ABSTRACT: Conventional Computer Aided Design (CAD) systems usually use 1D and 2D input/output (I/O) devices for 3D shape modeling. These devices require mapping processes between I/O devices and the modeling space, resulting in a non-intuitive, complicated design interface and low throughput between the designer and the system. To overcome these deficiencies a new approach for geometric modeling in a multi-modal multi-sensory Virtual Environment (VE) has been developed. This system provides an intuitive and natural way of designing using hand motions, gestures and voice commands. This approach also allows the designer to be immersed in a stereoscopic display and synthesized sound output, which enables high throughput between the designer(s) and the system and paves the way for a collaborative design environment. This system also has been integrated with a commercial CAD system to combine the advantages of conventional CAD systems with Virtual Reality (VR) techniques.

KEYWORDS: virtual environment, virtual prototyping, concept design, detailed design, parametric modeling, collaborative virtual environment.

INTRODUCTION: Despite the advances in the field of CAD and solid modeling, shape modeling in the conventional CAD systems remains a tedious and time-consuming task. Most of the conventional CAD systems generally use 1D and 2D I/O devices for modeling in 3D geometric space, which results in a non-intuitive design interface, unnecessary steps in modeling and difficulties in visualizing the complex 3D shapes correctly. Also, these CAD systems require expertise and in-depth understanding
of the modeling process and the system itself, thus increasing the modeling time and learning time considerably. Due to the nature of the conventional CAD systems’ interface, only one I/O device (e.g. either keyboard or mouse and monitor) are effectively used at a time. Though the designer (human being) has the built in capability to communicate in a multi-modal, multi-sensory interface, the restrictions inherent in CAD systems leads to a considerable waste of human resources. Moreover, most CAD systems are designed such that only one person can use them effectively at a time, thus making the collaboration process a tedious task. To overcome these problems a new methodology has been developed for concept shape design, detailed shape design and parametric surface modeling in a Virtual Environment. This paper discusses the COnceptual VIRtual Design system (COVIRDS), Detailed Virtual Design System (DVDS), parametric freeform surface modeling in VE and the hardware setup of the Virtual Design System.

DIFFERENCES BETWEEN CONVENTIONAL CAD SYSTEMS AND VR-CAD SYSTEMS: Figure-1 shows the mapping process in conventional CAD systems. The human sensories used in these systems are hands, fingers and eyes.

![Fig. 1 - I/O Interface in conventional CAD systems](image)

Figure-2 shows the interface in DVDS, where mapping processes are eliminated and high throughput between the designer and the system is achieved by multi-modal and multi-sensory interface. The human sensories used in VR-CAD systems are mouth, fingers, hands, head, body, eyes, skin and ears.

CONCEPTUAL VIRTUAL DESIGN SYSTEM (COVIRDS): Concept design is the phase of product design in which the overall functionality and shape of the product is determined. Details such as exact dimensions, positioning and tolerances are dealt with in the detailed design phase, rather than the concept design phase, allowing the designer more freedom in determining the features of the product. Most of the current CAD systems require the designer to define the model very precisely, and in many cases they do not allow the design to be easily modified later in the process. VR is an ideal tool for conceptual design, which requires a minimal amount of user input to create the concept shape. Through stereoscopic display it allows much-improved visualization of the design.

![Fig. 2 – I/O Interface in DVDS](image)
COVIRDS consists of two basic components: (i) user interaction and (ii) shape representation via virtual modeller. A multi-modal interface using voice and hand [3], [4] has been used for an intuitive input interface. To meet the requirement of real time interaction and editing of geometric shapes, a dual graph representation [5], [6] and D&S graphs (Design intent and Shape modelling graphs) are used in the virtual modeller. In this system the geometric primitives such as spheres, block, cylinder, wedges etc. are efficiently represented using D&S graphs to design and edit concept shapes.

DETAILED VIRTUAL DESIGN SYSTEM (DVDS): Detailed design involves the development of a detailed model of the product. This includes defining features, determining their dimensions, tolerances, materials, manufacturing processes, etc. Almost all CAD systems are developed for detailed design. But due to the interface and interaction techniques, they make shape modeling a tedious and non-intuitive task. The nature and architectural development of the DVDS provides higher dimensional, multi-modal, multi-sensory interaction between the designer and the system, thus making the designing process easy and intuitive.

DVDS is an intermediate software layer that resides between the hardware layer and the commercial CAD system. DVDS’ command parser module efficiently synchronises the multi-modal, multi-sensory I/O interface between the several I/O devices and the CAD system. Due to the architectural design of the conventional CAD systems’ interface, the sequence of operations is generally unidirectional. Since DVDS supports multi-modal, multi-sensory I/O, it allows the designer(s) to perform multiple operations simultaneously, for example changing the dimension of a feature while changing the orientation of the part using another mode of input.

Since the data at the solid modeling kernel level cannot be updated in real-time (i.e. >30fps for mono and >60fps in stereo mode) while editing the geometry, a new concept called “Liquid Features” is introduced. Liquid features can be edited/modified in real-time and once the operation on these features is completed it updates the data in the solid modeling kernel database.

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![System Architecture of DVDS](image)
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional CAD Systems</th>
<th>COVIRDS</th>
<th>DVDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept design</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Detailed design</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Parametric modeling</td>
<td>Yes</td>
<td>Limited¹</td>
<td>Yes</td>
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<tr>
<td>Intuitive design steps</td>
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<td>Yes</td>
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<tr>
<td>Industry standard CAD representation</td>
<td>Yes</td>
<td>Limited²</td>
<td>Yes³</td>
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<td>Multi-modal input</td>
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<tr>
<td>Multi-sensory interface</td>
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</tr>
<tr>
<td>Immersive display</td>
<td>No³</td>
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<td>Yes</td>
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<tr>
<td>Collaborative design</td>
<td>No</td>
<td>No³</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1 – Primitive based parametric modeling  
2 – Maintains its own representation and file format  
3 – Uses the same representation as that of the underlying CAD system  
4 – Allows only for viewing, not in editing mode

**Table 1 – Feature comparisons between conventional CAD Systems, COVIRDS and DVDS**

**SYSTEM SETUP:**

**Hardware:**
- Intergraph Realizm II (Rendering Engine)
- Ascension flock of birds (3D tracking)
- 5th Dimension Data glove (Hand gestures)
- IBM microphone set (Voice input)
- Electrohome projector (Stereoscopic projection)
- CrystalEyes emitter and glasses (Stereoscopic viewing)
- Sony speaker (Synthesized 3D sound output)

**Software:**
- WorldToolKit library (Graphics library)
- Visual C++ (Compiler)
- SolidWorks-99™ (Commercial CAD system)
- IBM Viavoice (Voice recognition)

**Fig. 4** – Model at intermediate stage. “Liquid Feature” shown in red/yellow shade

**Fig. 5** – Completed model created in DVDS

**Fig. 6** – Parametric Surface Model

**Fig. 7** – Multiple Designers collaborating in Virtual Environment
SUMMARY: This paper presents researches about a new paradigm developed for concept and detailed shape modeling in a multi-modal, multi-sensory Virtual Environment. The development of Conceptual Virtual Design System (COVIRDS), Detailed Virtual Design System (DVDS) and the hardware set-up of Virtual Design System is described.

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REFERENCES
IMAGE GALLERY

(Models created using the COVIRDS, DVDS)