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DEPARTMENT OF CIVIL ENGINEERING

19CET308- AR/VR in Civil Engineering

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AP/CIVIL

UNIT - IV AR/VR in Civil Engineering

DEVELOPMENT TOOLS AND FRAMEWORKS

Software in AR/VR

1. Introduction

Software is the backbone of AR/VR applications in civil engineering, enabling the creation, interaction, and simulation of virtual environments. Various software tools, frameworks, and platforms allow engineers to design, visualize, and test construction projects before execution.

Importance of AR/VR Software in Civil Engineering

- Enables real-time visualization of construction projects.
- Facilitates structural analysis and safety simulations.
- Supports collaborative design and remote site inspections.
- Reduces errors in planning and execution by providing interactive models.

2. Modelling Virtual World

Virtual world modeling involves creating realistic 3D environments to simulate infrastructure, buildings, and landscapes.

2.1 Steps in Virtual World Modelling

1. 3D Geometry Creation
   - Using CAD software (AutoCAD, Revit, SketchUp) to create detailed 3D models of buildings, bridges, and roads.
   - Importing models into game engines (Unity, Unreal Engine) for interaction and visualization.
2. Texturing and Material Mapping
   - Adding realistic textures to walls, floors, and structural elements using Blender, Substance Painter.
   - Physically Based Rendering (PBR) for accurate lighting and reflections.
3. Lighting and Shadows
   - Simulating natural sunlight, artificial lighting, and shadow effects for realistic representation.
   - Used for urban planning and energy efficiency analysis.
4. Physics-Based Interactions
   - Incorporating gravity, wind forces, and collision detection for realistic movement and simulation.

- **Integration with GIS (Geographic Information System)**
  - **Overlaying virtual models on real-world maps for accurate terrain visualization.**
  - **Used in flood analysis, land-use planning, and transportation networks.**

2.2 Applications in Civil Engineering

- **Architectural visualization – Engineers can walk through a virtual building before construction.**
- **Urban planning – Simulation of road networks, drainage systems, and smart cities.**
- **Site layout optimization – Using GIS-based virtual models to optimize construction sites.**

3. Physical Simulation

Physical simulation involves applying real-world physics to virtual environments, making them behave like real structures.

3.1 Key Elements of Physical Simulation

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Feature	Function	Application in Civil Engineering
Structural Simulation	Analyzes **building stress, material strength, and load distribution.**	Helps in **structural integrity testing before construction.**
Fluid Dynamics Simulation	Models **water flow, air circulation, and flood risks.**	Used in **dam construction, stormwater management, HVAC system design.**
Collision Detection	Ensures objects in VR behave realistically when interacting.	Used in **crane movement simulations, vehicle crash analysis.**
Gravity and Weight Simulation	Models **realistic object behavior under gravity.**	Used for **bridge design, earthquake-resistant buildings.**

3.2 Tools for Physical Simulation

- ANSYS VRXPERIENCE – Simulates stress, strain, and material durability in structures.
- Autodesk CFD (Computational Fluid Dynamics) – Used for wind tunnel testing and HVAC system simulations.
- Blender Physics Engine – Helps in motion simulation of construction equipment.

3.3 Applications in Civil Engineering

- Earthquake resistance testing – Simulating how a building reacts to seismic waves.
- Traffic flow analysis – Predicting congestion in urban road networks.
- Construction machinery simulation – Training workers to operate cranes and bulldozers safely in VR.

4. VR Toolkits

VR toolkits are software libraries and frameworks that simplify the development of AR/VR applications.

4.1 Popular VR Toolkits in Civil Engineering

VR Toolkit	Key Features	Application in Civil Engineering
Unity XR Toolkit	Supports VR interaction, object physics, and real-time rendering.	Used for real-time walkthroughs of construction projects.
Unreal Engine VR Toolkit	High-quality graphics, physics-based simulations.	Used for realistic visualization of bridges, skyscrapers, tunnels.
Vuforia	Marker-based AR, object tracking.	Used for overlaying 3D models on real-world construction sites.
Google ARCore	Plane detection, environmental understanding.	Used for placing virtual structures in real-world locations using smartphones.
OpenVR (by Valve)	Cross-platform VR development support.	Used for creating immersive VR training simulations for workers.

4.2 Benefits of Using VR Toolkits

- Reduces development time by providing pre-built AR/VR functions.
- Enhances compatibility with multiple AR/VR headsets.
- Improves user interaction with tools for gesture recognition, spatial mapping, and physics simulation.

4.3 Applications in Civil Engineering

- Remote collaboration – Architects and engineers can review project designs in real-time.
- Training and safety simulations – Workers can practice construction tasks in VR before working on-site.
- Interactive 3D modeling – Engineers can modify designs in VR and see the impact instantly.

5. Introduction to VRML (Virtual Reality Modeling Language)

5.1 What is VRML?

VRML (Virtual Reality Modeling Language) is a standard file format used for describing interactive 3D scenes in a web environment.

5.2 Features of VRML

- 3D Object Representation – Models buildings, bridges, and roads in a browser-based 3D view.
- Interactivity – Allows users to navigate through virtual structures.
- Web-Based Access – Can be embedded in web applications for project visualization.
- Animation Support – Simulates movement of construction elements like cranes, vehicles, and workers.

5.3 How VRML Works in Civil Engineering?

- Creates interactive 3D site plans for urban planning.
- Enables web-based 3D visualization of infrastructure projects.
- Helps clients view and interact with building designs before construction starts.

5.4 Tools that Support VRML

- Blender (Exports VRML files for web visualization).
- X3D (Successor of VRML for more advanced 3D modeling).
- Cortona3D (A VRML viewer for web-based 3D interaction).

6. Conclusion

- Software plays a vital role in AR/VR applications in civil engineering by enabling modeling, simulation, and interaction.
- 3D modeling software helps in designing realistic virtual environments.
- Physical simulation tools allow engineers to test stress, loads, and environmental factors before construction.
- VR toolkits simplify AR/VR development for immersive applications.
- VRML allows interactive 3D visualization on web platforms, making project presentations more engaging.

Real-World Use Case

A construction company used Unity VR Toolkit to create a virtual walkthrough of a highway project, allowing stakeholders to identify design flaws before construction, saving both time and cost.

Real-World Use Case: Virtual Walkthrough of a Highway Project Using Unity VR Toolkit

Background & Problem Statement

A construction company was tasked with designing and constructing a highway expansion project. Traditionally, engineers and stakeholders relied on 2D blueprints, CAD models, and physical site visits to assess feasibility and identify potential design flaws. However, these methods had significant limitations:

- **Lack of real-world visualization made it difficult to detect design inconsistencies.**
- **High costs and delays were caused by last-minute modifications after construction began.**
- **Communication gaps between engineers, government agencies, and contractors led to misunderstandings about project details.**

To overcome these challenges, the company decided to implement a Virtual Reality (VR) walkthrough using Unity VR Toolkit before breaking ground.

Implementation Using Unity VR Toolkit

The construction company followed these key steps to develop the VR walkthrough:

1. 3D Modeling and Environment Setup

- **Engineers imported highway CAD models (designed in AutoCAD and Revit) into Unity 3D.**
- **Terrain data was integrated using GIS (Geographic Information System) mapping to match real-world topography.**

- Assets such as roads, vehicles, trees, signboards, and streetlights were added for realism.

2. Interactive Virtual Walkthrough Development
- Camera-based navigation: Users could walk, drive, or fly through the highway in VR.
- Collision detection: Ensured vehicles and structures behaved realistically in simulations.
- Day/Night cycle simulation: Allowed engineers to test highway lighting conditions.
- Traffic flow simulation: Enabled analysis of congestion points and lane merging effectiveness.

3. VR Integration for Immersive Experience
- The project was optimized for Oculus Quest and HTC Vive to allow stakeholders to explore the highway in fully immersive VR.
- Hand-tracking and gesture controls allowed users to interact with objects, zoom into specific areas, and switch perspectives.
- Speech-enabled feedback system enabled stakeholders to leave comments directly in the VR model.

Key Benefits & Results

✅ Early Design Flaw Detection
- Engineers identified visibility issues at sharp turns, leading to realignment of certain sections.
- Detected poor drainage planning that could have caused flooding during heavy rains.
- Adjusted lane widths to accommodate future expansion needs.

✅ **Cost & Time Savings**

- **Prevented costly rework by fixing design flaws before actual construction.**
- **Reduced on-site inspections as many decisions were finalized virtually.**
- **Minimized materials wastage by optimizing designs in advance.**

✅ **Improved Stakeholder Collaboration**

- **Government officials, contractors, and engineers reviewed the project remotely.**
- **Non-technical stakeholders (investors, local authorities) understood the project better with VR than with traditional blueprints.**
- **Faster approvals and decision-making due to realistic project visualization.**

Conclusion

- **By using Unity VR Toolkit, the construction company was able to create a realistic and interactive highway walkthrough, leading to better design validation, cost savings, and streamlined decision-making. This case highlights how AR/VR is revolutionizing civil engineering, making complex infrastructure projects more efficient, accurate, and collaborative.**

Thankyou