Lathe Machine

A Technical Report
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Case Study

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by
Chukwudi Okerulu(22200538)
Tobias Doblinger(595236)
Tom Thushar(22202815)
Lukas Vogl(764117)

Supervised by
Prof. Dr.-ing. Anton Schmailzl
Silvio Angelillo

FACULTY OF MECHANICAL ENGINEERING AND MECHATRONICS
TECHNISCHE HOCHSCHULE DEGGENDORF
GERMANY

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Abstract

Virtual reality (VR) technology has emerged as a promising tool in the field of visualization, prototyping, manufacturing, engineering, and education. This paper presents an approach for incorporating Virtual Reality development into the teaching of manufacturing tools (Lathe Machine). The report demonstrates how virtual machine tools that operate similarly to 'real' machines can enhance training practice while eliminating dangers of use for both users and machines. The experiment utilized tools and software such as a photogrammetry scanner, blender, and Unity. Additionally, the paper discusses the principle working of a lathe machine, the safety procedure, and the maintenance requirements.

Virtual Reality (VR) hat sich zu einem vielversprechenden Werkzeug in den Bereichen Visualisierung, Prototyping, Fertigung, Technik und Bildung entwickelt. In diesem Beitrag wird ein Ansatz für die Einbeziehung von Virtual Reality in die Schulung an Fertigungsmaschinen (Drehmaschine) vorgestellt. Der Bericht zeigt, wie virtuelle Werkzeugmaschinen, die ähnlich wie "echte" Maschinen funktionieren, die Ausbildungspraxis verbessern und gleichzeitig Gefahren für Benutzer und Maschinen beseitigen können. Für das Experiment wurden Werkzeuge und Software wie ein Photogrammetriescanner, Blender und Unity verwendet. Darüber hinaus werden die prinzipielle Funktionsweise einer Drehmaschine, das Sicherheitsverfahren und die Wartungsanforderungen erörtert.

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Abbreviations

AR Augmented Reality

NPC Non Player-able Character

VR Virtual Reality

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1 Introduction

1.1 Purpose and Objectives

The primary purpose of this case study is to investigate the effectiveness and benefits of using VR technology for teaching lathe machine operation and safety. Engineers and technicians widely use lathe machines in manufacturing and industrial settings. Therefore, engineering students must know this machine's essential operation but it poses inherent risks requiring proper training and understanding of safety protocols. The case study explores the potential of VR technology to create an immersive and interactive training experience, enabling trainees to learn and practice lathe machine safety procedures in a realistic virtual environment.

The study aims to achieve the following objectives:

- **Assess the limitations of traditional safety training methods**
  Examine the shortcomings of conventional training approaches, such as static manuals or videos, in conveying essential safety practices for lathe machines.
- **Explore the potential of VR technology**
  Investigate how VR can enhance safety training by providing a realistic, hands-on experience that replicates the lathe machine environment.
- **Develop an immersive VR training program**
  Design and develop a VR training program that incorporates interactive simulations, demonstrations, and practical exercises focused on lathe machine safety.
- **Evaluate the effectiveness of VR in improving safety training**
  Assess the impact of VR-based training on trainees' comprehension, retention, and application of lathe machine safety procedures.

1.2 VR and AR State of the Art

Virtual Reality has received enormous publicity over the past few years, and it can be defined as a computer-generated digital environment that can be experienced and interacted with as if that environment were real [1] [2]. Virtual reality promises a multi-sensory system that provides a platform for the general-purpose communication medium. Although the complete scale of this promise has not been completely actualized (meaning we have not yet arrived at the utopia of the OASIS in the movie Ready Player One), there has been tremendous progress and application of virtual reality in different fields. The recent introduction of Apple's new Vision pro headset will further boost the VR market.

The market for VR technology has been expanding in parallel with its rapid development. The size of its worldwide market is predicted to soar from US$ 7.3 bn in 2018 to US$ 120.5 bn in 2026 (Fortune Business Insights 2019), reflecting its exponential growth [3].
However, a significant portion of the VR market share comes from consumer software, particularly video games, as VR headsets like Facebook's Oculus Quest and HTC's VIVE are on the cusp of transforming the gaming and entertainment space. Companies like IKEA, Volkswagen, and Takeda have embraced VR technology despite this. As such, this article sheds light on the potential applications of VR technology in non-gaming industries [3].

Cutting-edge research into the virtual and augmented reality realm can be classified into three main categories: hardware, software, and applications.

Regarding the applications of this innovative technology, the VR method is envisioned as a future learning tool due to its ability to transcend the limits of space and time. Its potential usage is vast, including for early childhood education and students with special needs [4].

Through the implementation of Augmented Reality technology, the three-dimensional (3D) virtual modeling of the anatomical shape of the human body can be visualized using a smartphone. An android or smartphone can operate AR applications for cupping points on the anatomy of the human body, which has been developed.

The utilization of Virtual Reality (VR) in education involves the integration of media as a complementary tool to teaching materials for science courses. The outcomes of product evaluations conducted among media experts, material experts, and students have yielded numerous favorable responses, thereby indicating that the virtual reality system of the solar system is ideal for educational purposes [4].

Implementing VR technology promotes innovation in learning media, distinct from traditional methods. This leads to greater student engagement, critical thinking skills, and a closer relationship with VR technology. The characteristics of VR technology can be effectively utilized in the teaching and learning process even during a pandemic, thereby generating interest among students and recreating the classroom atmosphere during offline learning [4].

1.3 Introduction to Lathe Machines

Lathe machines, with their unparalleled versatility and extensive usage in the manufacturing industry, play a pivotal role in shaping and machining an array of materials with utmost precision and accuracy. Their widespread application includes turning, drilling, cutting, facing, and threading operations. Having been present for centuries, these machines have undergone considerable advancements over time to cater to the dynamic requirements of diverse industries [5].

The basic principle behind a lathe machine involves rotating the workpiece while a cutting tool, controlled by the operator, removes material to achieve the desired shape or dimension. The workpiece is firmly secured and rotates at a regulated pace, enabling the cutting tool to shape it symmetrically and with utmost accuracy. The cutting tool can be adjusted to create different shapes, profiles, and surface finishes, making lathe machines versatile and adaptable to various applications.

The Lathe machines are available in various sizes, ranging from large industrial lathes capable of handling heavy-duty machining tasks to small benchtop models used for hobbyist projects. These machines can be operated manually, with the operator controlling the movement of the cutting tool and the rotation of the workpiece. Alternatively, they can be automated with computer numerical control (CNC) systems to improve accuracy.

The utility of lathe machines is diverse and span across numerous industries such as automotive, aerospace, construction, and furniture manufacturing. Lathe machines are valued for their ability to produce precise, symmetrical, and high-quality workpieces, making them indispensable in contemporary manufacturing processes [5].

A lathe machine requires trained operators with a good understanding of the machine's mechanics, cutting tools, and machining procedures. Working with lathe machines requires extreme caution due to the presence of moving components, high-speed cutting blades, and possible hazards if proper procedures are not followed.

1.4 Benefits of Virtual Reality in Training

The necessity of acquiring training for the lathe machine's operation has led to realizing the highly effective benefits of Virtual Reality. The ability of VR to create highly realistic simulations and scenarios has proven to be a game-changer in this application. Below are the key benefits of using Virtual Reality in training:

Immersive and Realistic Learning Environment
VR offers an immersive and realistic learning environment where trainees fully engage in a simulated environment that closely mirrors real-world scenarios. The immersive attribute of VR enhances learning by creating a sense of presence, enabling trainees to interact with objects, perform tasks, and experience the outcomes of their actions in a controlled setting. Additionally, adding some elements of gamification to learning [4] [6].

Risk-Free Training
Certain training scenarios involve risks or potential hazards that could pose safety concerns in the real world. VR allows trainees to practice in a risk-free virtual environment, where they can learn from mistakes without endangering themselves, others, or valuable equipment. This particularly benefits high-risk industries such as aviation, healthcare, and emergency response. [7]

Repetition and Mastery

VR training provides the opportunity for repeated practice and skill mastery. Trainees can revisit scenarios, tasks, or procedures as often as needed to improve their performance and build confidence. This repetition enhances learning retention and enables trainees to refine their skills until they achieve proficiency.

Cost and Resource Efficiency

VR training can be a cost-effective alternative to traditional training methods. It eliminates the need for physical equipment setups, travel expenses, and the consumption of resources required for in-person training. With VR, multiple trainees can undergo training simultaneously, maximizing efficiency and reducing overall costs. [8]

Remote and Collaborative Training

VR allows for remote training, enabling trainees to access training programs from different locations. This is particularly valuable for organizations with distributed teams or when physical presence is not feasible. VR also facilitates collaborative training, where trainees can interact and work together in a shared virtual environment, fostering teamwork and cooperation. [9]

2 Designing the Workshop Virtual Reality

2.1 Identifying Key Steps and Concepts

Identifying any training program's key steps and concepts is crucial for effective knowledge transfer and skill development. This process involves breaking down complex tasks or subjects into manageable components that trainees can easily understand and learn. Identifying and organizing the key steps and concepts ensures a structured and comprehensive training experience, whether with technical skills, procedural knowledge, or theoretical concepts.

The key concept for the lathe machine operation and safety training is to show the operation process, the rotation of the spindle, the translation of the Bed and tailstock of the lathe machine, and the safety instruction to follow for the operation of the machine.

Figure 1 shows the software used for the development of the training program.

Figure 1: Software used

2.2 Planning the VR Experience

The planning for the VR experience makes use of the design space analysis, an approach to representing design rationale. It uses a semi formal notation, called QOC (Questions, Options, and Criteria), to represent the design space around an artifact. The main components of QOC are questions that identify key design issues, options that provide possible answers to the questions, and criteria for evaluating and comparing options [10].

Questions such as how to display the virtual reality, track, travel, and manipulate the world space informed the choice of what VR technology to use and the development and deployment platform.

2.3 Creating the Lathe Machine Model

The project's Planning phase led to the use of Polycam, a photogrammetry tool that uses photographs to create a three-dimensional representation of an object or environment. By capturing multiple images from different angles and processing them with specialized software, it is possible to create a digital 3D model. This approach was applied to scanning a lathe machine to generate a virtual representation shown in Figure 2 that can be refined and cleaned using Blender.

After scanning the lathe machine, export the 3D model in a format compatible with Blender, such as OBJ or FBX. Open Blender and import the model into the software. Ensure that the scale of the imported model matches the real-world scale of the lathe machine.
Proceed to the cleaning-up stage; due to the scanning technique, the imported model may have some imperfections, noise, or unwanted artifacts in Figure 3. Use Blender's editing and sculpting tools to

Figure 2: Scanned Lathe Machine

clean up the model. This includes removing unnecessary geometry, smoothing rough surfaces, and fixing distorted or misplaced elements. Use Blender's powerful mesh editing capabilities to refine the model's appearance and cut out the moving parts, after which the parts shown in Figure 4, and material are exported out.

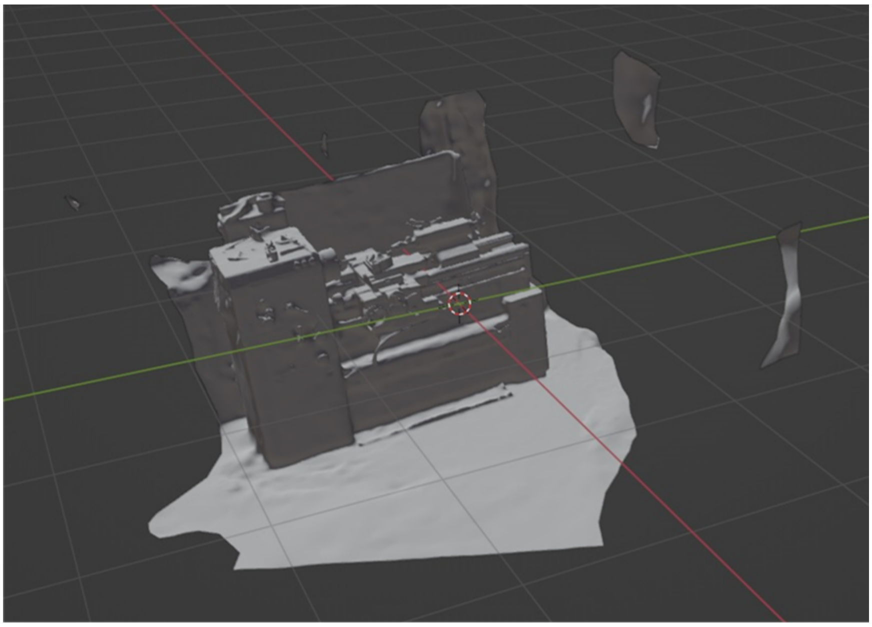

Figure 3: Lathe Machine with unwanted artifacts

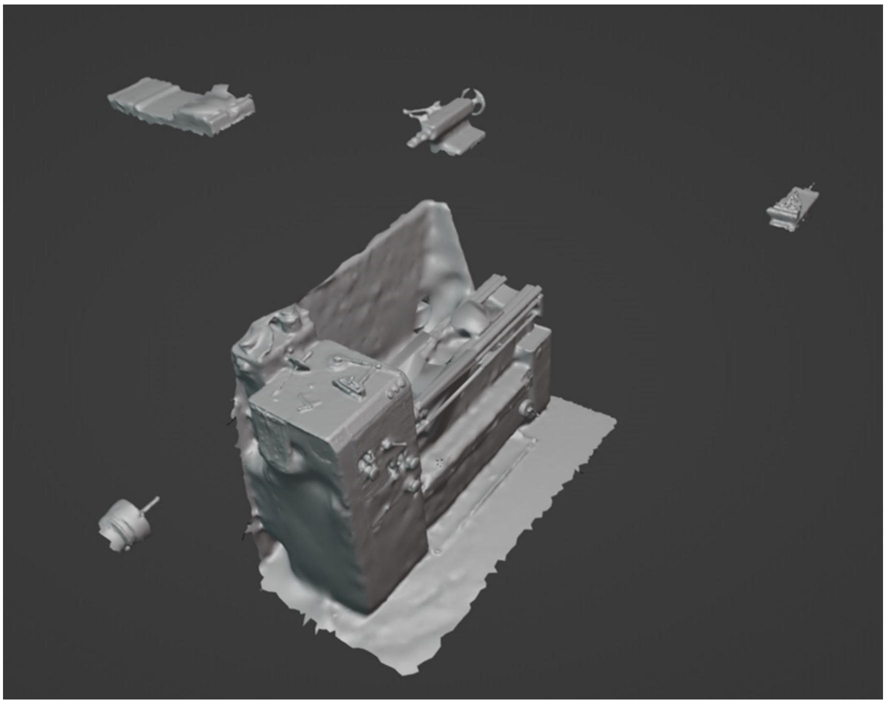

Figure 4: Lathe Machine and extracted moving parts

2.4 Simulating Lathe Machine Operations

One of the main challenges while simulating the Lathe machine operations is that it should closely resemble the real world functions of the machine. Audio, which plays a pivotal role in deciding how immersive the experience is, is also incorporated to enhance user experience. The machining sound is played only while Lathe is being operated and fades away as the user moves away from the machine. Our simulation model, although simplified to a large extend, have addressed all the key functionalities of a standard lathe machine. One such simplification is, for the ease of operation we have substituted all the control switches onto a control stand. A C# script connects all these buttons to the movement of the part associated. The figure 6 shows the control stand with all the buttons. All these buttons and the key functionalities are discussed below.

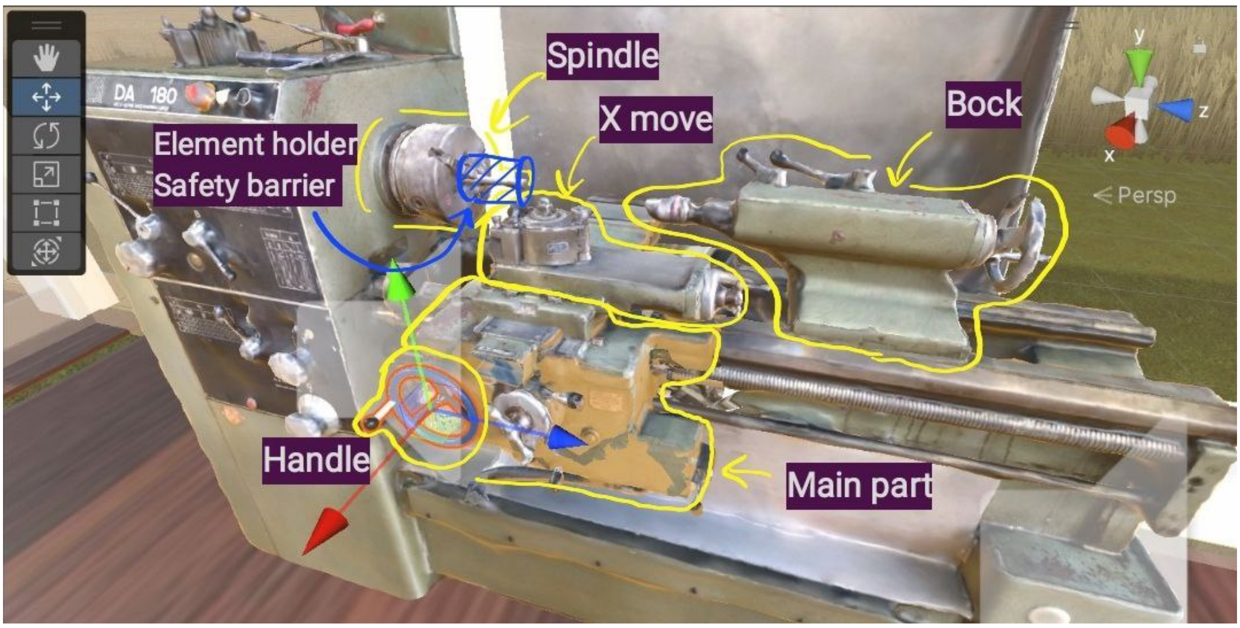

Figure 5: Each component displayed

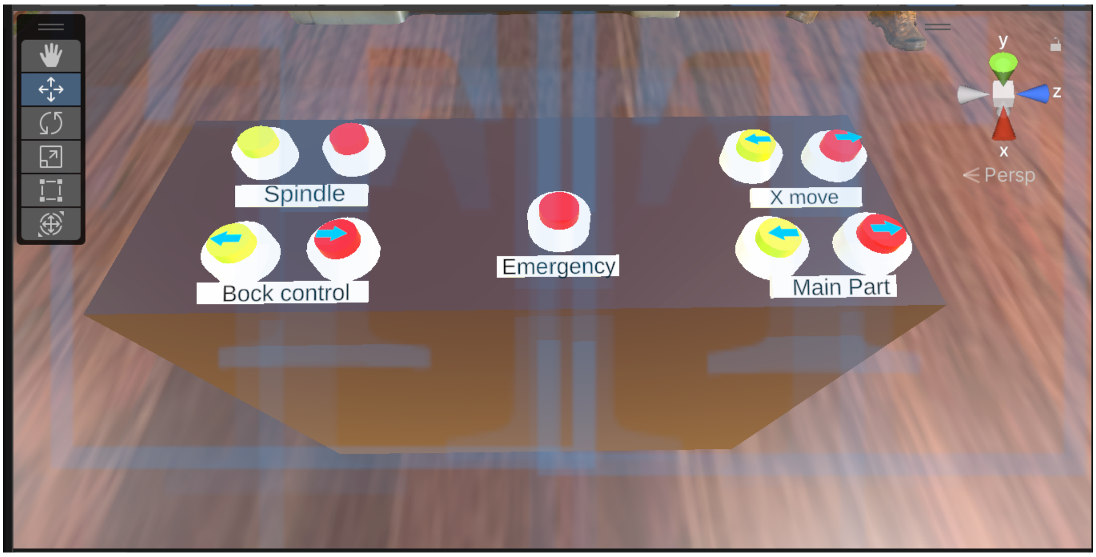

Figure 6: Control stand

- **Main body control**
  The Bed of the lathe is moved along the machine. The handle associated with the motion of this part also rotates when the button is pressed until the part reaches its extremities to simulate its actual working. In future, push button can be replaced by enabling rotating interaction on the handle.

- **X move**
  The part on top of the main body part is moved along the axis perpendicular to the motion of the main body part.

- **Bock control**
  Moves the tail stock along the length of the machine.

- **Spindle**
  Rotates the spindle. This part also has a the feature to attach different elements such as wood and metal (found floating on the table) onto it. The attached element also rotates along with the part. Further animation for trimming down of this elements are possible as a future scope.

- **Emergency Button**
  Immediately stops all operations currently active on the machine.

Utilizing the specific advantage of training in VR, that is the user is allowed to make mistakes without having the collateral damage associated with a typical physical training program, safety barriers are also added in our VR training program. The user receives audio feedback when safety barriers are breached.

2.5 Designing Realistic Workshop Environment

To create a realistic impression for immersion, it is necessary to house the lathe machine in an environment to closely resembles the real world. Therefore, there is a need to design a realistic workshop environment; this is done in Blender and Unity and involves creating a detailed 3D model of the space, adding realistic textures and materials, incorporating appropriate lighting, and optimizing the scene for real-time rendering. Here's an overview of the process:

- **Planning and Reference Gathering:** Visual references of real-life workshops inform the design process. This includes studying structures, images, and blueprints, or visiting physical workshops if possible. Identifying the key elements, layout, and workshop materials guided our design.
- **Modeling in Blender:** The desired layout was imported into Blender and used as a plane, and scaled to a realistic dimension for building the 3D model of the workshop. Begin with the primary structural elements such as walls, floor, and ceiling. Pay attention to accurate dimensions and proportions. Add details such as workbenches, tool racks, machinery, and other objects typically found in a workshop. Use Blender's modeling tools to create the geometry and refine the shapes and sizes to match the reference as seen in 7.

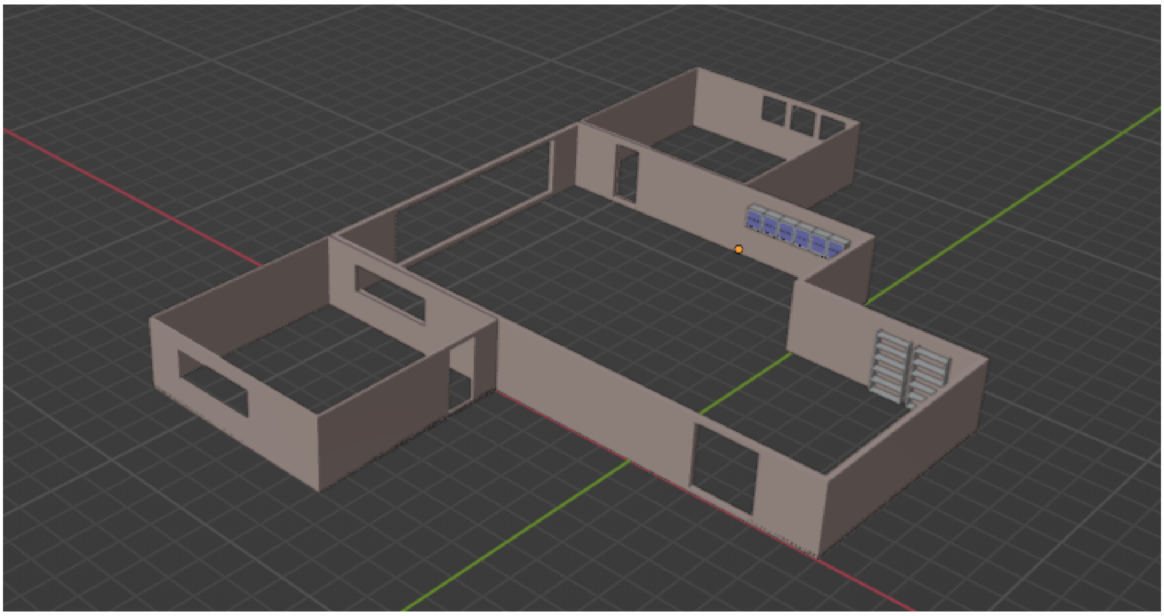

Figure 7: Blender Model of Workshop

- **Exporting to Unity:** Export the completed workshop model from Blender into the Unity game engine. Unity supports various file formats, such as FBX or OBJ.
- **Texturing and Materials:** Apply realistic textures and materials to the 3D model in Unity. Use high-quality texture maps for concrete, metal, wood, and plastic surfaces. Unity provides a material package online that reflects realistic appearances.
- **Building the terrain in Unity:** Additional details such as terrain, rivers, flowers and trees, and animations were incorporated to bring the workshop to life. As shown in Figure 8 unity provides a wide range of tools and assets to further enhance the realism of the environment.

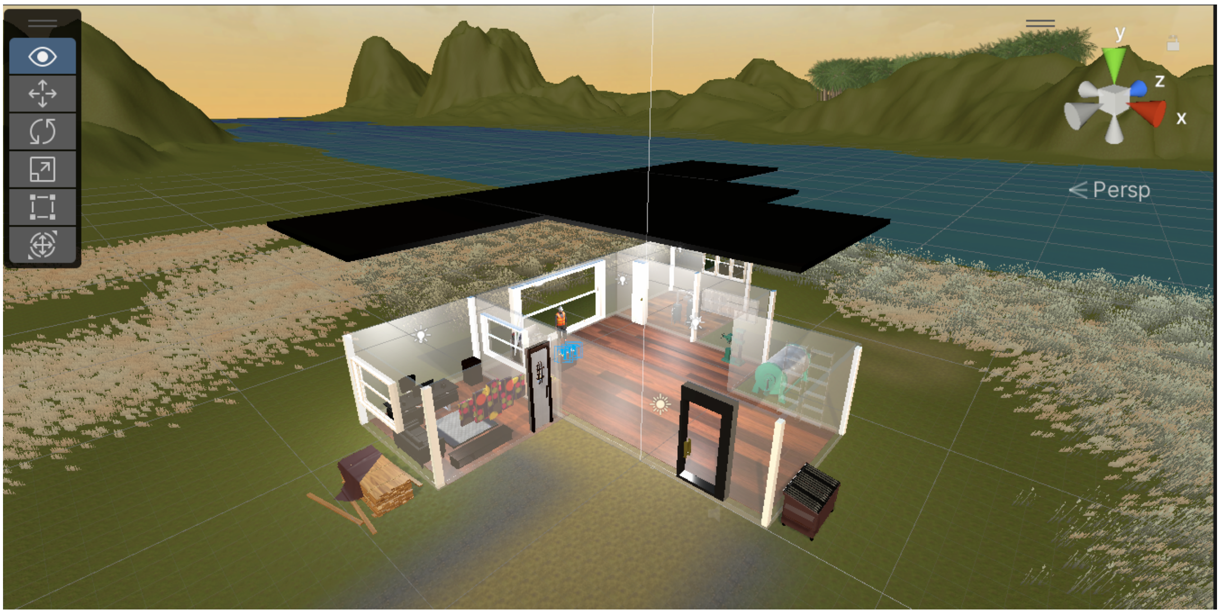

Figure 8: Workshop in the Environment

- **Lighting and Post-Processing in Unity:** Fine-tune the lighting and post-processing effects in Unity to achieve the desired visual quality. Adjust the intensity and color of the light sources, add shadows, and apply post-processing effects.

2.6 Incorporating Interactive Elements and User Movement

XR simulator, a component which handles mouse and keyboard input from the user and uses it to drive simulated XR controllers and an XR head mounted display (HMD). Because of limited access to a VR headset, our program was tested and developed using this simulator. The motion controls can be manually selected. By default, W,A,S,D give basic movement to the avatar while holding down shift or space bar for left and right hand respectively. Hands are simplified and shown in the simulation as white (left hand) and red (right hand) balls which are moved forward and backward using the mouse scroll. Using these, the user can grab the intractable element and place it on the spindle of the lathe. With this task, the user is learning the procedures in a machining process. Figure 9 depict the hands and the two elements/work pieces (wood and metal)

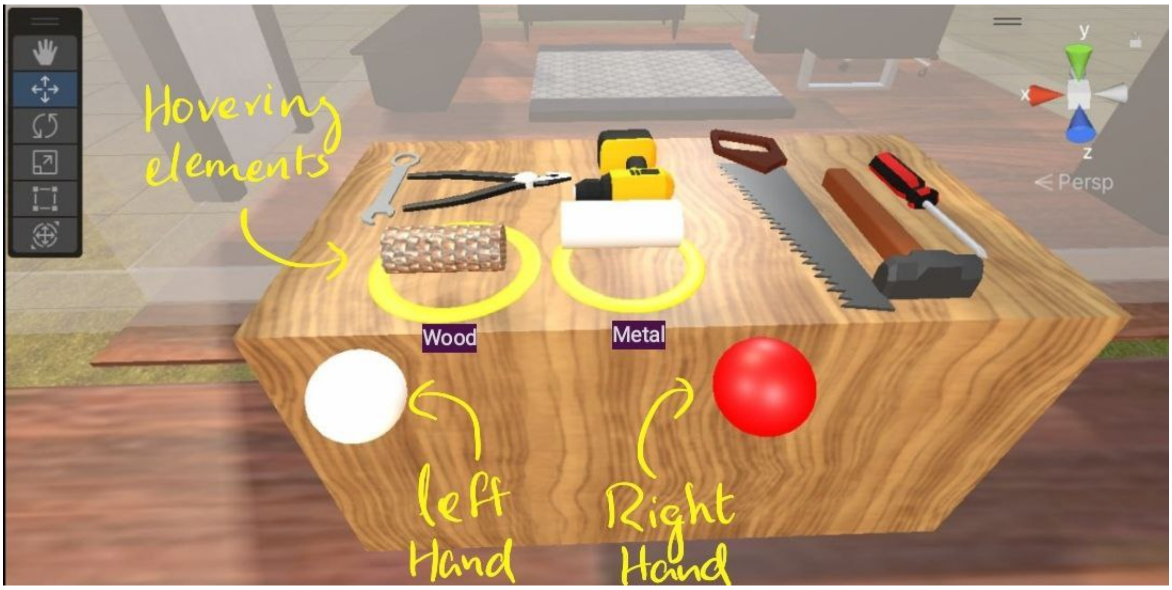

Figure 9: User interaction

Similarly, using a collider we have enabled interaction with an Avatar and doors. The Avatar and its basic animation was imported from maximo, adobe's free 3D character resource. The interaction is enabled by a C# script. The user can scroll through the predesignated dialogues about the machine and choose which questions to ask the avatar to which the avatar responds to that specific question. The safety instructions are also made scroll-able using mouse click interactions as shown in figure 10.

Figure 10: Avatar and slides

3 Developing Interactive Learning Modules

Interactive learning modules are crucial in engaging learners and facilitating active participation in the learning process. These modules combine instructional content with interactive elements to create an immersive and dynamic learning experience. To do this for the safety instruction of the lathe machine, the safety manual is condensed to a creative interactive manual.

3.1 Step-by-Step Lathe Safety Instructions

Lathes are machines that are widely used in metalworking and woodworking industries for shaping, cutting, and drilling materials. Although lathes provide a quick and efficient way to produce specific types of work pieces, they can be hazardous to operators if not handled with care. Non-closed, traditionally operated lathes, in particular, can be extremely dangerous if safety regulations are not adhered to. Therefore, it is crucial to follow the safety guidelines to prevent any potential accidents [9].

Personal Protective Equipment (PPE)

Wearing appropriate personal protective equipment is essential to safeguard operators from potential hazards. The following PPE should be worn while operating a lathe:

- Safety glasses or face shield: Protects eyes from flying debris, chips, and coolant splashes.
- Long Hair and Body Jewelry: Hair should be tightly tied in a knot to prevent entanglement in rotating parts. Jewelry like rings and piercings should be removed for the duration of the lathe's operation.
- Ear protection: Reduces the risk of hearing damage from the noise generated by the lathe.
- Protective clothing: Operators should wear appropriate, snug-fitting clothing covering the body to prevent injuries from entering or contacting rotating parts.
- Gloves: Non-snagging, cut-resistant gloves can protect hands from sharp edges and hot materials. However, gloves should be worn with extreme caution and only when no parts are moving!

Machine Inspection and Maintenance

Before operating a lathe, it is important to conduct a thorough inspection to ensure it is in proper working condition. Additionally, regular maintenance should be carried out, including:

- Check for loose or damaged components, such as belts, gears, and fasteners.
- Verify that safety guards and shields are functioning correctly.
- Ear protection: Reduces the risk of hearing damage from the noise generated by the lathe.
- Lubricate moving parts as per the manufacturer's instructions.
- Ensure proper alignment of tooling and work-holding devices.

Workspace Preparation

Maintaining a clean and organized workspace is crucial for safe lathe operation. Follow these guidelines:

- Clear the area of clutter, debris, and tripping hazards.
- Keep the floor dry and free of oil or coolant spills to prevent slips and falls.
- Provide adequate lighting to ensure good visibility during operation.
- Establish a safe distance between the lathe and other equipment or obstacles for safe movement.

Safe Operating Procedures

Adherence to proper operating procedures is paramount for the safe use of lathes. Consider the following guidelines:

- Familiarize yourself with the lathe's controls, emergency stop button, and power supply location.
- Always refer to the lathe's instruction manual and follow the manufacturer's guidelines for setup and operation.
- Securely fasten workpieces and use appropriate work-holding devices to prevent movement or ejection.
- Use the correct cutting tools, ensuring they are sharp, properly secured, and appropriate for the material being machined.
- Avoid excessive cutting depths or speeds that could lead to tool breakage or other dangerous situations.
- Do not reach into the rotating workpiece or remove chips by hand while the lathe is running. Use a brush or appropriate tool to clear chips.
- If a lathe requires manual adjustments, ensure that the lathe is turned off and completely stops before making any modifications.

Emergency Procedures

In the event of an emergency, operators should be familiar with the following procedures:

- Locate and familiarize yourself with the position of the emergency stop button.
- Know the location of fire extinguishers and how to operate them.
- Establish clear communication protocols and emergency contact information for immediate assistance.
- Regularly conduct drills and train operators on emergency response procedures.

Training and Supervision

All lathe operators should receive comprehensive training on lathe operation, safety procedures, and emergency protocols.

3.2 Demonstrating VR Safety Procedures

The content from the safety instructions for the lathe machine is condensed to a easy to consume version for the Virtual Reality training.

Figure 11: Lathe Machine safety - Page 1.

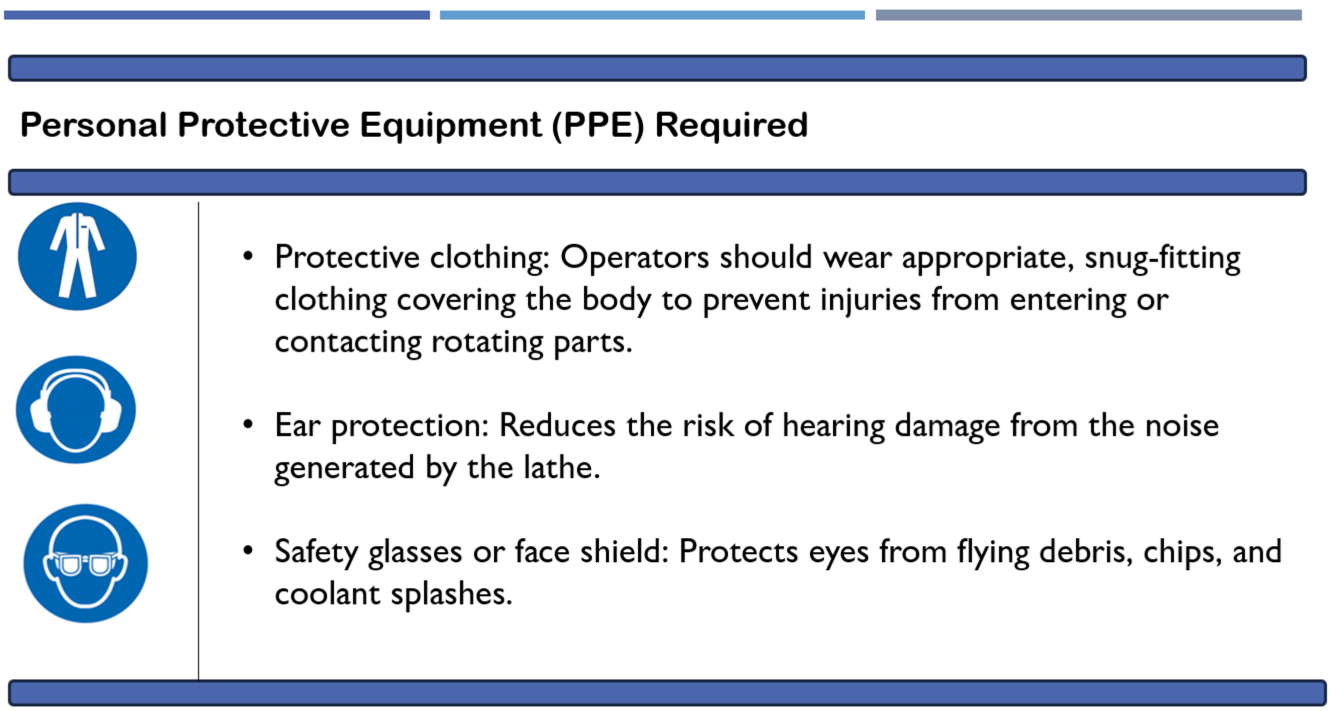

Figure 12: Lathe Machine safety - Page 2.

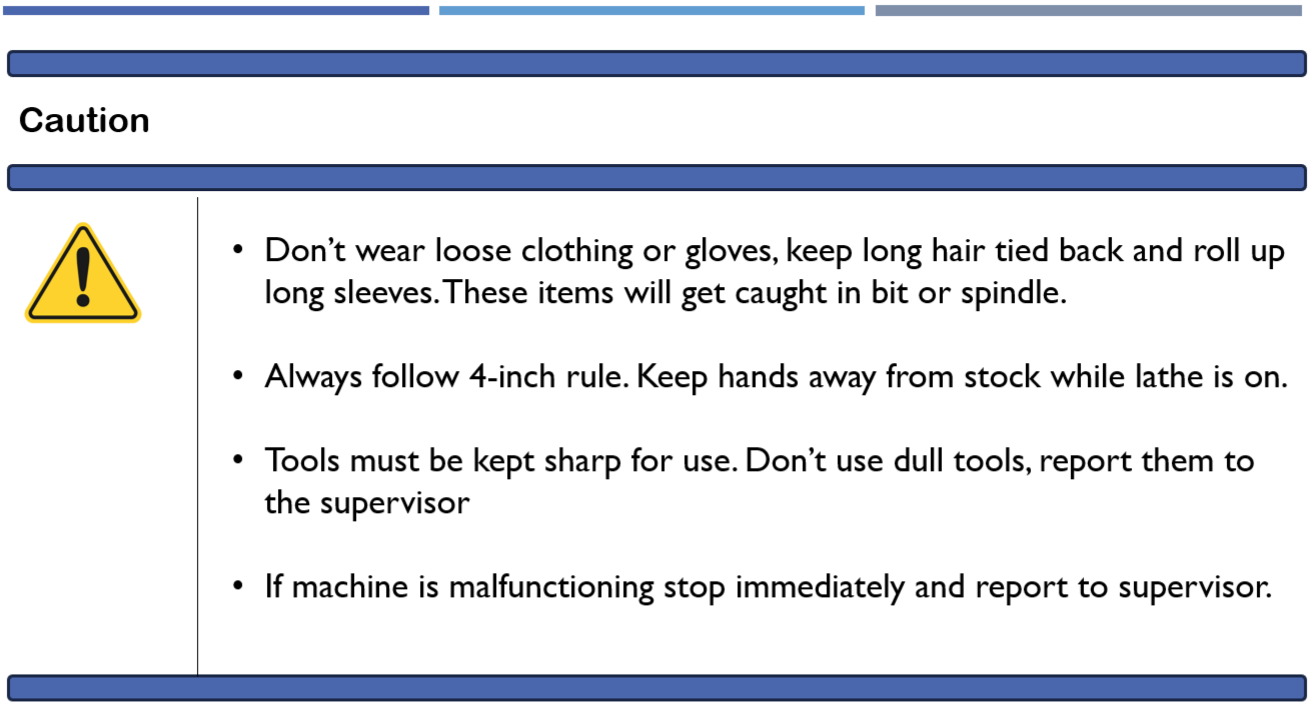

Figure 13: Lathe Machine safety - Page 3.

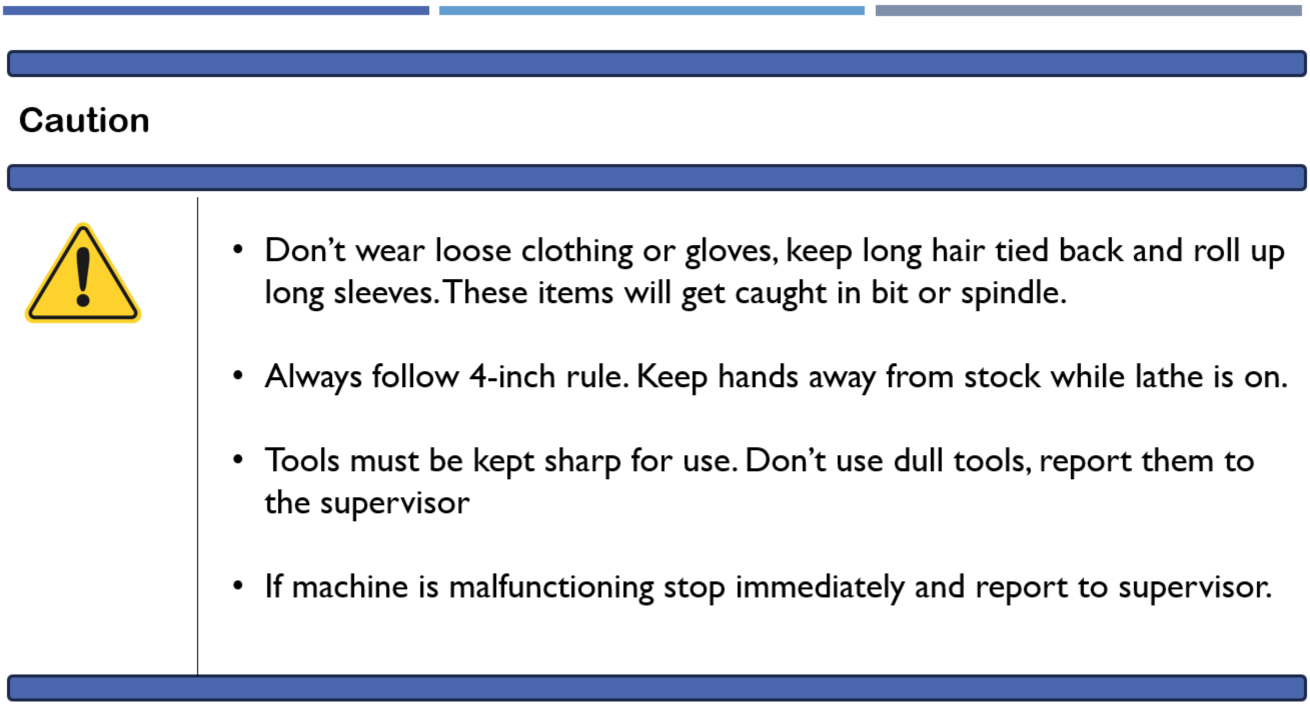

Figure 14: Lathe Machine safety - Page 4.

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4 Evaluation and Future Enhancements

4.1 Assesing the Effectiveness of the VR Tutorial

VR Training, while still in a very early stage of development, already sees excellent engagement from both trainers and trainees as it offers valuable advantages compared to traditional training:

- **Safety:** VR simulations allow trainees to practice operating lathes without the risks associated with real machines. Mistakes made in a virtual environment do not have the same consequences as in a physical setting.
- **Cost-effective:** Traditional training on lathes often requires dedicated machinery and materials, which can be expensive. VR training eliminates the need for physical resources, reducing costs associated with material waste, machine wear and tear, and the need for a dedicated training space.
- **Realistic simulations:** VR technology has advanced significantly, enabling highly realistic simulations. Trainees can experience a virtual lathe environment that closely resembles the real-world setting, allowing them to practice various tasks, such as tool selection, setup, and cutting operations.
- **Repeatable and scalable:** VR training allows trainees to repeat exercises and scenarios, allowing trainees to practice as much as needed. It also offers scalability, allowing multiple trainees to participate simultaneously and providing consistent training experiences across different locations.
- **Engagement and interactivity:** VR training can be more engaging and interactive than traditional methods. Trainees can manipulate virtual lathe controls and observe the outcomes of their actions in real time, enhancing their understanding and retention of the material.

While VR training is valuable to real hands-on experience, especially early on, it should always be complementary as it can not replace the training on a real machine.

4.2 Gathering User Feedback and Satisfaction

Besides the obvious training aspect, user satisfaction is this application's primary goal. If the experience for the user is not enjoyable or even creates a negative sentiment toward the actual lathe operating, the VR training won't see any use. To achieve a high satisfaction grade, extensive application testing is required. Test subjects should be veteran workers, trainers, and newbie trainees to fully project the scope of potential users. As no program is perfect from the start, this has to be an iterative process.

4.3 Identifying Areas for Future Enhancements

Movement and controls: Our lathe model has basic controls. One of the apparent improvements is to make the lathe fully interactable, where you can control the buttons, handles, and levers on the lathe itself. In addition to that, a more natural form of movement can reduce the motion sickness induced by the snap-turning settings and allow for easier and more targeted actions.

Additional Lathe functionality

Our lathe only had bare-bone functionality due to limited time and programming knowledge. Improvements can be:

- **Object collision**, i.e., every part of the machine and environment should act as a solid object and reacts accordingly when touched by the operator or other entities. This must also include a safety aspect, where when a collision is too fast, a warning should pop up, telling the trainee that irreversible damage could have occurred.
- **Physics:** An essential part of the training is to be able to work on materials and create work pieces, shaping them like on a real machine, Setting different rotations per minute, clamping individual parts, and using the main clamp incl. tool to secure work pieces
- **NPC upgrade and AI integration:** The NPC is a vital part of the learning process as it can provide important information and help the user. In its current iteration, its functionality is minimal. The best way to target specific learning goals is to expand its database to provide more in-depth information and guidance. However, if the scenarios should be more varied and even provide unforeseen challenges, an excellent way to implement that is to integrate an AI like, for example, GPT4/5 to make use of its generative and interactive capabilities.
- **Different Lathe Models and other Machines:** After providing a comprehensive lathe training experience, the next goal should be to upgrade the simulation to include additional equipment, like different lathe models and other machinery (milling, grinding, drilling, among others.)

5 Conclusion

In summary, virtual reality can affect almost every field in which visualization is involved. The case study pinpoints its application in educational content, and it has the potential to be a powerful form of content delivery. Because the current generation cannot remember times when computers were not heavily involved in their life, we project a very high acceptance rate.

On the other hand, the content development has not proven to be without its challenges because of the required knowledge necessary for this. Future advancements in the design of 3D models will decrease these challenges. Advancements like sketching out your plans and an Artificial intelligent plugin will help to design and fine-tune the concepts in the designer's head, and with time who knows, we might get to experience life in the OASIS.

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