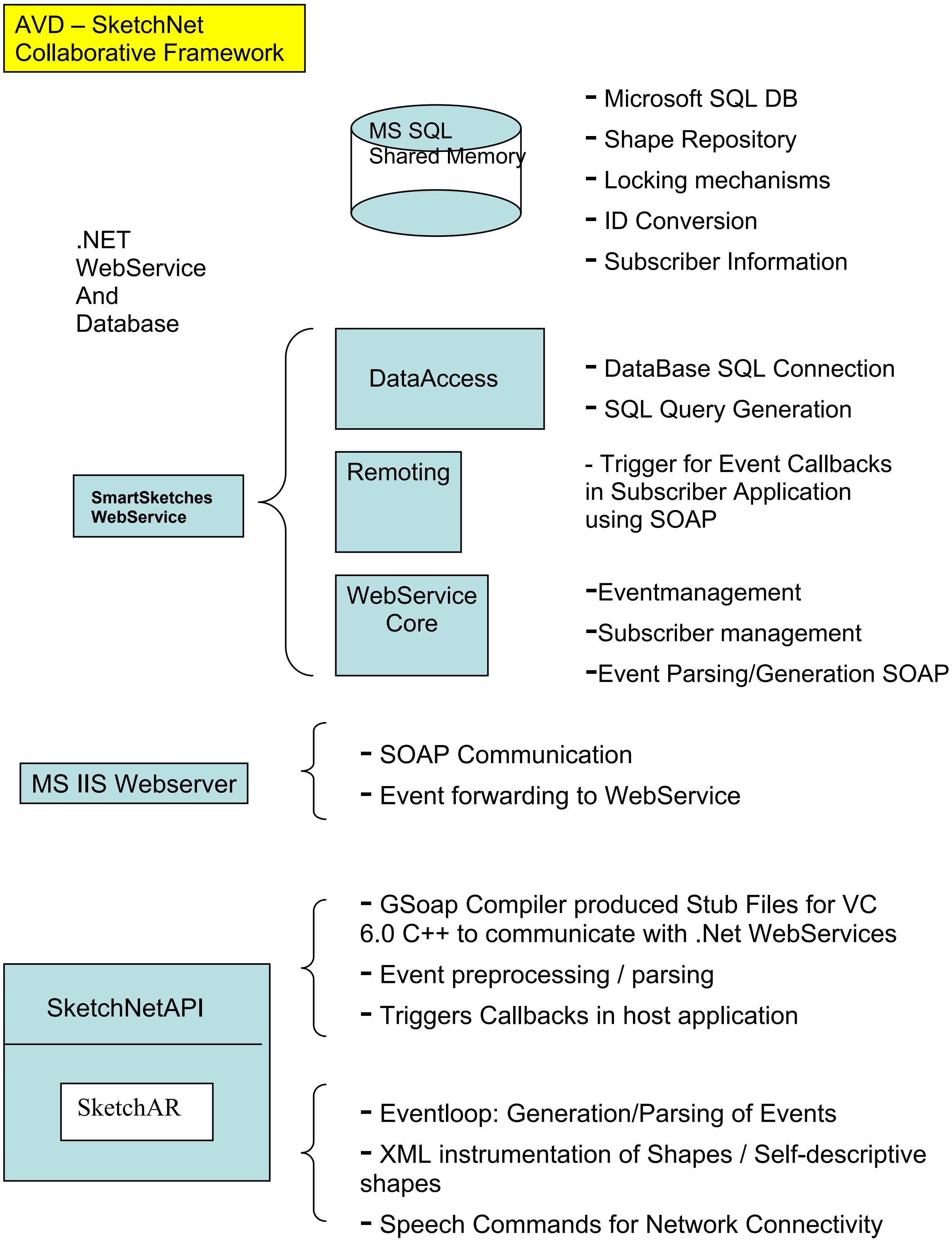


Figure 50: SketchNet

On the server-side there is a Web Server, which hosts a Web service. The Web Service is made of three parts. One is the business logic to process subscriptions and incoming events to an SQL data base which is used as shared memory. The second part is a Data Access Module which handles connection to the database and executes table modifications. The third part is a SketchNET remoting Module used to establish a connection back to each subscriber.


AVD – SketchNet
Collaborative Framework
MS SQL
Shared Memory
- Microsoft SQL DB
- Shape Repository
- Locking mechanisms
- ID Conversion
- Subscriber Information
.NET
WebService
And
Database
DataAccess
- DataBase SQL Connection
- SQL Query Generation
SmartSketches
WebService
Remoting
- Trigger for Event Callbacks
in Subscriber Application
using SOAP
WebService
Core
-Eventmanagement
-Subscriber management
-Event Parsing/Generation SOAP
MS IIS Webserver
- SOAP Communication
- Event forwarding to WebService
- GSoap Compiler produced Stub Files for VC
6.0 C++ to communicate with .Net WebServices
- Event preprocessing / parsing
- Triggers Callbacks in host application
SketchNetAPI
SketchAR
- Eventloop: Generation/Parsing of Events
- XML instrumentation of Shapes / Self-descriptive
shapes
- Speech Commands for Network Connectivity

7.7.2 Connecting and Disconnecting to/from SketchNET

Operation	PIP	Pie	Gesture	Speech Recog-nition	Speech Synthes is	Inter-action Device
SketchNET Connect				"connect <username>"	Ack	Speech
SketchNET Disconnect				"network disconnect"	Ack	Speech
SketchNET Userlist				"userlist"	Returns users online	

SketchNET connection is activated and deactivated by speech commands. If a local user wants to connect to SketchNET he says: "connect <username>", where <username> is his name and the name he will be known to SketchNET. At the same time all events will be subscribed.

SketchNET connection is deactivated if a local user says: "network disconnect". He will unsubscribe from all events and log off SketchNET.

SketchNET provides a userlist of users online, it the user says: "userlist"

8 Annex A – References

[1] NVidia Corporation, USA
HomePage: **http://www.nvidia.com/page/quadrofx_family.html**

[2] ATI Corporation, USA
HomePage: **http://www.ati.com/products/fireglz1/**

[3] Advanced RealTime Tracking GmbH, Herrsching, Germany
HomePage: **http://www.ar-tracking.de/**

[4] 3D Connexion Company, USA
HomePage: **http://www.3dconnexion.com/**

[5] Fraunhofer-IGD, A2 Industrial Applications, Darmstadt, Germany
HomePage: **http://www.igd.fhg.de/igd-a2/index.html**

[6] StereoGraphics Corporation, USA
HomePage: **http://www.stereographics.com/**

[7] Barco Corporation, Belgium
HomePage: **http://www.barco.com/VirtualReality/**

[8] Liesegang Optoelectronics GmbH, Germany
HomePage: **www.liesegang.de**

[9] A.C.T. Kern GmbH & Co. KG, Germany
HomePage:
http://www.actkern.info/eHome/eProdukte/eprodukte.html

[10] Trivisio Prototyping GmbH, Germany
HomePage: **http://www.trivisio.de**

[11] Microsoft Corporation, Redmond, WA, USA
HomePage: **http://www.microsoft.com/windows/default.mspx**

[12] Mercury Computer Systems, USA
HomePage: **www.tgs.com**

[13] Spatial Corporation, Dassault Systems, France
HomePage: **www.spatial.com**

[14] TAO Corba Solution and ACE Abstract Socket Library, U.Washington, USA
HomePage: **http://www.cs.wustl.edu/~schmidt/TAO.html**

[15] Magic Software Utility Libraries
HomePage: **http://www.magic-software.com/SourceCode.html**

[16] Studierstube Augmented Reality Project, TU-Wien, Austria
HomePage: **www.studierstube.org**

[17] OpenTracker – Abstract Tracking System Support, TU-Wien, Austria
HomePage: **http://studierstube.org/opentracker/**

[18] Apache Software Foundation, USA
HomePage: **http://xml.apache.org/xerces-c/**

[19] Microsoft Corporation, Redmond, WA, USA
HomePage: **http://www.microsoft.com/speech/**

9 Annex B - Operation Table

Operation	PIP	Pie	Gesture	Speech Recognition	Speech Synthesis	Inter-action Device
Editing						
Move	Edit ->Move	Edit ->Move				Pen
Copy	Edit ->Copy	Edit ->Copy				Pen
Select	Edit ->Select	Edit ->Select	Ellipse		"(un-) selecting shape"	Pen
Delete All	Edit ->Erase	Edit-> delete All				
Delete Select	Edit-> Clear Select	Edit-> Delete Select	Rectangle		"deleting shape"	Pen
Undo	Edit->Undo	Edit->Undo	Bold Rectangle	"undo operation"	"undoing operation"	Pen
Redo	Edit->Redo	Edit-> Redo	Bold Triangle	"redo operation"	"redoing operation"	Pen
Curve Creation						
Free Sketch	Curve ->Free Sketch	Curve ->Free Sketch				Pen
Closed Sketch	Curve ->Closed Sketch					Pen
Line	Curve ->Line					Pen
NURBS Curve	Curve ->NURBS Curve	Curve ->NURBS				Pen
Freehand Spline	Curve-> Freehand Spline	Curve-> Freehand Spline				Pen
Poly Line	Curve-> Polyline					Pen
Tape Draw	Curve ->Tape Draw					Fingers
Surface Creation						
Spline Extrude	Surface-> Spline Extrude	Surface-> Spline Extrude				Pen
NURBS Surface	Surface-> NURBS Surface	Surface-> NURBS Surface				Pen
Skin Surface	Surface-> Skin Section	Surface-> Skin Section				Pen
Skin Select Surface	Surface-> Skin Select	Surface-> Skin Select				Pen
Net Surface	Surface-> Net Surface	Surface-> Net Surface				Pen
Net Select Surface	Surface-> Net Select	Surface-> Net Select				Pen

Coon Patch	Surface-> Coon Patch	Surface-> Coon Patch				Pen
Select Coon Patch	Surface-> Coon Select	Surface-> Coon Select				Pen
Primitive Creation						
Sphere	Primitive ->Shape1 ->Sphere					Pen
Quad	Primitive ->Shape1 ->Quad					Pen
Cylinder	Primitive ->Shape1 ->Cylinder					Pen
Cirular Cone	Primitive ->Shape1 ->CircCone					Pen
Cirular Prism	Primitive ->Shape1 ->CircPrism					Pen
Cirular Pyramide	Primitive ->Shape1 ->CircPyr					Pen
Ellipse Cone	Primitive ->Shape1 ->EllipCone					Pen
Ellipse Cone	Primitive ->Shape2 ->EllipCone					Pen
Ellipse Prism	Primitive ->Shape2 ->EllipPrism					Pen
Ellipse Pyramide	Primitive ->Shape2 ->EllipPyr					Pen
Circular Trunc Cone	Primitive ->Shape2 ->CircTrunc Cone					Pen
Circular Trunc Cone	Primitive ->Shape2 ->CircTrunc Cone					Pen
Circular Trunc Pyramide	Primitive ->Shape2 ->Circ Trunc Pyr					Pen
Ellipse Trunc Cone	Primitive ->Shape2 ->Ellip Trunc Cone					Pen
Ellipse Trunc Pyramide	Primitive ->Shape2 ->Ellip Trunc Pyr					Pen

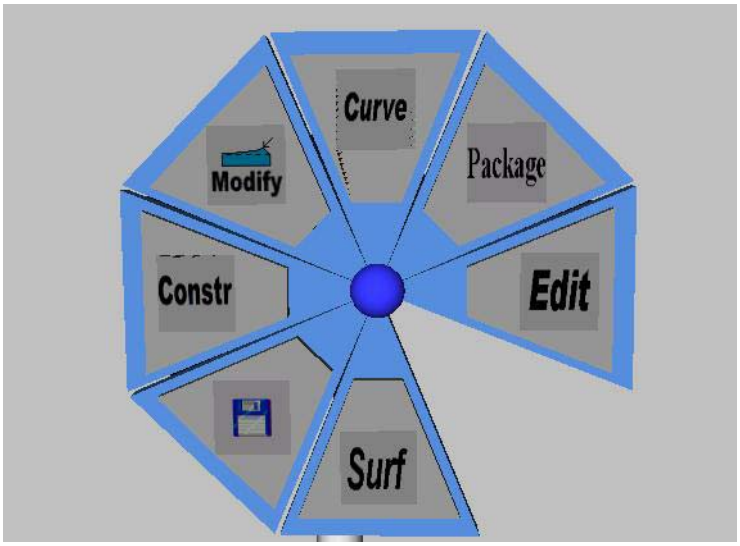
Conceptual Design						
Sliding Joint	Conc. Design-> Sliding Joint					Pen
Block with Hole	Conc. Design-> Block with Hole					Pen
Block with Bolt	Conc. Design-> Block with Bolt					Pen
Disc	Conc. Design-> Disc					Pen
Pivor Lever	Conc. Design-> Pivot Lever					Pen
Upright Bar	Conc. Design-> Upright Bar					Pen
Simple Block	Conc. Design-> Simple Block					Pen
Drilled Lever Bar	Conc. Design-> Drilled Lever Bar					Pen
Bolted Lever Bar	Conc. Design-> Bolted Lever Bar					Pen
Resize	Conc. Design-> Resize					Pen
Semantic Filter						
Semantic Filter On/Off	Context Specific Semantic Filter-> On/Off					Pen
Geometry Modification						
Edit Control Points	Edit-> EditCPs					Pen
Over-sketching	Edit-> Oversketch					Pen
Boolean +	Primitive ->Bool -> Bool+					Pen
Boolean -	Primitive ->Bool -> Bool-					Pen
Boolean Intersect	Primitive ->Bool-> Bool int					Pen
Realtime Boolean +	Primitive ->Bool					Pen

	-> Real+					
Realtime Boolean -	Primitive ->Bool -> Real-					Pen
Realtime Boolean Intersect	Primitive ->Bool-> Real int					Pen
Color Selection	Edit-> Material Editor			"black", "white", etc (7 colors)	"black", "white", etc (7 colors)	
Package						
Wheel Adjust-ment	Package-> Wheels	Package-> Wheels				Pen
Dimension Adjust-ment	Package-> Overall	Package-> Dimensions				Pen
Ergonomic Adjust-ment	Package-> Human	Package-> Ergomomic				Pen
Encum-brance Adjust-ment	Package-> Tech Free	Package-> Enc.				Pen
Package On/Off	Package-> On/Off					Pen
Collision Detection	Package-> Collision Detect	Package-> Collision Detect				Pen
Supporting Operations						
Snap	Tools-> Snap					Pen
Work plane	Tools-> Work- plane	Tools-> Work-plane				Plane, Pen
Work plane to Table	Tools-> Table Projection					Plane, Pen
Mirror plane	Tools-> Mirrorplane	Tools-> Mirror-plane				Plane, Pen
Clipping Plane	Tools-> Clipping Plane	Constraint ->Clip				Plane, Pen
Freeze Scene	Tools-> Model Toggle					Pen
Freeze View	Tools-> Head Toggle					Pen
Camera Zoom / Move	Tools-> Camera Sliders					Pen
Layer	Tools-> Layer					Pen
4 Side View	View-> FourView	View-> FourView				Space mouse, Pen
Ortho View	View-> OrthoView	View-> OrthoView				Pen

Constraint Operations						
Coincident	Primitive -> Constr. -> coincident					Pen
Parallel	Primitive -> Constr. -> parallel					Pen
Perpen- dicular	Primitive -> Constr. -> perpen- dicular					Pen
Tangent	Primitive -> Constr. -> tangent					Pen
Concentric	Primitive -> Constr. -> concentric					Pen
Dimen- sioning	Primitive -> Constr. -> dimension					Pen
Fix/ Unfix	Primitive -> Constr. -> (un)fix					Pen
Show / Free	Primitive -> Constr. -> show/free					Pen
Network Collaboration						
SketchNet Connect				“connect <username>”		Speech
SketchNet Disconnect				“network disconnect”		Speech

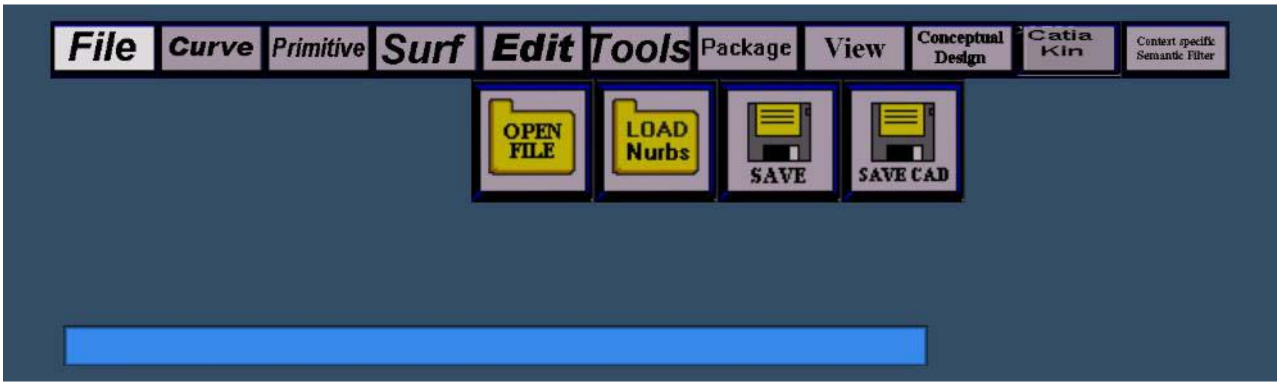
10 Annex C – Menu Reference

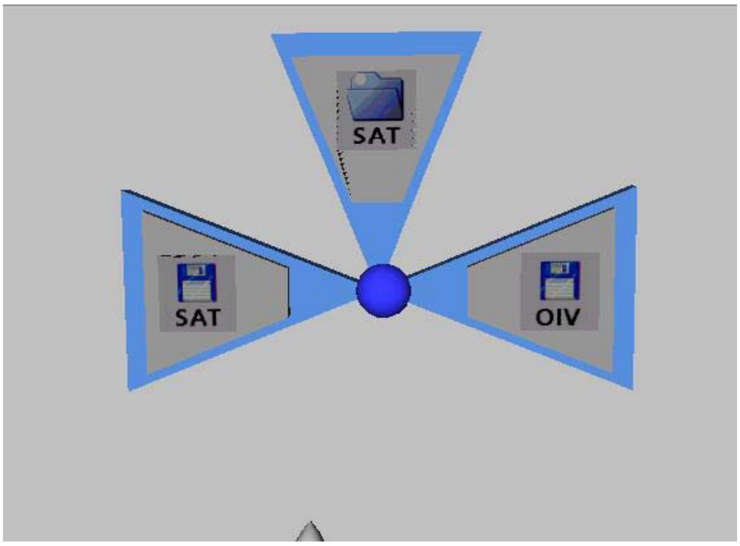
Functionality



Main pie menu

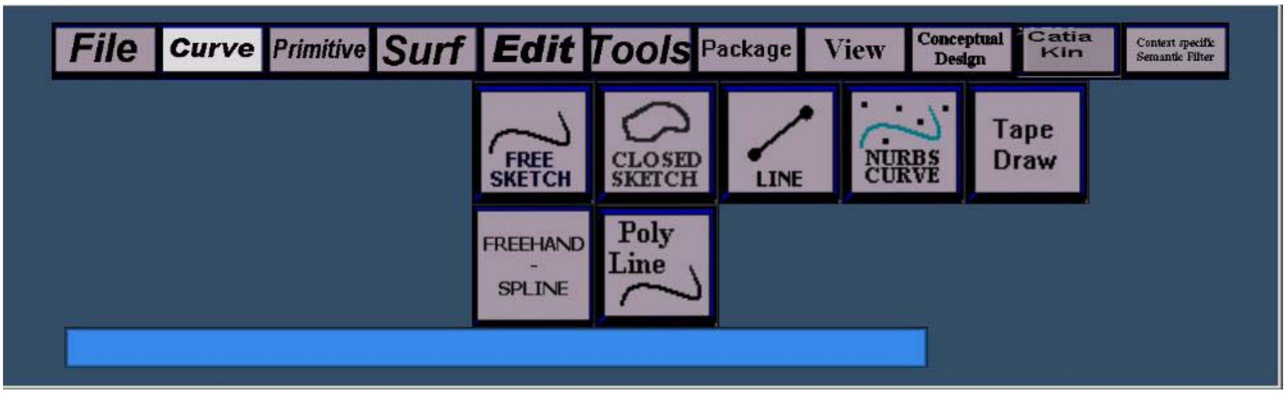
File

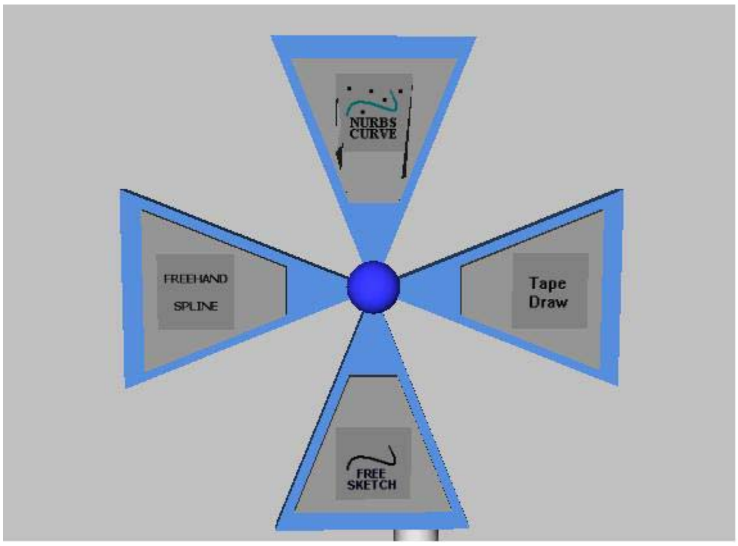




File pie menu

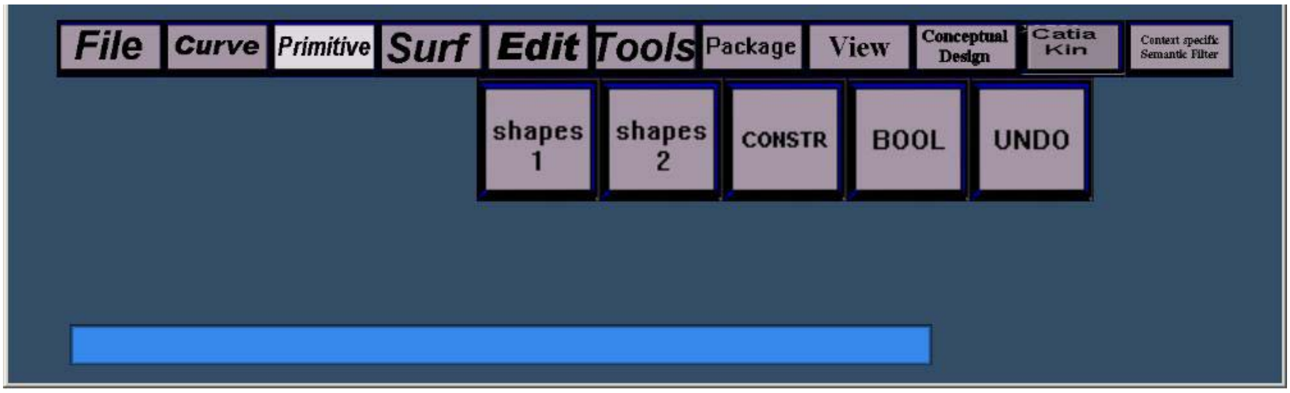
Curve



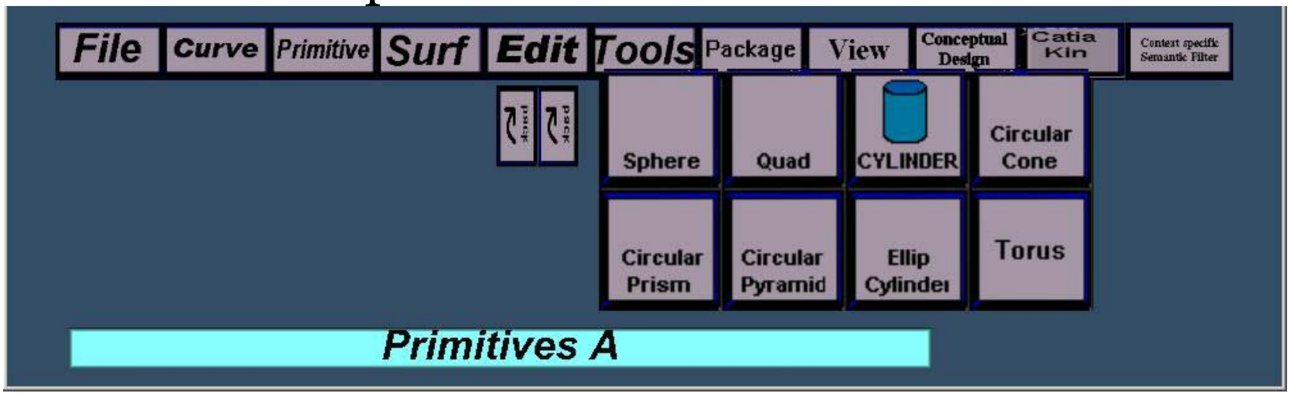


Curve pie menu

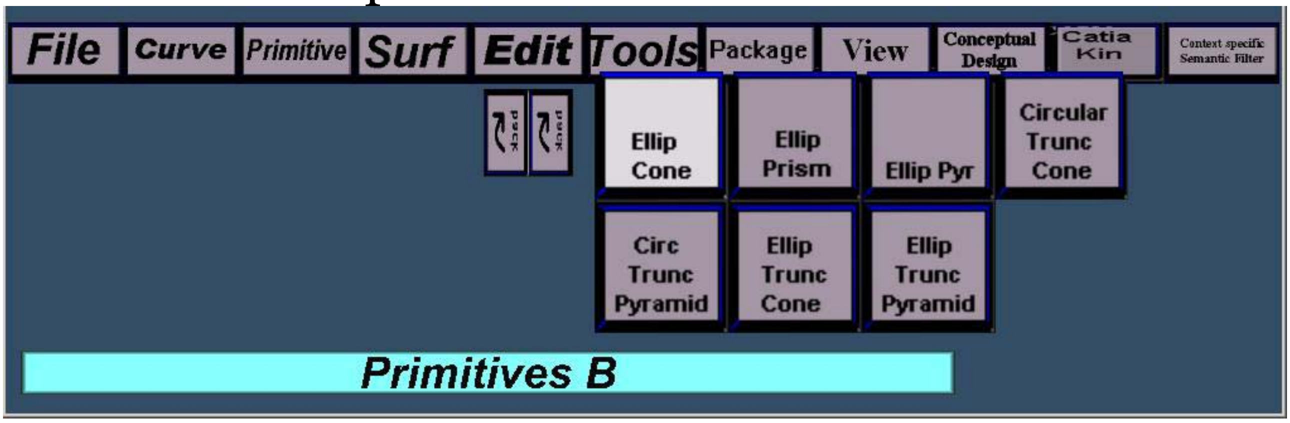
Primitive



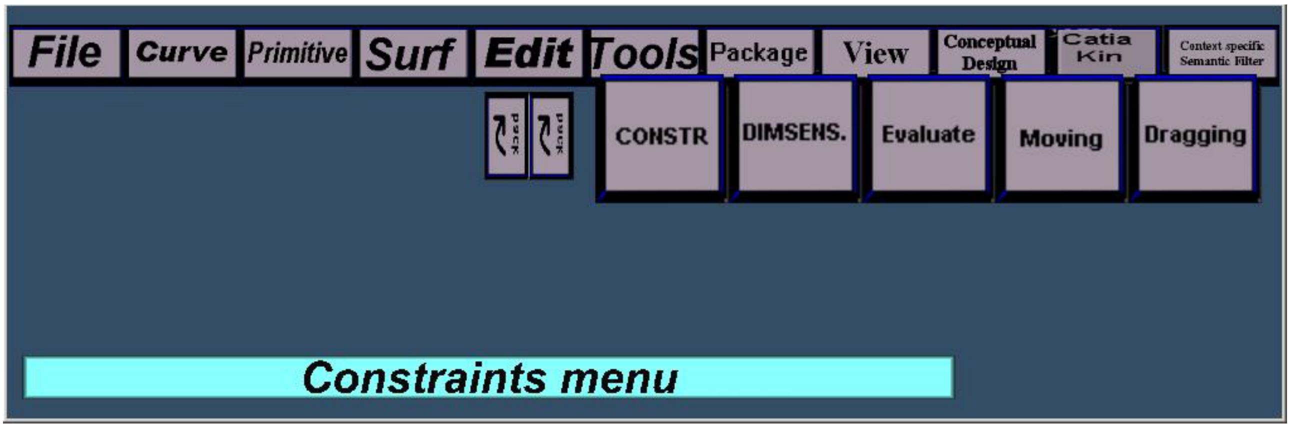
Primitive->Shape1



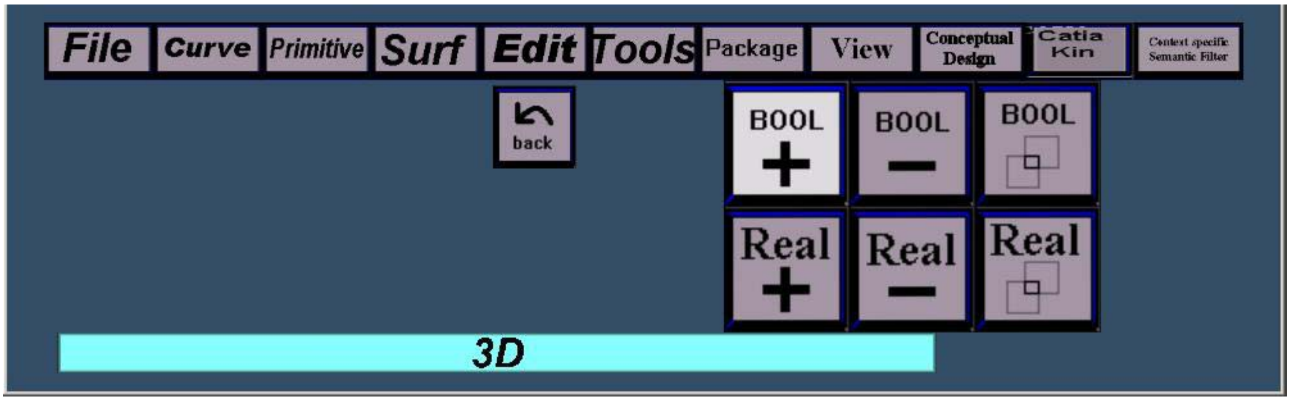
Primitive->Shape2



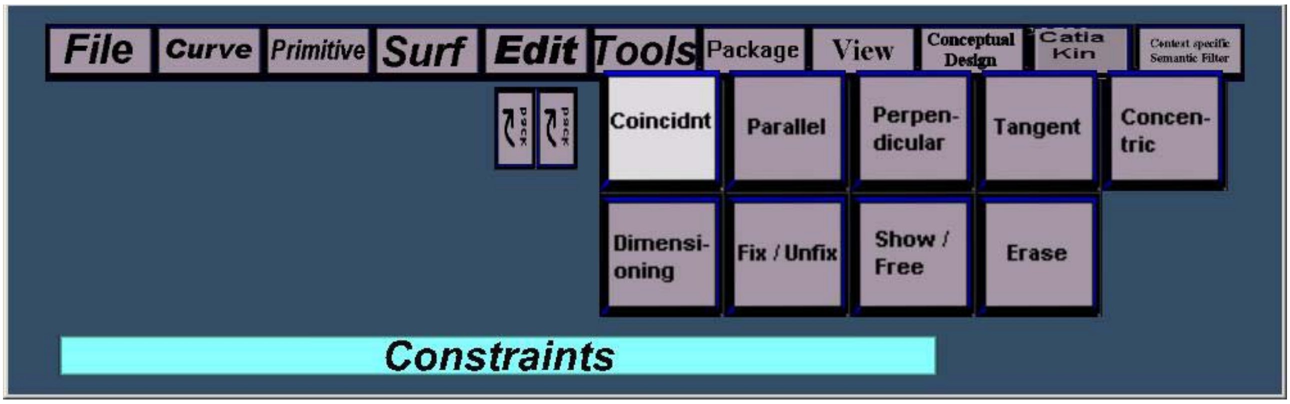
Primitive->Constraints



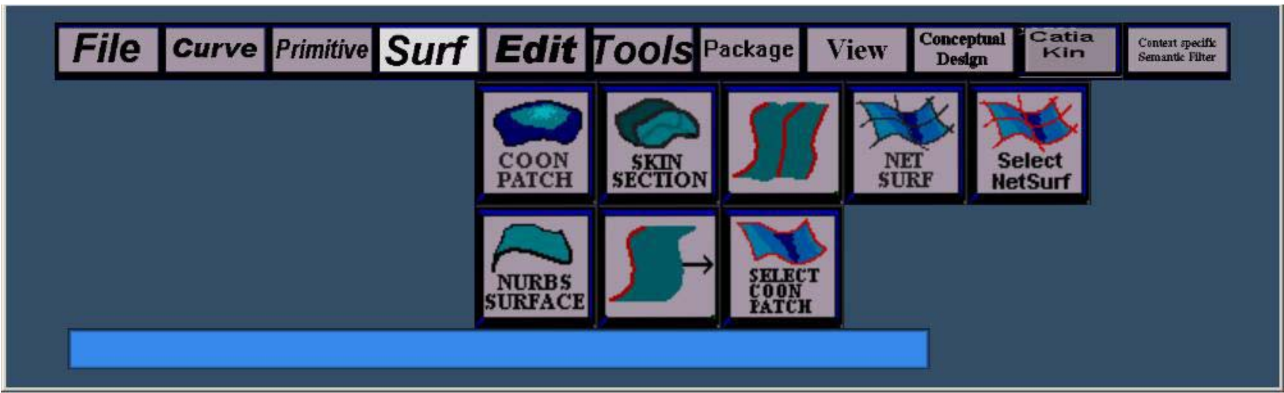
Primitive->Bool



Primitive->Constraints->Constr



Surf

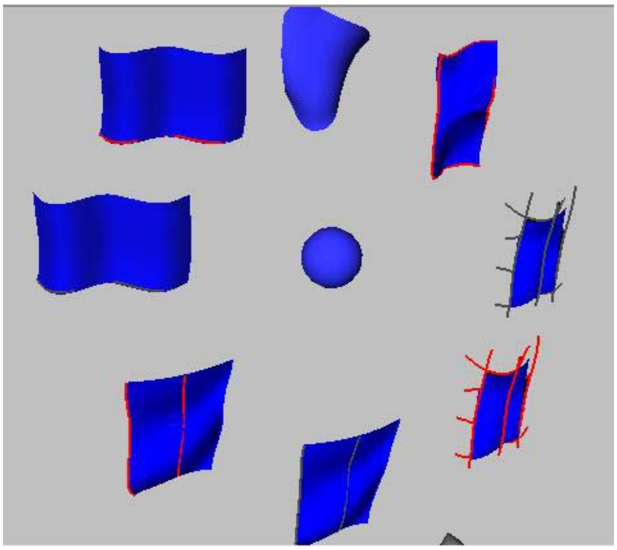


The surf menu allows to create:

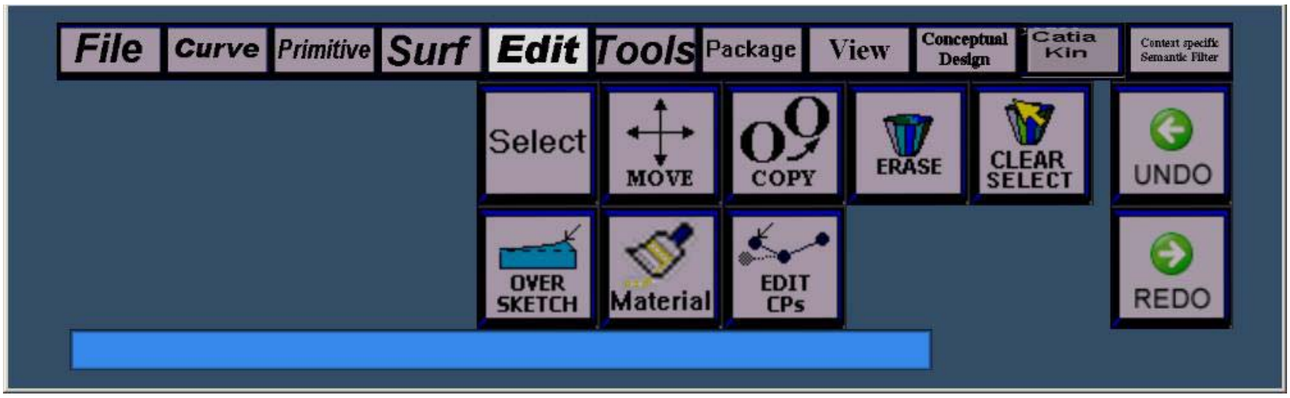
1. a Coons patch from one 3D stroke
2. a skin surface by sketching several 3D curves
3. a skin surface by selecting several existing 3D curves
4. a net surface by sketching several 3D curves in arbitrary order and direction
5. a net surface by sketching several existing 3D curves
6. a NURBS surface by sketching a curve and directly extruding it in a singe interactive step
7. a NURBS surface by extruding an existing 3D curve
8. a Coons patch by selecting 4 existing curves which have to match at its endpoints

For NURBS curve extrusion the eraser pen approach is active so that the operation can be partially undone by moving 'backwards'.

These operations are also available form a corresponding pie menu (see below).

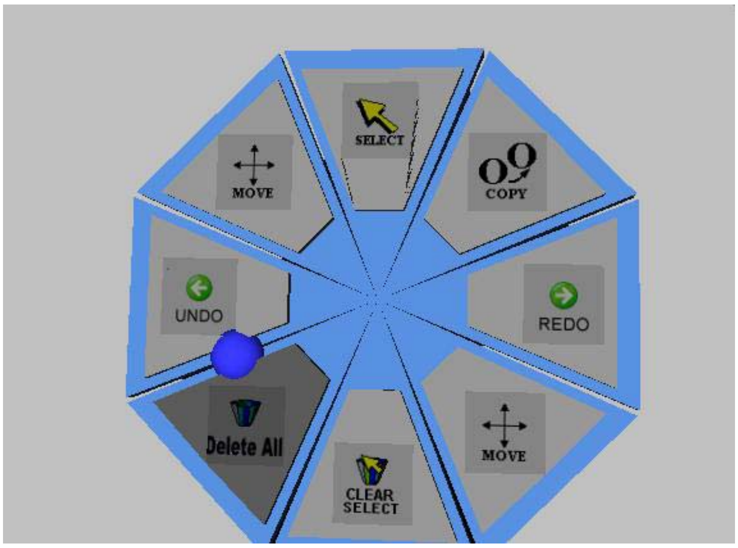


Edit



The edit menu allows to initiate the following operations:

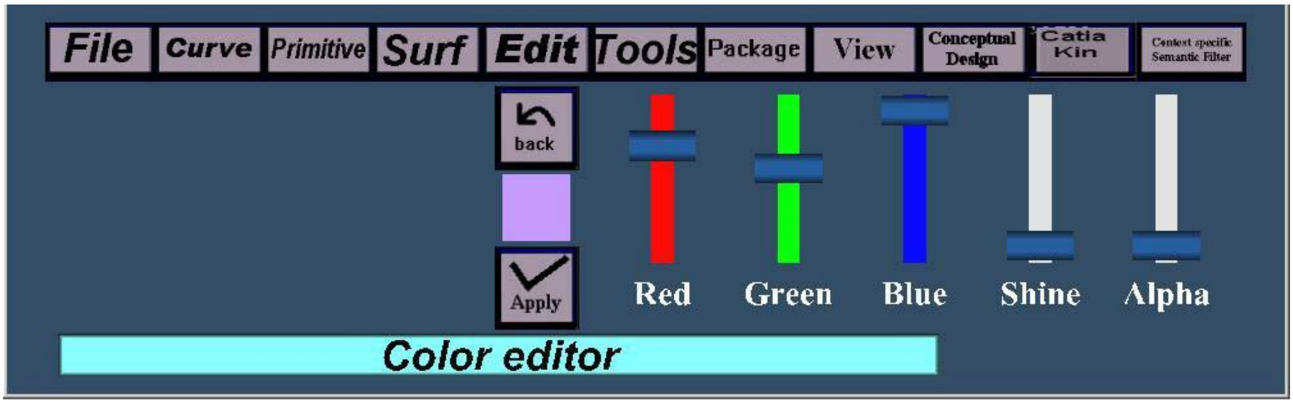
1. select a shape
2. move a shape
3. copy a shape
4. erase (delete) the selected shapes
5. clear the selection
6. UNDO the last operation (can be called successively)
7. REDO the last undone operation (can be called successively)
8. oversketching
9. material editor
10. edit control points



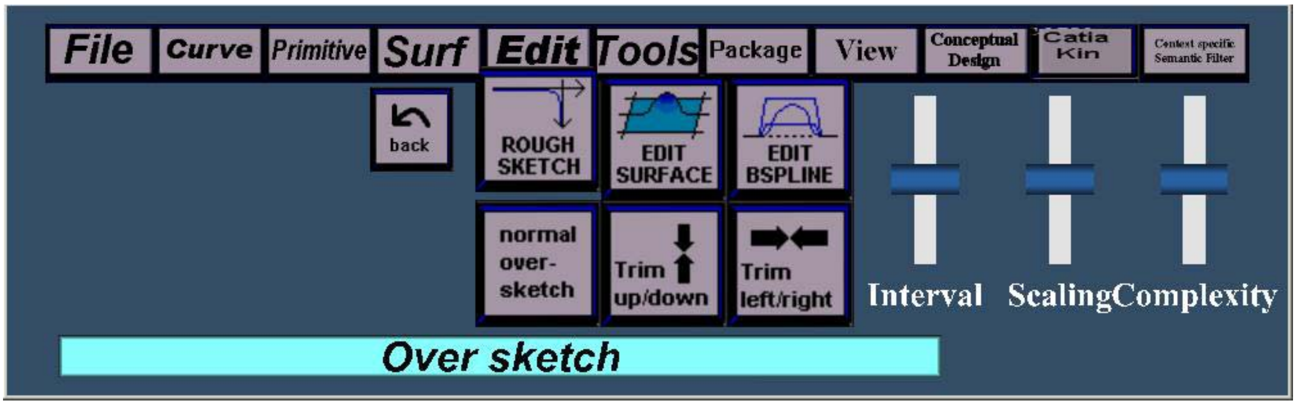
Edit pie menu

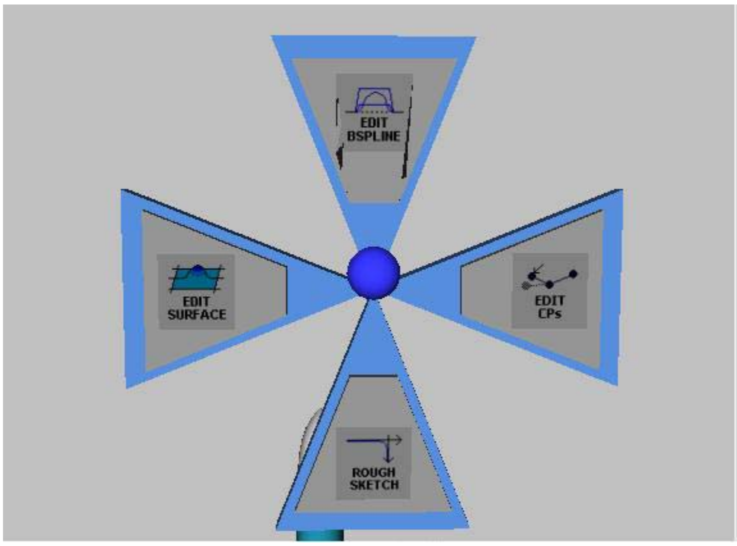
Edit->Material Editor

Edit->Material Editor->Color Editor



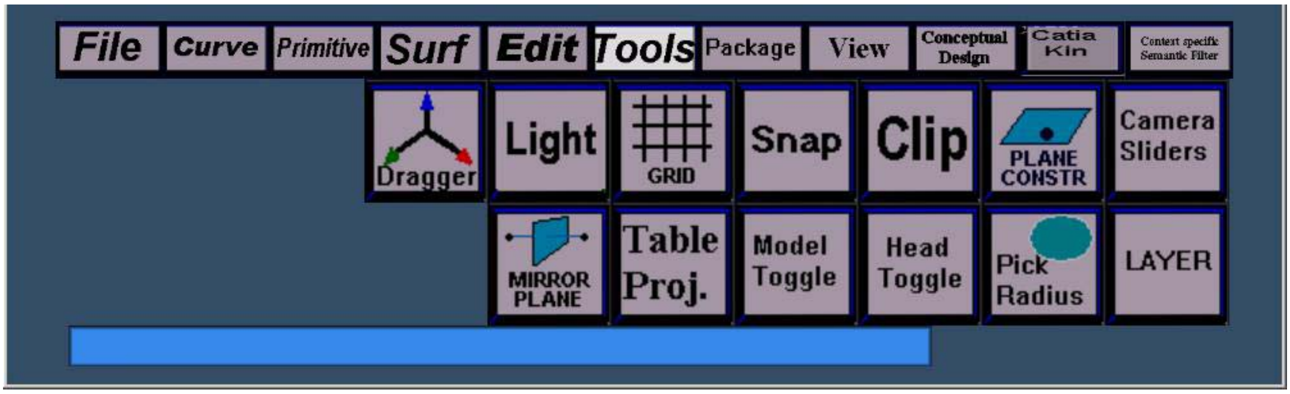
Edit->Oversketch

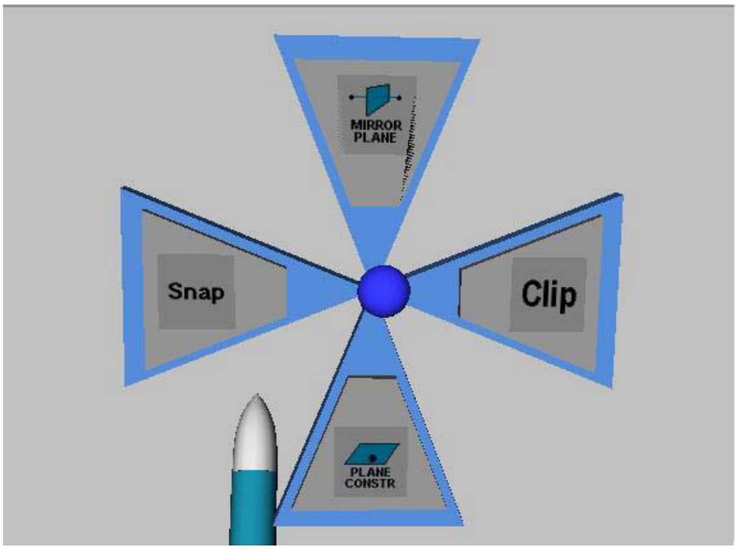




Modify pie menu

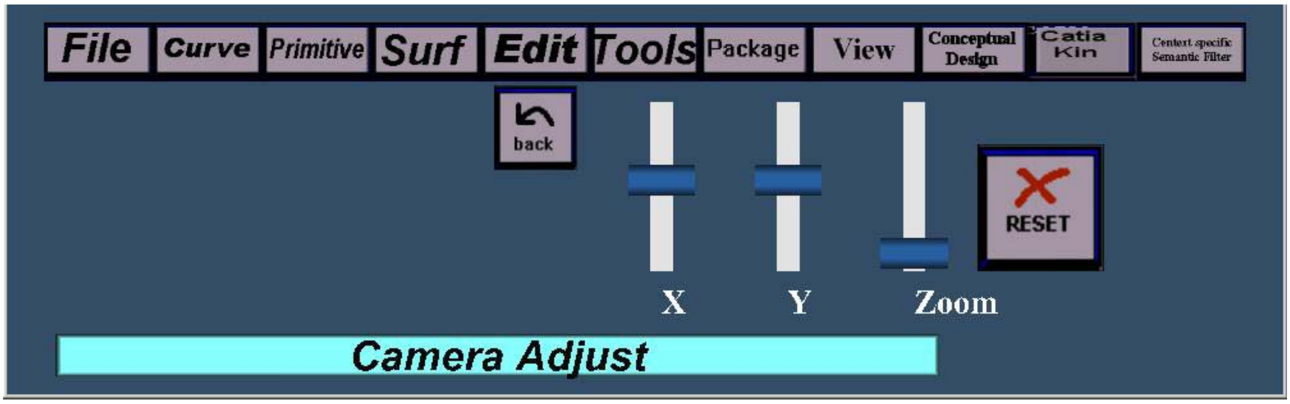
Tools



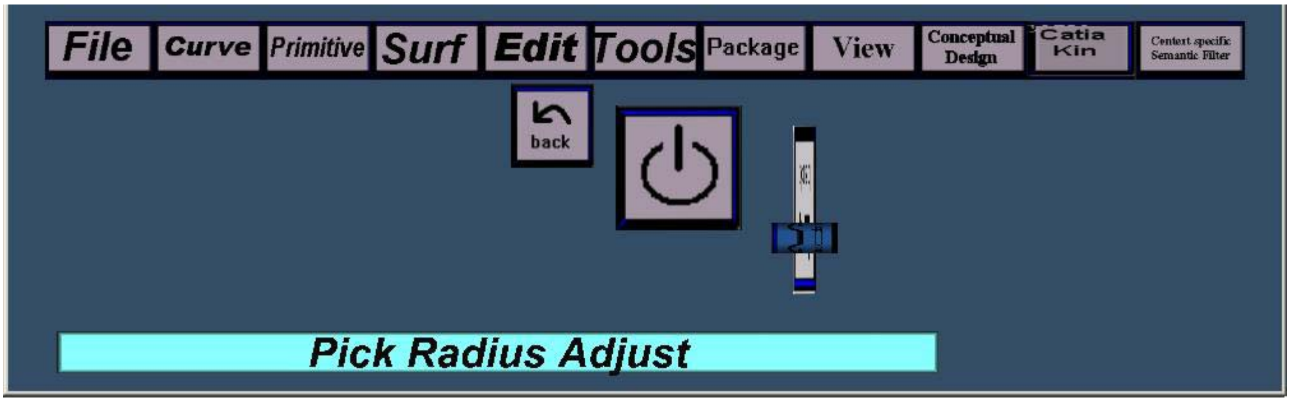


Tools pie menu

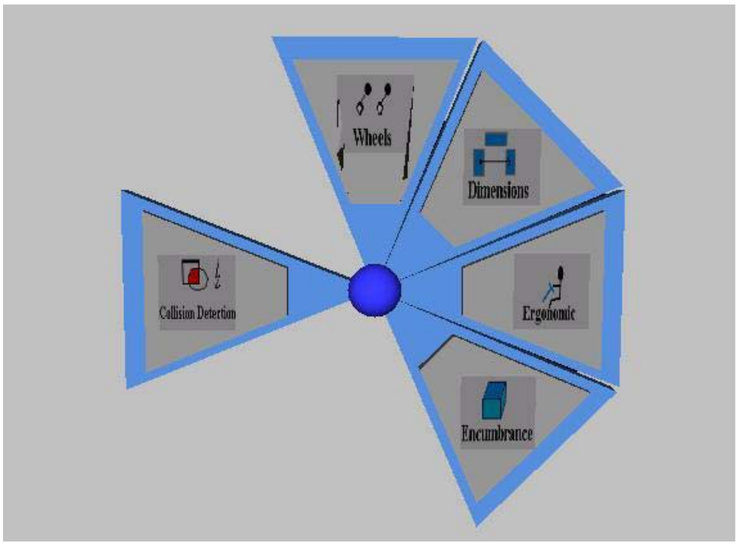
Tools->Camera Sliders



Tools->Pick Radius

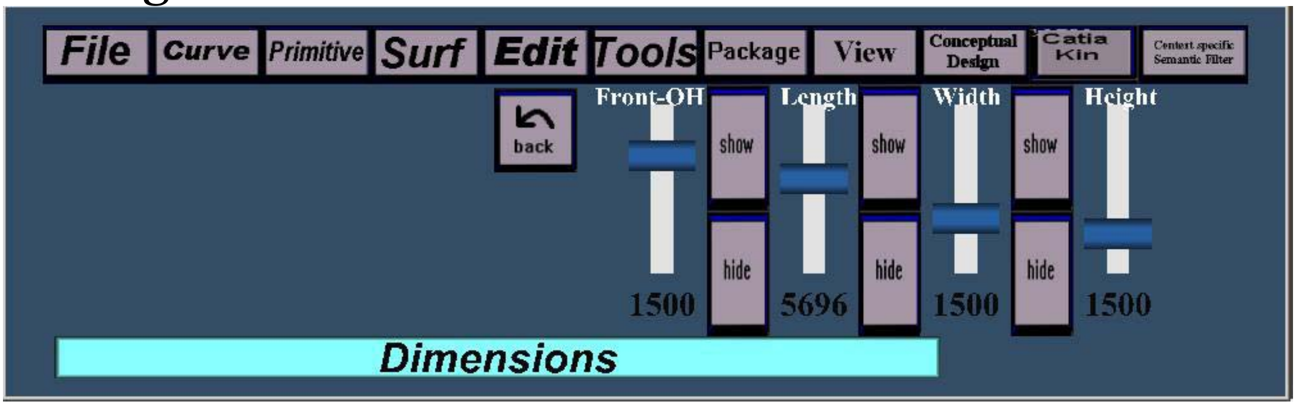


Package

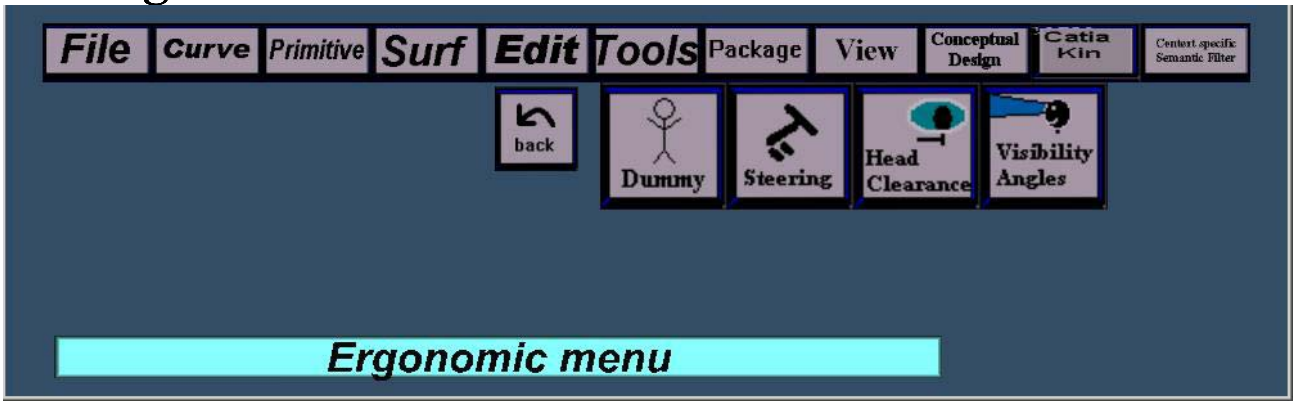


Package pie menu

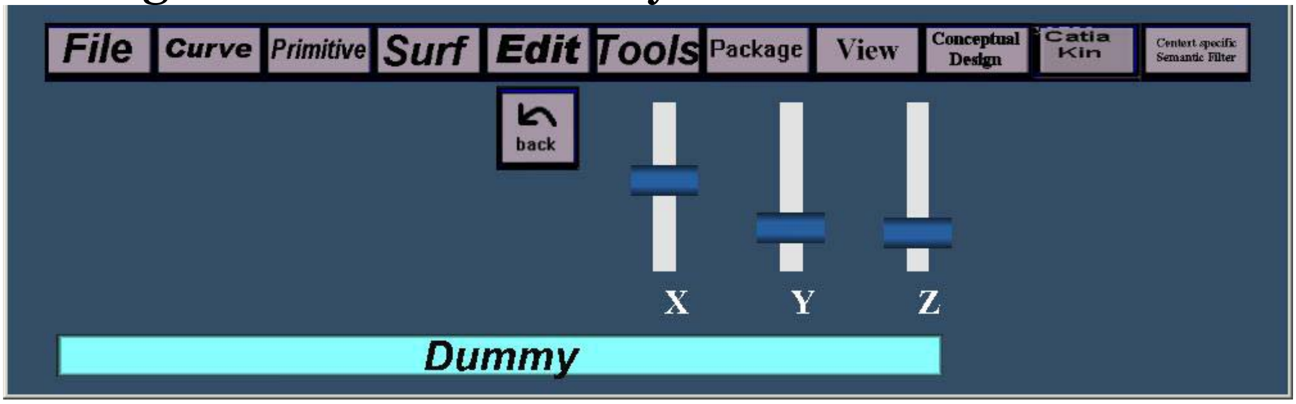
Package->Dimensions



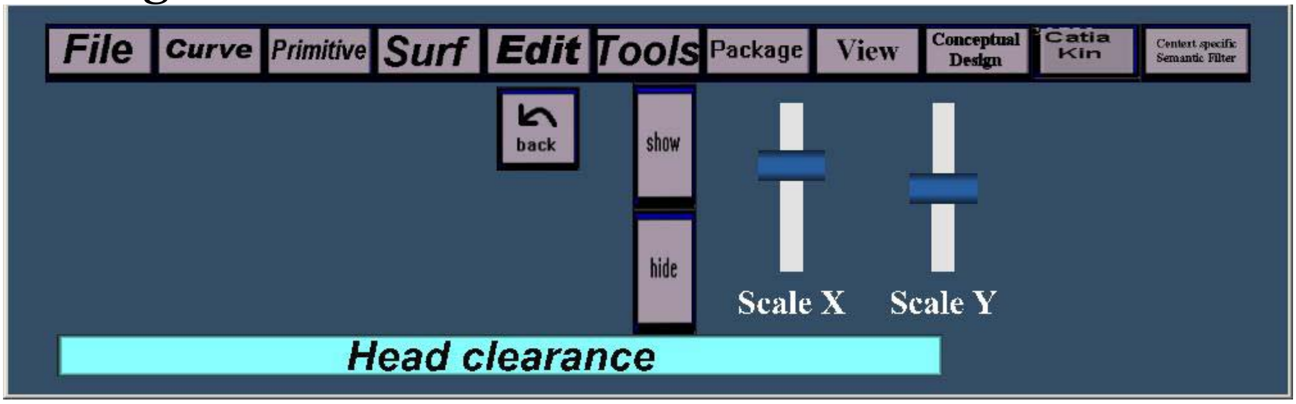
Package->Human



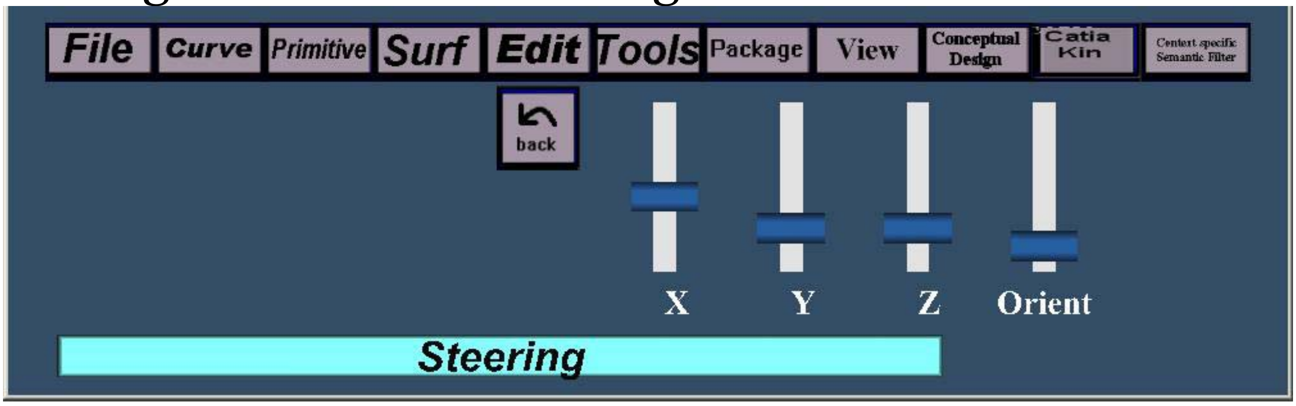
Package->Human->Dummy



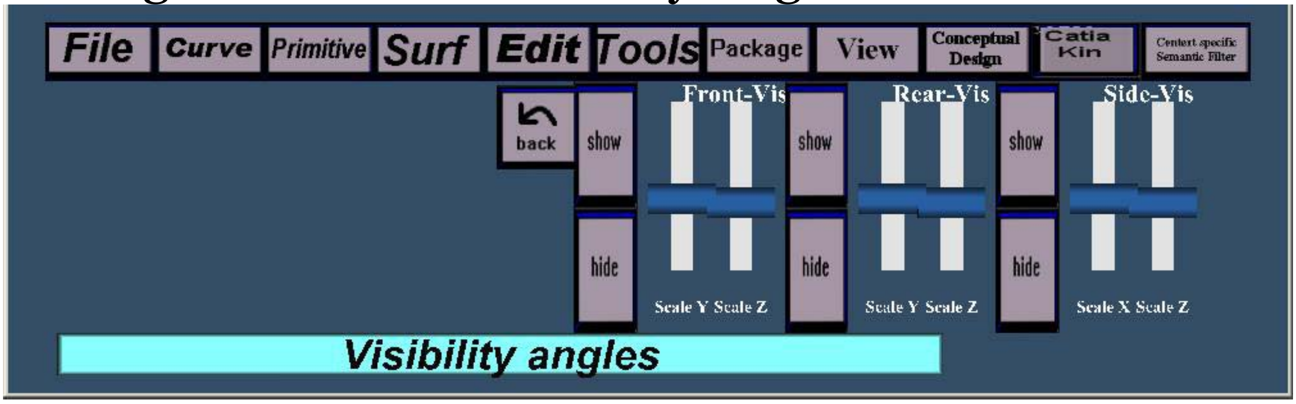
Package->Human->Head Clearance



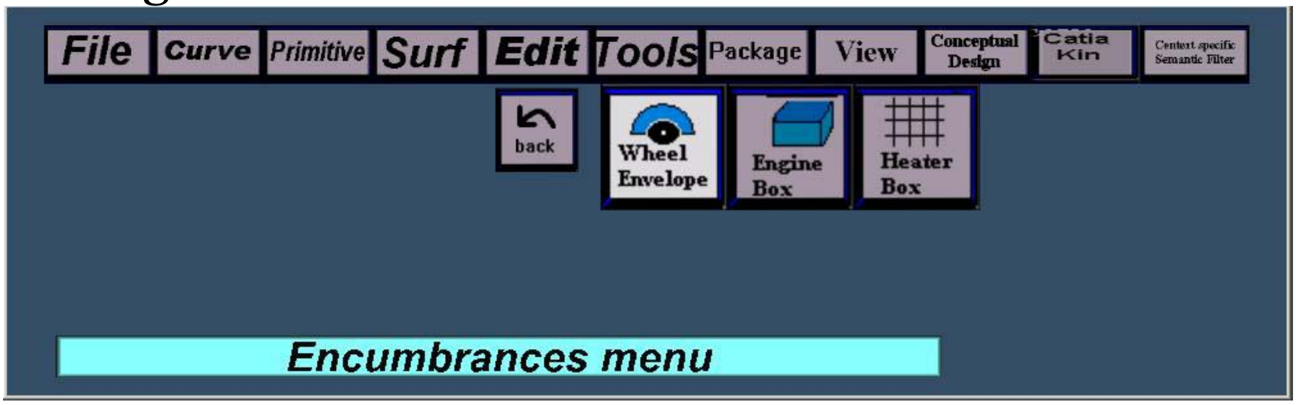
Package->Human->Steering



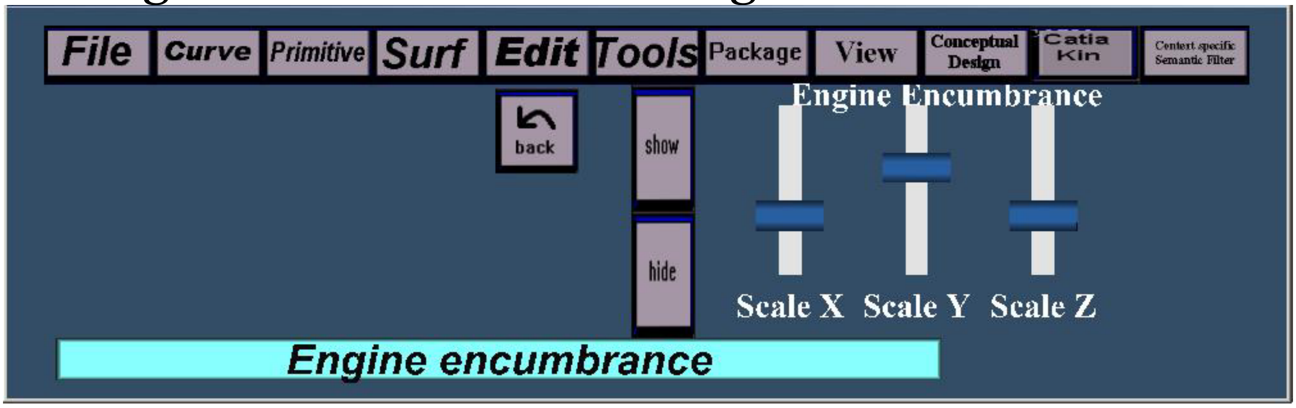
Package->Human->Visibility Angles



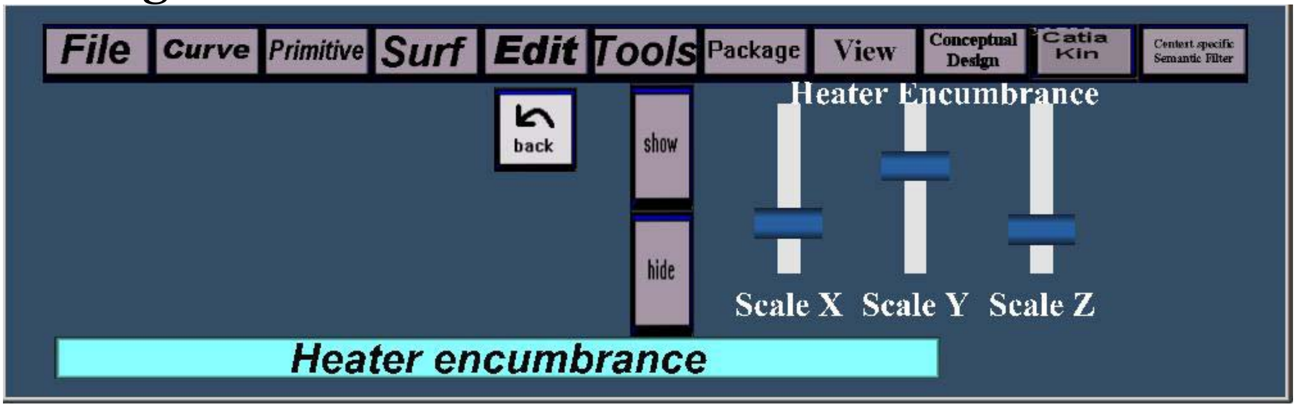
Package->Tech Clearance



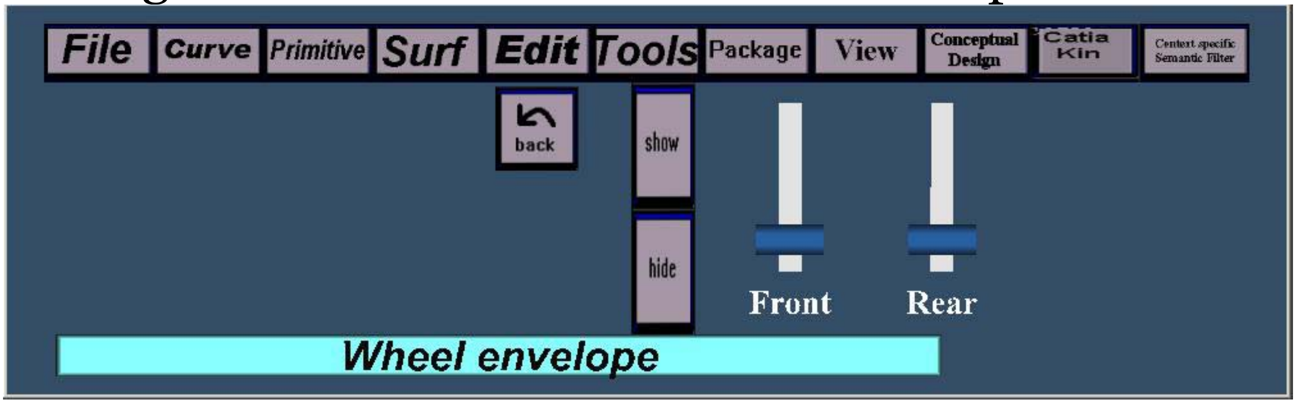
Package->Tech Clearance->Engine Encumbrance



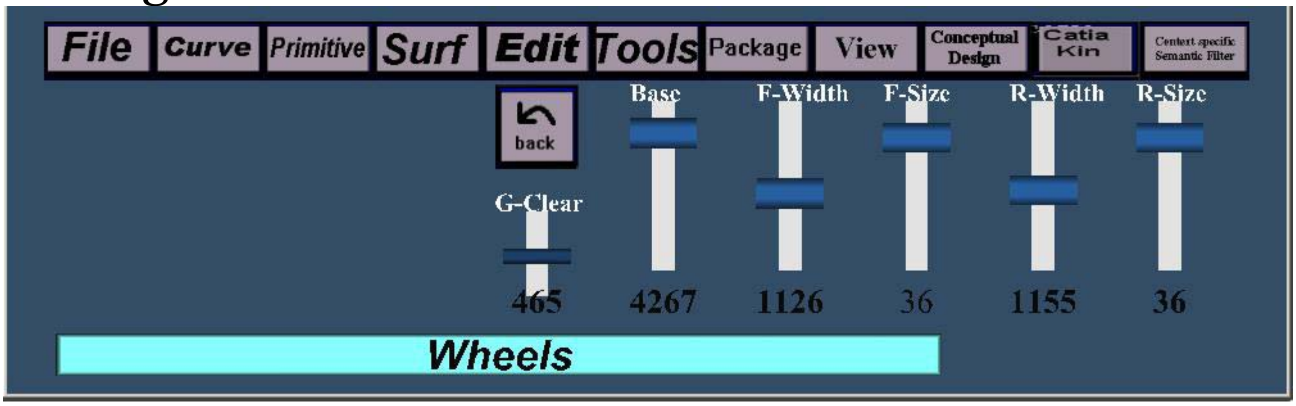
Package->Tech Clearance->Heater Encumbrance



Package->Tech Clearance->Wheel Envelope



Package->Wheels



View

Scene Modeling and Assembly