LAB University of Applied Sciences

Scope of Extended Reality in Mechanical Engineering

Virtual Reality, Augmented Reality and Mixed Reality

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Nelson Chowattukunnel Thomas

Abstract

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Seppo Toivanen, Lecturer, Lab University of Applied Sciences.

Abstract

With rapid development of technologies in the world, Extended Reality which includes Virtual reality (VR), Augmented Reality (AR) and Mixed Reality (MR) is a transformative technology with vast potential across various domains. In Mechanical engineering has various application such as in design, manufacturing, training, teaching and maintenance process.
In this thesis the research begins with an overview of XR technology but is more concentrated on applications with AR in mechanical engineering.

Keywords

AR, MR, VR, XR, Virtual reality, Augmented Reality, Mixed Reality

Contents

List of symbols and abbreviations

3D- Three dimensions

API- Application programming interface

AR-Augmented reality

CAD- Computer-Aided design

MR-Mixed Reality

SDK- Software development kit

UI-User interface

UX-User experience

VR-Virtual Reality

XR- Extended Reality

1 Introduction

Extended reality is a generic term referring VR, AR and MR. These technologies extend reality by adding to or simulate the real world through digital materials. It combine technology to enhance human perception of reality by reducing the boundaries of real and digital environments.

In this thesis, even though brief understanding of all kinds of XR technologies are mentioned the research is main done on AR and its scope in the field of mechanical engineering.AR is used and can be widely used in various field starting form generating an idea, Designing, Analysis, conceptualisation, training, maintenance, Academics, manufacturing etc. The thesis will discuss some of the aspects of application in theses field later. Theses has a research part and an experiment part.

1.1 Objective

The thesis topic was conceived during the winter of 2023, when the scope of visualising a design created using a CAD software in real world was told to the author during a discussion with the teacher. This led the author to the world XR where the design in CAD can be visualised and interacted in real world using certain interfaces. The integration of XR in mechanical engineering is a paradigm shift in how engineers conceive, create, and interact with complex systems and machinery. With VR, engineers can immerse themselves in virtual environments to visualize, simulate, and refine designs .AR, on the other hand, facilitates real-time overlay of digital information onto physical objects, enabling engineers to enhance visualization. Meanwhile, MR seamlessly blends virtual and physical worlds, offering immersive experiences that bridge the gap between digital prototypes and real-world applications. XR is a technology that is still young. It has not been explored completely or standardised.

The objective of this thesis is to provide basic knowledge about the technology, explore some of the application of AR in Mechanical engineering and discuss about the scope and limitations faced now.

1.2 Methodology

For this thesis research literature and experiments will be carried out. The first part will be consisting of research about the basic idea behind the technology and about the various branches of the XR technology. Second part will be containing scope and limitation of AR

in various field of mechanical engineering. Third part will include details about the experiment conducted.

2 Extended Reality (XR)

Extended reality is a universal term referring VR, AR, MR, in addition to including any type of environment that combines real world experiences with virtual and allow us to interact through a digital device such as a mobile phone, camera, VR glasses etc. Figure 1 shows the representation of XR.

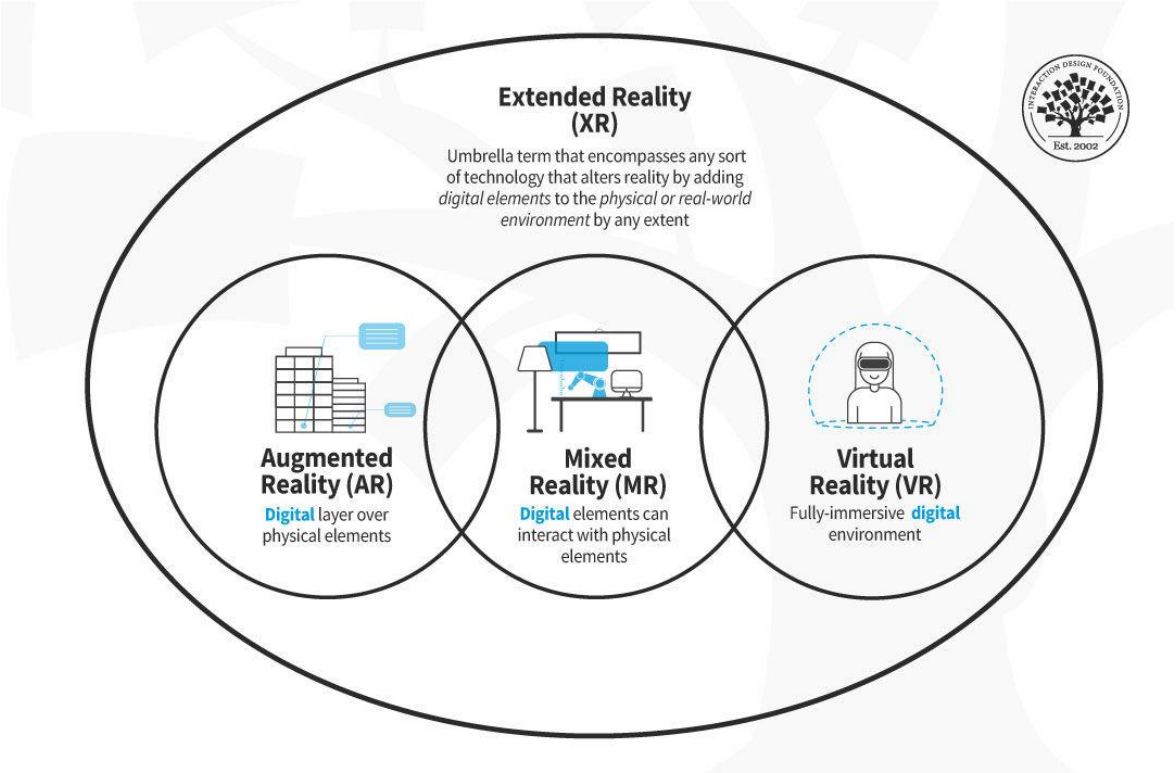

Figure 1. What is extended reality (interaction design.org 2024)

Extended reality works by interaction with the visual data accessed locally or from a shared network to the senses of user. Real time response and interaction with digitally created virtual environment make this experience great. Making XR effective requires various essential hard ware and software components as described below . (Devices, Spaces, & Deployment Considerations | Universal Design for Learning, 2023)

2.1 Hardware devices

To have an ER experience we should have a hardware device such as:

- VR glasses
- AR glasses

- Smartphone
- Tablets

Every hardware device will be having a camera to full fill various functions such as understanding the environment, recognising gesture, tracking positioning etc.

2.2 Sensors

XR devices are required to have various sensors to fulfil various functionalities such as position, analysing depth, orientation, lighting, tracking the movement and speed. Some of the sensors used are as following:

- Magnetometer
- Accelerometer
- Gyroscope

2.3 Input devices

Input devices help us to interact between real world and virtual world. Motion controller and gesture recognition system are used as input devices. Input device may have switches touchpads, triggers etc.

2.4 Software and development tools:

- Game engines such as Unity and unreal engines are commonly used to create a 3D experience
- Software development Kits (SDK) and Application programming interface (API) offer resources and tools for developing XR applications
- 3D software is used for creating 3D images. Most commonly used 3D software is, SolidWorks, Autodesk Maya, blender, Adobe creative suits

2.5 Networking, communication infrastructure and UI/UX

High speed internet connections are very critical in communicating real time data and interacting with others. A good UI/UX makes the interaction more realistic and interesting.

2.6 Branches of XR

XR is a universal term used to describe either one of the following:

- VR-Virtual reality.
- AR-Augmented Reality.
- MR-Mixed Reality.

2.6.1 Virtual Reality

VR is completely a computer generate simulation of an environment that immerses the user in a completely virtual environment. To experience VR, user should use some kind of display device usually a head mounted device (HMD) which is place on the user's head and blocks ears and eyes, detaching the user from real world and replacing with a generated virtual world. The user interacts with the virtual environment using some kind of controller as an input device. It has application in gaming, training education, healthcare and more. HTC vive, Meta quest, Occulus Quest and Sony PlayStation VR are some popular VR devices. (How Virtual Reality Technology Has Changed Our Lives: An Overview of the Current and Potential Applications and Limitations, 2022)

Figure 2. VR HMD and controller (HMD vs Cave in the world of VR,2024)

2.6.2 Augmented Reality

AR is a technology that overlays virtual object or digital information onto the real-world environment. Unlike VR AR doesn't necessarily need any HMD. AR can be experience through any device such as smartphone, tablets, smart glasses or even HMD. AR devices

use camera, sensors and algorithms to understand and detect the real environment in real time and can super impose virtual object to the real world. This thesis will be discussing more application of AR in upcoming chapters. It is commonly used in gaming, designing, retail E-commerce and more. (virtual and augmented reality | designboom.com, 2023)

Figure 3. AR experience using a tablet (Ixr labs 2024)

2.6.3 Mixed Reality

MR is a technology that combine both AR and VR, allowing digital and physical objects to coexist and interact in real time. By using MR virtual objects are not only overlaid onto the real world like an AR but also anchors and integrated into the real-world enabling user to interact with it as if it is real. This is achieved using techniques such as spatial mapping, tracking and rendering techniques which enables created objects to interact with real world objects surface, space lighting conditions. MR is used in industrial design and engineering, training, simulations, education, entertainment, gaming. (XR in Higher Education: Adoption, Considerations, and Recommendations | EDUCAUSE Review, 2024)

3 AR In Mechanical engineering

AR which is still in a development stage has the potential to transform the way mechanical engineers work from the very point of conceptualising until the sales process. Thesis w ill be discussing some of the applications in detail.

3.1 Design

Product development starts from an ides made into design. AR allows the user to visualise the 3D mode in a real-world environment before the prototype is made.

3.1.1 Scope:

- Visualising: AR enable to visualise the design in real world before even a prototype is made by overlaying the 3D model onto physical environment in real-time. This makes engineers to analyse the concept, scale, practicality of design with respect to a 3D model. Many iterations can be made without any material wastage.
- Interactive Prototyping: AR enables engineers to assemble, disassemble and manipulate3D models in real world scale which enables quick experimentation, iteration and validation of the prototype.
- FEA: FEA result can be overlayed on real model which helps engineers to visualize the behaviour of stress, strain, flow etc on the prototype and the design can be improved by manipulating various factors. By visualising FEA results in the real environment engineers can make informed decisions about the designs.

3.1.2 Limitations:

- Hardware: current AR devices have limitations in processing power, battery life display resolution which affects the quality and performance of complex designs
- Accuracy: Tracking and registration algorithms may not always provide precise or accurate alignment of virtual objects within the real environment which results in misalignment, occlusion or inconsistency between real and physical objects affecting reliability.
- Complexity: The more complex the 3D model, it is more difficult to make into AR applications. This will be more time consuming and affects the scalability.

3.2 Assembly and manufacturing

AR can have significant impact on assembly and manufacturing processes, improving efficiency, accuracy and training. Some of the benefits of AR in assembly and manufacturing is as follows:

- Work instructions using AR: Paper manuals can be replaced by digital instruction overlaid onto the working area by suing smart glasses, tablet or even mobile phone. Worker will be able see components and assembly instruction in real World and scale which makes it easy for the worker.
- Virtual overlay: AR can project final assembly to the workspace which make workers to ensure everything is fit and assembled correctly.
- Light guidance: light can be projected by AR into parts or bins, guiding workers to the correct components for the assembly thus saving time
- Enhanced quality control: If AR is integrated with machine vision and AI the physical model can be compared with the digital model and deviation can be informed in the real time.
- Efficiency and productivity: Using clear visual instructions and real-time feedback errors can be minimised. And with more visual aids workers can complete task quickly. (Töröková, 2021)

3.3 Maintenance and repair

AR applications provide great help in repair and maintenance activity where even humans cannot be reached. Some of the applications of AR in maintenance and repair are as follows:

- Remote Assistance: Guidance from senior technician can be facilitated by using a camera with AR software to show the equipment allowing expert to see the problem in real time.
- Can be operated in dangerous situations: With help of small robots with AR software and camera combined with machine vision, defects can be detected and with AI tools calculation can be made on the condition of the equipment and proactive measures can be made.
- Interactive tools: AR as an interactive tool in maintenance manual improves efficiency and make maintenance personnel more understanding about the maintenance process.

- Data analysis: With the help of digital model, working conditions, wear and tear, duration between maintenance etc can be monitored and effective actions can be taken.

4 Creating an AR Model

As part of thesis an experiment is done to create an AR model. For this user should have a 3D designing software, game engine or software to create 3D experience, an API or interface for converting 3D model to AR model

4.1 Creating a AR model of spur gear

As an experiment, a 3D model of spur gear was created, as it is single peace and can be converted into AR model without much processing power. Different methods, software and tools or a combination of different tools can be used for obtaining the same result. Entire process for this model creation is described below.

4.1.1 Designing a 3D model

3D model of a spur gear was designed using solid works. The model was saved as *.prt*/sldprt format.

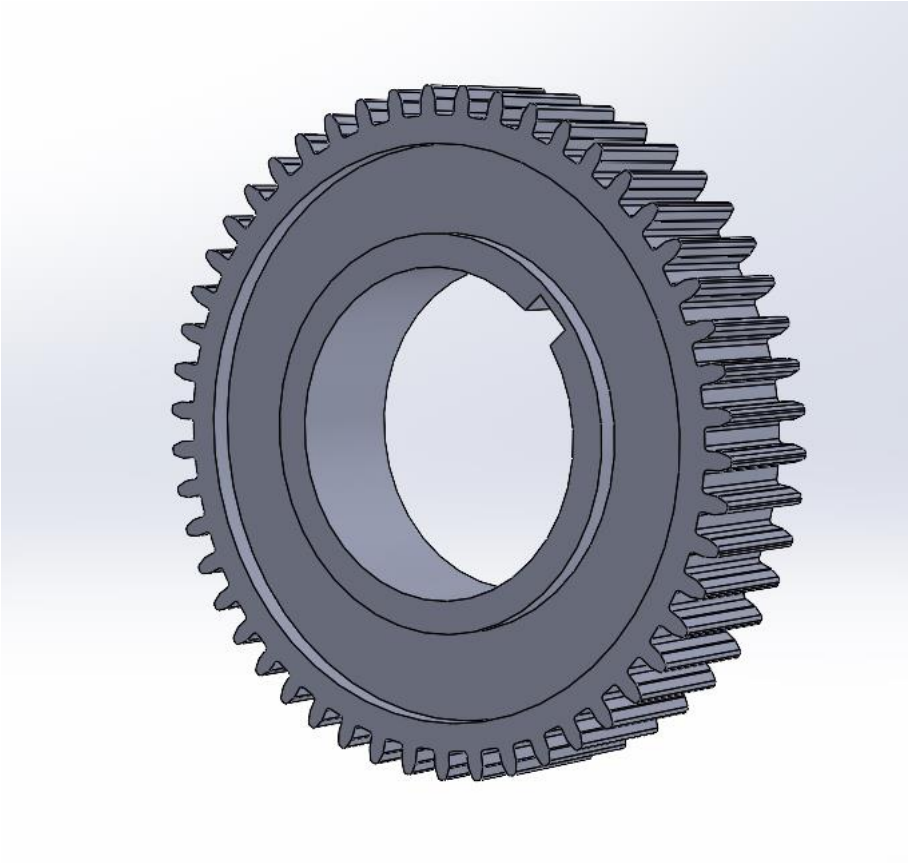

Figure 4. Spur gear

4.1.2 Converting to 3D experience

The 3D model created was converted into 3D experience using solid work visualization. this can be done with other game engines such as Unreal Engine or Unity. Save the model as gITF or GLB files.

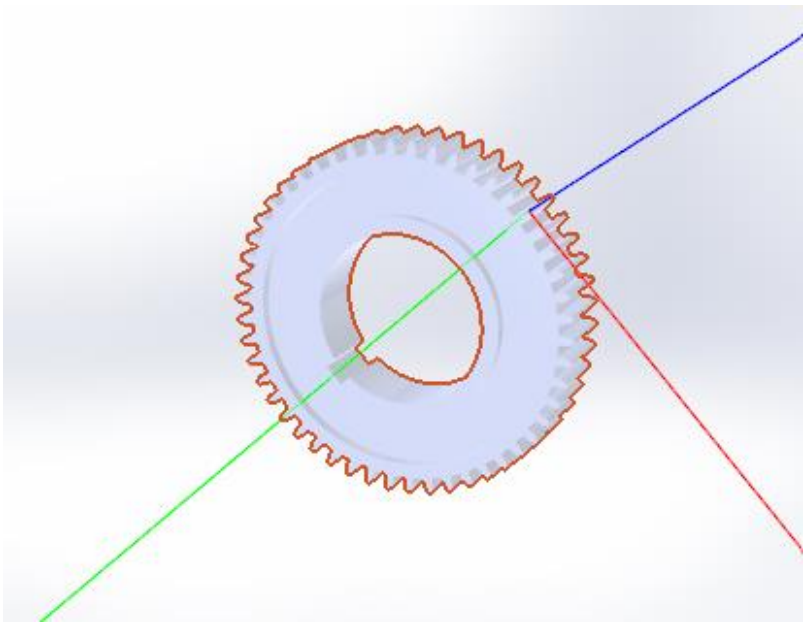

Figure 5. Spur gear made into 3D experience using SolidWorks Visualize

4.1.3 Viewing the model in AR

Open a browser and type https://modelviewer.dev/ , a page as shown in Figure 6 will appear on the screen

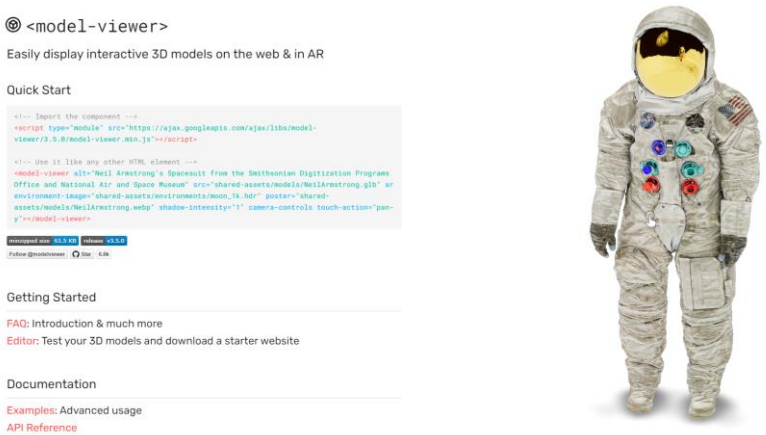

Figure 6. Home page of modelviewer

Click the option editor written in red colour which leads you to the page as shown in Figure. 7.

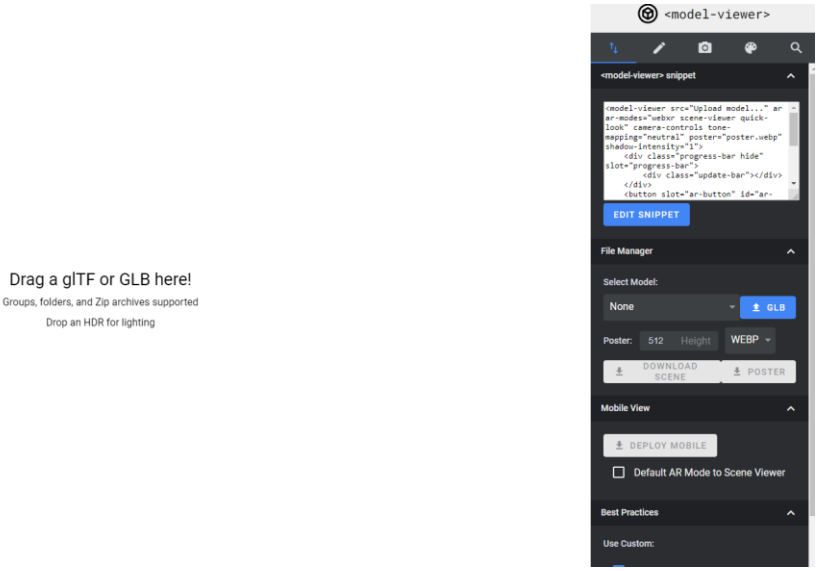

Figure 7. Page of modelviever

Drag the saved model in gITF or GLB files. The user will be able to see the model as in Figure 8.

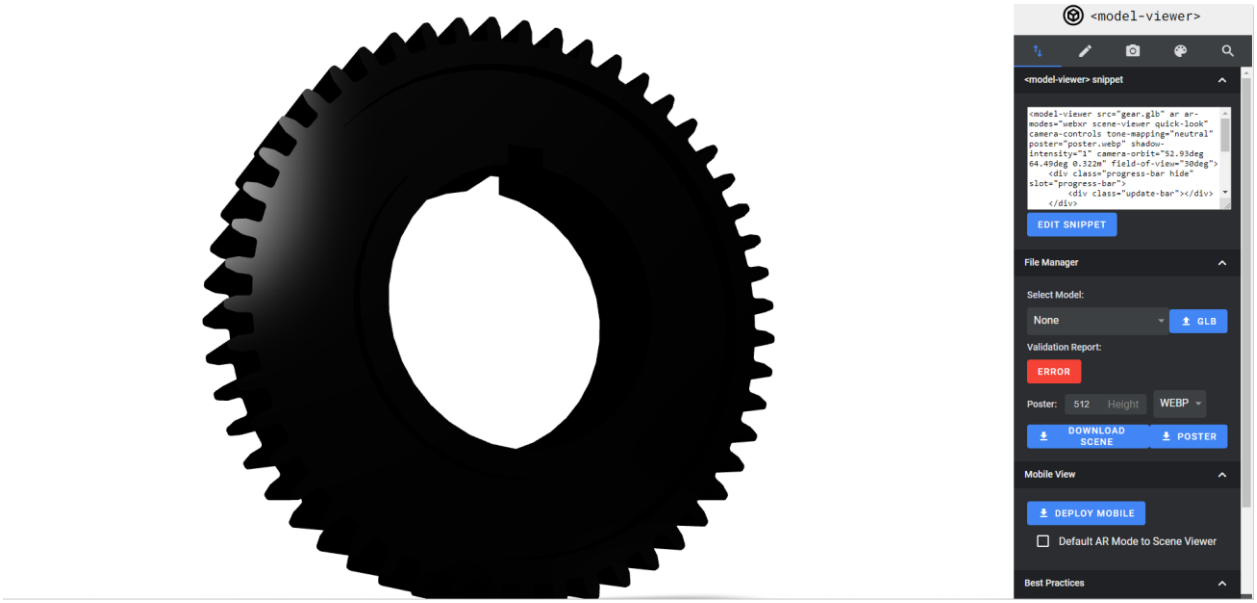

Figure 8. View of imported model in model viewer

Press the deploy button on the right bottom of the screen to view the model in a real environment. When the deploy mobile button is pressed user will be seeing a QR code in the screen. Scanning the QR code will make the model appear in user's real environment as seen in Figure 9.

Figure 9. AR model in real environment

5 Limitation of AR

AR is relatively new technology and have immense potential but has certain limitations. Some of the limitations are as follows:

- Hardware: AR devices such as AR glasses are bulky, heavy and uncomfortable to wear. AR application consumes high power which drains the battery quickly.
- Processors: AR requires high processing speed to overlay real time data to function smoothly. The processing power of normal AR devices is not very good, and if a device with high processing power is required it will be costly.
- Cost: Developing and implementing AR applications is expensive now.
- Limited content: AR is a growing technology so quality application, and contents are limited (AR Development — Jasoren, 2019)

6 Conclusion

The objective of this thesis is to have a basic understanding of XR technology and its sub-categories. This thesis was also aimed to view applications of AR technology in mechanical engineering and creating an AR model. Research was done to provide a foundational understanding of XR technology, its subcategory and practical application of AR in engineering design, manufacturing and maintenance processes.

With specific focus on AR in mechanical engineering, the thesis elucidates transformative potential of AR technology across various facets of the engineering lifecycle. From design conceptualization to product assembly, maintenance, and repair, AR offers many benefits, including enhanced visualization, interactive prototyping, guided assembly instructions, and remote assistance. Despite the promising prospects, the study also highlighted the inherent limitations and challenges associated with AR technology, ranging from hardware constraints and accuracy issues to complexity in implementation and scalability.

As a conclusion of the research journey, the thesis presented an experiment demonstrating the process of creating an AR model of a spur gear, underscoring the practical feasibility and utility of AR technology in engineering applications. Through this experiment, the study showcased the seamless transition from 3D modeling to AR visualization, providing a demonstration of the transformative power of AR in bringing digital designs to life in the real world.

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