Augmenting Product Development with Virtual Reality

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1. What is Virtual Reality?
2. VR – historical overview.
3. Structure and basic principles of VR systems.
4. Types of VR systems.
5. Main application areas of VR systems.
6. VR application projects at the VR lab of the technical university of Sofia.
7. VR in product design education at the Faculty of German Engineering and Industrial Management Education, TU - Sofia.
What is Virtual Reality?

Virtual Reality (VR) is an environment that is simulated by a computer, trying to imitate the real space.

• Most virtual reality environments are primarily visual experiences:
  – Displayed either on a computer screen, through special stereoscopic displays or other displays
  – Sound through speakers or headphones
• Some simulations include additional sensory information
  – Limited tactile feedback etc.

"French Higher School L’École de design Nantes Atlantique offers master program Virtual Reality Courses are presented in English"
Commonly it could be referred to “a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels” [Burdea, 2003].

VR is based on so called 3 “I’s”:

1. Immersion,
2. Interaction, and
3. Imagination.
1. **Immersion** - VR applications give users a sense of immersion into some sort of virtual space. This space can model physically existing reality, or be something entirely fictitious.
VR Main Elements

2. **Interaction** – the virtual objects in the virtual environment can be selected and manipulated in a manner equal or very close to those in an natural environment.

3. **Imagination** – the computer generated environment stimulates the imagination of the user – the VR system can be considered as some sort of CAI equipment (CAI stands not for Computer Aided Instruction but rather for Computer aided Imagination).
VR Definition

• Virtual Reality (VR) is an environment that is simulated by a computer, trying to imitate the real surroundings – to create a realistic-looking world, a believable computer-generated experience.
• Engage multiple channels and stimulate several senses:
  – Visual presentation, displayed either on a computer screen, through special stereoscopic displays or other displays
  – Sound through speakers or headphones
  – Some simulations include additional sensory information
  – Limited tactile feedback etc.
Traditional work with computer

Test of Bill Buxton: Draw in 15 sec computer

About 80 % draw screen, keyboard and mouse.

The user implements the computer basically through input/output technologies.
Development of the computer Hardware

Moore’s Law

Double the performance every 18 months
Development of the potentials of the human’s brain

constant

Need to improve the interface
HCI
Standard HCI (Human – Computer Interface)

Unchanged during the last 25 years

Based on Windows, Icons, Menus and Pointers.

**WIMP** (Windows, Icons, Menus and Pointers)
Only screen resolution increases – the basic principle remains unchanged.
Standard HCI (Human – Computer Interface)

Technology for people with:
- one eye
- one ear
- one hand
- one finger
- without mouth
- without body
How to develop HCI?

Not only WIMP.

Immersion – be in the environment – increase this feeling through additional sensorial channels.

(www.w2vr.com)
Basic features:

- Virtual content
- Immersion
- Real time feedback
- Interaction
- Imagination
Old China’s proverb:

Hear – Forget
See – Memorize
Examine – Understand

虚拟环境使得有可能对模拟环境进行检查，并对其进行测试和验证其特性在接近自然条件下的性能。

老 于 Laozi
6 BC.
Augmented Reality

Real environment enriched with computer generated objects
Augmented Reality - Technologies

Two basic principles:
• optical seethrough - left
• video seethrough - right
Virtual commercial – Text “Pacific Bell” и “Pennsylvania Lottery” is AR.
VR - Historical Overview

First Generation: 1960-1985

"Virtual reality workstation"
Invented by M. Heilig 1962
Simulation of a motorcycle ride, no computers used!
Stereo movie
Sound
Smell
Wind
Vibrations

Morton Heilig Sensorama (1962)
VR - Historical Overview

First Generation: 1960 - 1985

– Ivan Sutherland, Ultimate Display (1970)
Presentation Outline

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VR - Historical Overview

Second Generation: 1985 - 1995

– Scott Fisher, VIEW (1985)

First Commercial Systems
Second Generation: 1985 -1995

First Applications – Game with Data glove and HMD (Head Mounted Display)
Second Generation: 1985 - 1995

First Applications – Virtual walk-through
Second Generation: 1985 - 1995

First Applications – Surgery simulations
Third Generation: 1995 - 2000

**Summary:**
- Graphics supercomputers SGI
- Immersive Projection Technology - IPT
- Industrial Applications

- Example: CAVE

(Cave automatic virtual environment)
Third Generation: 1995 - 2000

- Stereoscopic projection
- Workbench
- CAVE (Cave Automatic Virtual Environment)
Third Generation: 1995 - 2000

- Marker based AR System
Forth Generation : 2000 - today

**Summary:**
- Mobile AR system.
- Various, but expensive
  Software tools.
Fourth Generation: 2000 - today

**Summary:**
- Hardware components are available: PC clusters, stereoscopic visualization, sensors
- Missing standards
- Missing standard workflow
The 4DX Technology – old idea in a new implementation

Developed by CJ 4DPLEX, functionality quite close to “Sensorama”
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Traditional structure – [Burdea and Coiffet]
Conceptual model of VR system
Conceptual model of VR system

**Virtual world** – description, storage and representation of the virtual world, mainly in the form of the so-called Scene Graph.

[Diagram of VR system components]

- **Virtual world**: Description of the objects in the scene in the form of a scene graph.
- **Simulation Processor**: Behavior simulation of the objects in the virtual world.
- **Input processor**: Processing of the input signals.
- **Output processor**: Rendering: Calculating and generating of the output signals.
- **Format transformation**: CAD model, FEM model.
- **Description of the objects’ behaviour**.
- **Contact surface**: User – VR environment (CHI issues: metaphor, task).
- **Input devices**: Tracking system, Bluetooth, WiFi.
- **Output devices**: Video channel, Audio channel, Haptic channel.
Simulation processor – simulates the behavior of the objects in the virtual world – usually scripts, describing the behavior are activated when some event occurs.
Conceptual model of VR system

Input processor – signals acquisition and processing.
**Conceptual model of VR system**

**Output processor** – calculating of all output signals (rendering): the scene graph is traversed and all output signals are calculated, generated and transferred to the output displays.
The VR system is a multimodal (multisensory) system.

The VR system stimulates user senses for:

**Vision** – stereoscopic image (the user can estimate the 3rd dimension – the depth)

**Hearing** – space sound (taking into account reflection and absorption of the sound waves by objects in the virtual scene)

**Touching** – with and without force feedback
Stereoscopic image – the basic principle

Our brain combines: 2 slightly different images, delivered to the brain by the left and the right eye respectively.
Stereoscop

Basic principle: to show 2 slightly different images separately to both eyes of the user.
Stereoscopic basics

**Parallax**: an apparent displacement or difference in the apparent position of an object viewed along two different lines of sight.
**Stereoscopic basics**

**Parallax**: an apparent displacement or difference in the apparent position of an object viewed along two different lines of sight.
Stereoscopic basics

**Parallax and convergence** (angle between optical axes of both eyes – this information is processed by our brain and the depth (the distance to the observed object) is estimated.

Diagram showing the relationship between eye separation, focal length, projection plane, and apparent point.
The differences in the two retinal images are called horizontal disparity, retinal disparity, or binocular disparity.
Stereoscopic clues

Motion Parallax
Adding Sound

Three Stages: Modeling, Propagation, Rendering

Modeling
- Acoustic Geometry
  - surface simplification
- Acoustic Material
  - absorption coefficient
  - scattering coefficient
- Source Modeling
  - area source
  - emitting characteristics
  - sound signal

Propagation
- Specular Reflection
- Scattering
- Diffraction
- Refraction
- Doppler Effect
- Attenuation
- Interference

3D Audio Rendering
- Late Reverberation
- Personalized HRTFs for 3D sound
- Digital Signal Processing
  - Interpolation for Dynamic Scenes

Topic: VR in Product Development
Adding Sound

Three Stages: **Modeling**, **Propagation**, **Rendering**

Modeling materials and sound sources

**Visual Geometry**

**Acoustic Geometry**
Adding Sound

Three Stages: Modeling, Propagation, Rendering

Sound in computer games:

Obstructions: Direct path is muffled, Reflections are clear

Occlusion: Direct path is muffled, Reflections are muffled

Exclusions: Direct path is clear, Reflections are muffled
Adding Sound

**Three Stages:** Modeling, Propagation, Rendering

### Modeling
- Acoustic Geometry
  - Surface simplification
- Acoustic Material
  - Absorption coefficient
  - Scattering coefficient
- Source Modeling
  - Area source
  - Emitting characteristics
  - Sound signal

### Propagation
- Specular Reflection
- Scattering
- Diffraction
- Refraction
- Doppler Effect
- Attenuation
- Interference

### 3D Audio Rendering
- Late Reverberation
- Personalized HRTFs for 3D sound
- Digital Signal Processing
- Interpolation for Dynamic Scenes

### Traditional Pipeline
- Audio scene description
- Positions of sources and listener
- Waveform audio data
- Pre-mixing
- Resampling
- Source directivity
- Reverberation
- Positional audio
- Re-equalization
- Occlusion filtering
- Positional audio
- Positional audio
- Mix
- APU
- Sound output
Haptics

Haptic devices: with and without force feedback

**Phantom** desktop haptics device - 6DOF
Haptics

Haptic devices: with and without force feedback

CyberTouch
data input device
from Virtual Technologies
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Stereoscopic projection

Three different technologies are mainly used to achieve this:

• **Active 3D stereo**
• **Passive 3D stereo**
• **Autostereoscopic projection**

The first two approaches use glasses (active or passive) and can be exploited for multiuser applications while the third requires no glasses, but for the most part is limited to present the content in stereo to one user only. In the following slides we describe briefly the principles of these technologies and give implementation examples.
Stereoscopic projection

Two slightly different images are shown to both eyes – Different principles

**Active** – Images are shown in a sequence (shutter glasses – 120 Hz)

**Passive** – images for the left and right eyes are shown simultaneously: how to divide: a) color filters, b) polarization filters.
**Stereoscopic projection**

**Passive Stereo** – images for the left and right eyes are shown simultaneously: how to divide: a) color filters, b) polarization filters.
Anaglyph Stereo – images for the left and right eyes are shown simultaneously. How to divide: color filters.
Stereoscopic projection

Anaglyph Stereo – Example.
Polarization Stereo – images for the left and right eyes are shown simultaneously. How to divide: polarization filters.
Passive Stereo – Basic Principle
The benefits of passive 3D stereo include: simple and cost effective system, best channel splitting, it does not put stress on the observer’s eyes.
Stereoscopic projection

**Shutter Glasses** – basic principle.

![Diagram illustrating the basic principle of shutter glasses](image_url)
Stereoscopic projection

Shutter Glasses – Example.
Stereoscopic projection

Active 3D stereo example: NVidia 3D Vision Technology
Visual Decision Platform VDP - Review  (IC:IDO www.icido.de)
VR Demo:

Visual Decision Platform VDP - Package

[Image of VR Demo: Visual Decision Platform VDP - Package]
VR Demo:

Visual Decision Platform VDP - Ergonomics

IDO:ERGONOMICS
VR Demo:

Visual Decision Platform VDP - Reflect

IDO:REFLECT
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VR Main Application Areas

Common features:

• VR is a tool for presenting information in the 3-dimensional space, which can be manipulated by specialized interface devices.

• What's why every task which requires for presentation in a 3-dimensional space is expected to be able to take advantage of the VR technology. This is also true for multidimensional tasks, which can be reduced to some kind of 3-dimensional presentation.
VR Main Application Areas

**Common features:**

- Usually the VR applications are linked to the task of creation of a computer model of some object or event. If this computer model can be created without implementing significant resources then a successful application can be developed using VR methods and tools.

- Example: Object 3D representation as Scene graph and resulting visualization.
VR Main Application Areas

1. Virtual prototyping:
   • The Virtual Prototype represent close enough not only the geometry, but using various simulation approaches also important features of the designed product. The virtual prototype can be explored, tested and verified from different points of view, e.g. proper design or ergonomic features or simple assembly and disassembly of the components etc.

   • The main advantage of this technology is time saving and reduced time-to-market, but also simplified process of document creation and management.
Main advantages

- Reduced number of physical prototypes (approximately by 20%),
- Reduced number of design errors, which are removed at earlier stages of product development,
- Reduced time-to-market,
- Increased product quality
- Better communication, especially in interdisciplinary teams,
- Easier verification of different product versions at a lower price.
- Better presentation of the design results

(IFIP, RWTH, Aachen)
2. Visualization:

- Evaluation and extracting information from big data sets
- Example: Visualization of CFD data

(cfdthermo.hut.fi)
VR Main Application Areas

3. Education

- Various types of simulators: flight, car, truck etc.
3. Education

- Clear metaphor for representing the real 3-dimensional world.

Virtual welding simulator

( FCS Control Systems, Netherlands)
3. Education

- Train the crew how to react in dangerous situations.

(www.tradekorea.com)
VR Main Application Areas

4. ... Entertainment, movies, virtual museums ...

(www.googleartproject.com)
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VR in Bulgaria

• VR Laboratory at the Technical University of Sofia

• Established 2008
Virtual reality Lab at the Technical University of Sofia

• In cooperation with LESC KIT, Germany
Virtual reality Lab at the Technical University of Sofia

• Hardware
Virtual reality Lab at the Technical University of Sofia

Topic: VR in Product Development
Virtual reality Lab at the Technical University of Sofia

<table>
<thead>
<tr>
<th>Software</th>
<th>COVISE-Basis</th>
<th>COVISE Work-Flow-GUI</th>
<th>COVISE CFD</th>
<th>COVISE VR</th>
<th>COVISE-VRML</th>
<th>COVISE-DEV</th>
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In-house developed VR software
Virtual reality Lab at the Technical University of Sofia

- Workflow
Automated workflow: CAD → VR

Major steps in the developed procedure:

• CAD model export in a format supported by both systems (e.g. VRML),
• Activating a batch process for model file transfer to the VR system and launch of the VR application,
• All steps are fulfilled in the CAD environment.
Automated workflow: CAD → VR

- CAD model
- Presentation in VR system
Projects: Virtual Product Configurator

- Open web page
- Import modules from catalog
- Place and arrange modules
- Customize modules
- Check order details
- Send order

Topic: VR in Product Development
Projects: Virtual Product Configurator

- Web
- VR
VR Product Validation

• investigate Properties of Car instruments in VR
Create and manipulate Objects through Gestures

• VR

• Diagramm

Topic: VR in Product Development
VR Product Validation

- Compare features of real and virtual objects

- Image of a VR product showing a comparison of weights: 248 g vs. 305 g
- Image of another VR product showing a comparison of weights: 797 g vs. 780 g
VR applications – integrating Wii Remote as interface device in a VR system

- Wii Remote
- VR system

VR Lab, TU - Sofia
VR applications – exploring surface roughness with force feedback haptic device

• Настолна VR система
VR applications – marker-based Augmented reality system

VR Lab, TU - Sofia

- Visualization of the object linked to the marker, captured with the camera
При VR applications – marker-based Augmented reality system on mobile device

VR Lab, TU - Sofia

• AR mobile application
VR applications – presentation and exploration of CAE results in VR system

- Modeling and FEM analysis of a gas heater

- Physical prototype of the product

VR Lab, TU - Sofia
VR applications – presentation and exploration of CAE results in VR system

• Modeling and FEM analysis of a gas heater

• FEM model
VR applications – presentation and exploration of CAE results in VR system

- Modeling and FEM analysis of a gas heater

- Presentation of the results: temperature distribution is presented with color coding
VR applications – presentation and exploration of CAE results in VR system

• Modeling and FEM analysis of a gas heater

• Multimodal presentation of FEM results: simultaneous (visual and acoustic) presentation of temperature distribution and strength.
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VR in Product Design Education at FDIBA

Course “Virtual Engineering” at bachelor level (3-rd year), for both specialties:
- Mechanical Engineering
- Computer Systems and Technologies

Curriculum (2 lecture hours, 2 practical exercises)
- Introduction and main concepts,
- PLM (Product life-cycle management),
- CAD models,
- CAM/CAE,
- VR systems and technology - Emphasize: how to implement this approach as a tool for solving product design problems.
VR Books

1. Virtual Reality Technology
2. Understanding Virtual Reality
3. Developing Virtual Reality Applications
Summary

• VR and AR are currently affordable also under limited budget and provide for a new way human-computer interaction;
• VR technologies allow us to explore virtual worlds in a new way, not possible in real life;
• VR is very interdisciplinary (both applications & technology), it is not an isolated island;
• VR will be applied in many fields, but not only in the ways as we may think currently;
• Expand our mind and creativity;
• Give us new ideas and perspectives.
References:

• SIGGRAPH 2004 Course Notes: Seeing, hearing, and touching: putting it all together.
• SIGGRAPH 2008, Class Notes: Don’t be a WIMP (http://www.not-for-wimps.org).
• SIGGRAPH 2009, Class Notes: Interactive Sound Rendering, (http://www.gamma.cs.unc.edu/SOUND09/).
• SIGGRAPH 2009 Course Notes: Interaction - interfaces, algorithms, and applications.
Questions?