# Project Final Report

# Title:

## A training VR environment to repair robots in a factory

UNIVERSITY OF ALBERTA

Introduction to Virtual and Augmented Reality and Telepresence

MM 806 - Fall 2023

Team 4

21 Dec 2023

# 1- Executive summary

## 1.1 - Background

In recent years, the synergy of virtual reality (VR) tech, industrial automation, and immersive learning has revolutionized workforce training in manufacturing. The Meta Quest 3 and Unity 3D empower advanced VR simulations for industrial training, specifically targeting the skills gap in repairing complex industrial robots amid Industry 4.0. Our project utilizes VR simulations with Unity 3D and Meta Quest 3, recognizing the demand for skilled technicians. Integrating digital twin tech enhances realism, allowing technicians to practice in virtual replicas of their workspaces. This approach aligns with trends, providing a technologically advanced solution for skilled workers in industrial robot repair.

**Keywords**: VR training simulation, Industrial robot repair training, Meta Quest 3, Unity 3D Industrial Robotic Manipulators Bundle, Digital Twin, NVIDIA Omniverse, Factory Simulation, Immersive Learning

## 1.2 - Introduction

The manufacturing industry is undergoing a significant transformation with Industry 4.0, integrating digital technologies into industrial processes. This shift has increased the use of complex industrial robots, improving productivity. However, maintaining and repairing these robots requires skilled technicians, and traditional training methods often lack hands-on experience. In response, this project aims to leverage virtual reality (VR) technology for immersive learning, recognizing the evolving landscape of Industry 4.0 in manufacturing. The goal is to revolutionize workforce training by providing technicians with the specialized knowledge and expertise needed for repairing complex robotic systems.

## 1.3. Project Objectives

- Bridging the skills gap by developing a sophisticated VR training environment utilizing Unity 3D and Meta Quest 3. This environment provides technicians with a realistic and immersive simulation of their workspaces, facilitated by the incorporation of digital twin technology from NVIDIA Omniverse.
- Including and crafting an authentic VR simulation that replicates the physical characteristics and challenges of industrial robot repair scenarios. To achieve this, we employed the Industrial Robotic Manipulators Bundle Unity 3D asset, ensuring a hands-on and pedagogically effective learning experience. Additionally, the integration of digital twin technology elevated the realism of the simulation, enabling technicians to practice on virtual replicas of their specific work environments.
- Contribution to workforce preparedness in the era of smart manufacturing. By aligning with industry trends and providing a technologically advanced solution, we strive to meet the urgent demand for skilled workers in the specialized field of industrial robot repair.

## 1.4 - Necessity of a VR Environment for Robot Repair

Traditional training methods for industrial robot repair often rely on classroom instruction, textbooks, and static simulations. These methods lack the immersive and interactive nature of VR, which can significantly enhance learning outcomes. VR training provides several advantages over traditional methods:

- Immersion: VR creates a fully immersive environment that allows technicians to feel like they are actually working on a robot, enhancing their understanding and retention of information.

- Interactivity: VR simulations allow technicians to interact with virtual robots, performing diagnostic tests, troubleshooting problems, and practicing repair procedures.
- Repeatability: VR simulations can be repeated as many times as needed, allowing technicians to refine their skills and confidence.
- Safety: VR simulations eliminate the potential hazards associated with working on real robots, providing a safe environment for training.

## 1.5 - Industry Challenges

The proposed VR training environment addresses several critical challenges faced by the manufacturing industry:

- Skills Gap: The increasing complexity of industrial robots requires technicians to possess specialized knowledge and skills that are often difficult to acquire through traditional training methods. VR provides an effective solution to bridge this skills gap.
- Training Costs: Traditional training methods can be expensive and time-consuming, often requiring technicians to travel to centralized training facilities. VR offers a cost-effective and scalable alternative that can be implemented in situ at manufacturing facilities.
- Employee Engagement: VR training can be highly engaging and motivating, fostering a positive learning experience that enhances employee satisfaction and retention.
- The complexities associated with repairing industrial robots demand a more dynamic and practical training approach. Traditional methods often involve theoretical instruction or limited hands-on experience, leading to a significant gap between theoretical knowledge and practical application. Moreover, the rapid evolution of robotic technology necessitates continuous learning and adaptation, further underscoring the limitations of conventional training methodologies.

## 1.6 - Scope of Work

Technical Scope

- Development of a VR training environment for industrial robot repair.
- Integration of Meta Quest 3 and Unity 3D for immersive simulations.
- Use of Industrial Robotic Manipulators Bundle Unity 3D asset.
- Incorporation of NVIDIA Omniverse's digital twin technology.
- Emphasis on creating a realistic simulation of industrial robot repair scenarios.

Deliverables

- An authentic VR simulation replicating physical characteristics and challenges of industrial robot repair.
- Integration of digital twin technology for enhanced realism.
- Utilization of Meta Quest 3's portability for convenient and accessible training.
- Detailed documentation outlining the VR environment, features, and technologies used.
- Assessment tools for technicians to practice diagnostic tests, troubleshooting, and repair procedures.

Targeted User Group

- Skilled technicians in the manufacturing industry.

- Workers in need of specialized knowledge for repairing complex industrial robots.
- Those facing challenges with traditional training methods in adapting to Industry 4.0.

# 2. Methodology

This project developed using a structured and iterative methodology that encompasses the following phases:

**1. Planning Phase:** Conducting a thorough analysis of project requirements, objectives, and deliverables. This includes defining VR training scope, identifying target users, outlining skills to be taught, and creating a project timeline with resource allocation.

**2. Unity 3D Development:** Creating an immersive industrial robot repair environment using Unity 3D. This involves building 3D models of robots, designing interactive elements, and implementing core mechanics for the VR training.

**3. NVIDIA Omniverse Integration:** Enhancing VR training realism by integrating NVIDIA Omniverse, a platform for creating digital twins. This involves simulating real-world scenarios in a digital twin of an industrial robot repair environment, enhancing the learning experience for technicians. (Due to time limitation and lack of real-time data, we mostly considered theorical aspects for NVIDIA integration)

**4. Testing and Optimization:** Rigorously testing the VR training environment for functionality, usability, and effectiveness. This includes user, performance, and compatibility testing. Feedback used to refine and optimize the VR training performance.

**5. Documentation:** Developing clear instructions for the VR training environment, covering installation, setup, operation, troubleshooting, and detailed explanations of training modules and assessment tools.

# 3 - Implementation Timeline and Team members' responsibilities

1. Week 1: November 20 - November 26 **(All team members are involved)**
    - Day 1 (November 20): Project Kickoff
        - Introduction to the team.
        - Discussion of project goals and objectives.
        - Initial planning and allocation of roles.
    - Days 2-4 (November 21-23): Detailed Project Planning
        - In-depth discussion on technical scope and challenges.
        - Identification of potential risks and formulation of mitigation strategies.
        - Detailed planning for each development phase.
    - Days 5-7 (November 24-26): Begin Planning Phase
        - Outline the specifics of the VR training environment.
        - Determine the features and functionalities to be included.
        - Start documentation outlining the VR environment, features, and technologies.
2. Week 2: November 27 - December 3

- Days 8-12 (November 27-December 1): Unity 3D Development **(Morteza, Sanjana Sanjana)**
    - Initiate the development of the VR training environment using Unity 3D.
    - Incorporate the Industrial Robotic Manipulators Bundle Unity 3D asset.
    - Begin crafting a realistic simulation of industrial robot repair scenarios.
- Days 13-15 (December 2-4): NVIDIA Omniverse Integration **(Sanjana Guntha, Ahalya Jupalli)**
    - Integrate NVIDIA Omniverse's digital twin technology.
    - Ensure seamless collaboration between Unity 3D and Omniverse.
    - Test the integration to address any potential issues.
- Days 16-18 (December 5-7): Testing and Optimization **(Morteza, Sanjana Guntha)**
    - Conduct thorough testing of the VR environment.
    - Optimize performance and address any bugs or issues.
    - Begin creating assessment tools for diagnostic tests and troubleshooting.

3. Week 3: December 4 - December 10
    - Days 19-21 (December 8-10): Documentation **(Sanjana Sanjana, Ahalya Jupalli)**
        - Finalize documentation outlining the VR environment, features, and technologies used.
        - Create user manuals and guidelines for technicians.
        - Prepare for the upcoming user testing phase.
    - Days 22-23 (December 11-12): Deliverables Creation **(Morteza, Sanjana Sanjana)**
        - Polish the VR simulation to ensure authenticity and realism.
        - Develop additional features that utilize the Meta Quest 3's portability.
        - Create detailed documentation for assessment tools.
4. Week 4: December 11 - December 15
    - Days 24-25 (December 13-15): User Testing and Feedback **(Sanjana Guntha, Ahalya Jupalli)**
        - Conduct user testing with the targeted group.
        - Gather feedback on usability, realism, and effectiveness.
        - Incorporate user feedback to refine and enhance the VR environment.
    - Day 25 (December 15): Finalization and Presentation Preparation **(Morteza, Ahalya Jupalli)**
        - Finalize the VR training environment based on user feedback.
        - Prepare a comprehensive documentation package for the final presentation.

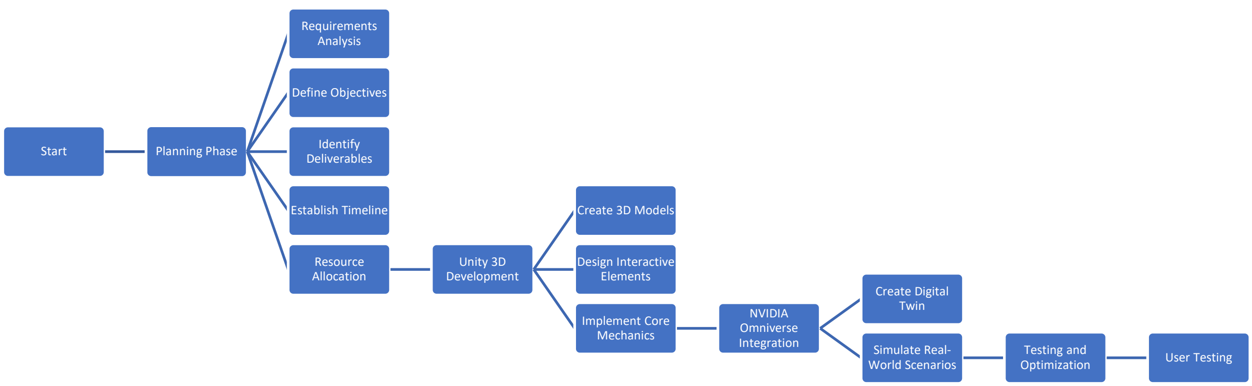
# 4 -Project Resources

1. Hardware:
    - Meta Quest 3 VR Headsets (for development and testing) (MRC)
    - High-performance computers/workstations for VR development (AHCI Computer)
    - NVIDIA GPU-compatible with Unity and Omniverse requirements
    - VR-compatible peripherals for user testing
2. Software:
    - Unity 3D: For VR development and creating the immersive training environment.
    - NVIDIA Omniverse: To integrate digital twin technology into the VR simulation.
    - VR Development Software: Tools and plugins compatible with Unity for VR development.

- Documentation Tools: Software for creating detailed documentation, manuals, and guidelines.
- Collaboration Tools: Platforms for team communication and collaboration.

3. VR Development Assets:
   - Unity Asset Store Resources: Additional assets for environment design, textures, and models.
4. User Testing Resources:
   - User feedback collection tools
   - Evaluation forms and surveys for usability testing
5. Project Documentation Tools:
   - Documentation software (e.g., Microsoft Word, Google Docs) for project reports, plans, and manuals.
   - Version control tools (e.g., Git) for managing changes in the project.

# 5 - Project Implementation Workflow




# 5.1 - Workflow of the final application

The final product of this project is a virtual reality (VR) training application designed for the Meta Quest 3 device, aimed at training technicians for repairing industrial robots in a factory setting. Here's a step-by-step overview of what a person experiences when running the VR application on the Meta Quest 3 headset:

1. Opening the Application
2. Initialization of the App
3. A Text-based tutorial for navigation, grabbing items, etc.
4. Training Session through immersive learning environment (including vibration Haptic feedback and factory-related audio sounds) and hands-on training
5. Repeatable Simulations through restart menu
6. Exit the environment part

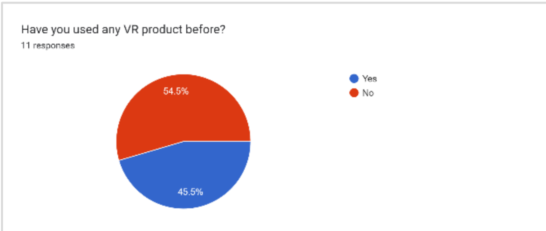
## 6 - Usability Test

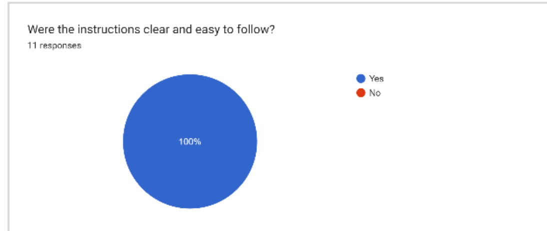
We conducted a usability test on 11 participants to evaluate the effectiveness and user-friendliness of our VR app. The participants were a mix of individuals with and without prior VR experience.

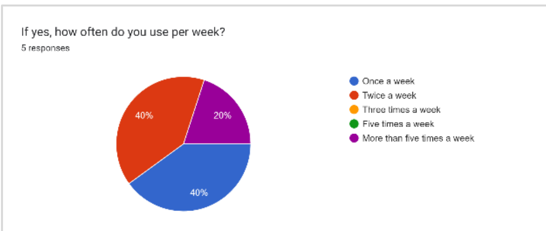
## 6.1 – Test questions and their topics

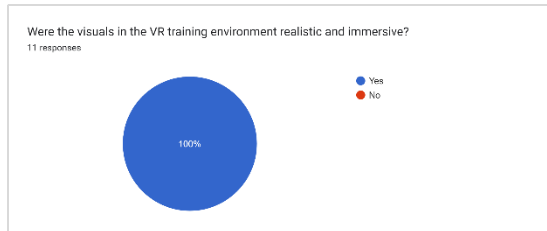
| # | Topics | Questions |
|---|---|---|
| 1 | Prior VR Experience | Have you used any VR product before? |
| 2 | Frequency of VR Usage | If yes, how often do you use per week? |
| 3 | Task Completion | Were you able to complete the tasks outlined in the training scenario without errors? |
| 4 | Use of Diagnostic Tools | Were you able to effectively use the diagnostic tools to identify and troubleshoot problems with the virtual robot? |
| 5 | Repair Procedure Success | How successfully were you able to perform repair procedures on the virtual robot? |
| 6 | Navigation Ease | How easily were you able to navigate through the VR training environment? |
| 7 | Clarity of Instructions | 7Were the instructions clear and easy to follow? |
| 8 | Realism and Immersion | Were the visuals in the VR training environment realistic and immersive? |
| 9 | Sound Effects | Were the sound effects appropriate and enhance the realism of the training environment? |
| 10 | Difficulty Encountered | Did you find any difficulty during any part of the project? |
| 11 | Comfort Level | How comfortable was the experience? |
| 12 | Motion Sickness or Discomfort | How comfortable was the experience regarding to motion sickness or discomfort? |
| 13 | Guidance and Instructions | Was there sufficient guidance or instructions to assist in understanding what to do next? |
| 14 | Suggestions for Improvement | Are there any specific features or aspects that you would like to suggest? |
| 15 | Final Thoughts | Do you have any final thoughts on what you saw today? |

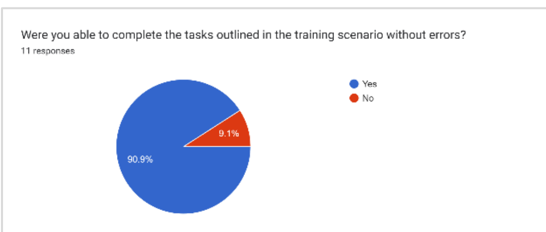
# 6.2 – Visualizations

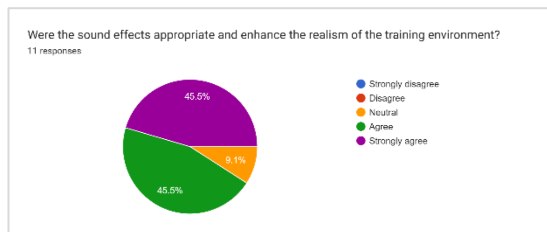


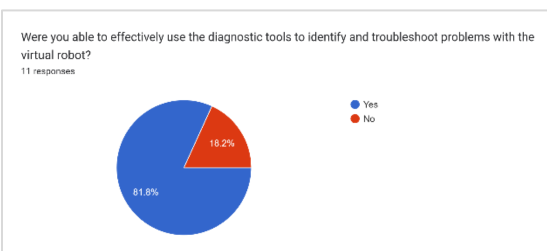



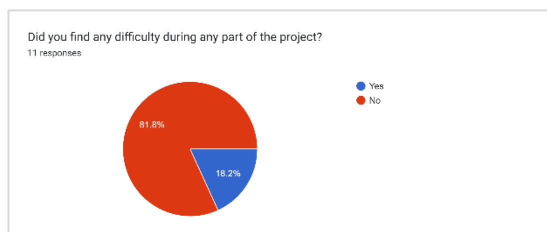



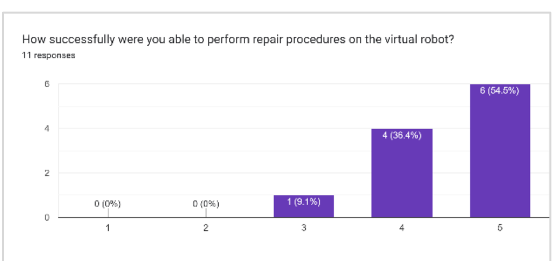



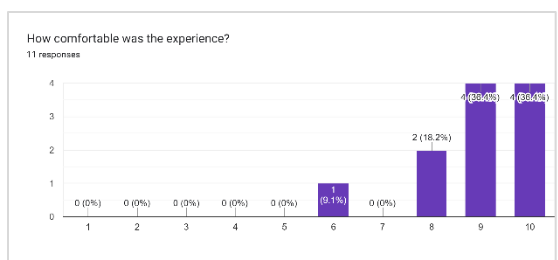



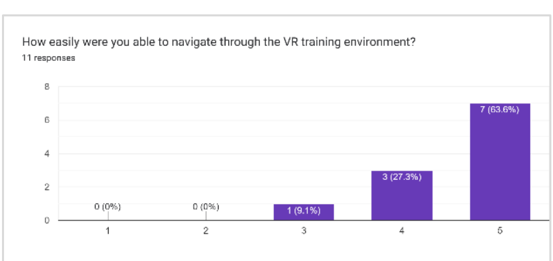



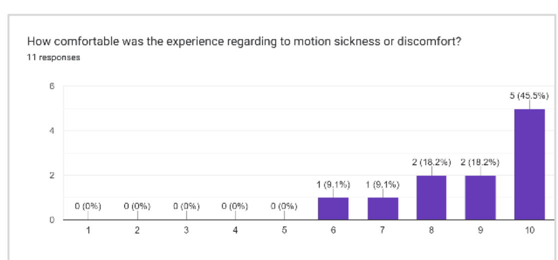



## 6.3 – Key Findings

1. **Prior VR Experience:**

   54.5% of participants had prior VR experience, while 45.5% were newcomers to VR.

2. **Frequency of VR Usage:**

   Among those with prior experience, the majority (40%) used VR once a week, and another 40% used it twice a week. No participants reported using VR more than twice a week.

3. **Task Completion:**

   90.9% of participants were able to complete the tasks outlined in the training scenario without errors.

4. **Use of Diagnostic Tools:**

   81.8% found the diagnostic tools effective in identifying and troubleshooting problems with the virtual robot.

5. **Repair Procedure Success:**

   The majority (54.5%) rated their success in performing repair procedures as a 5, while 36.4% rated it a 4.

6. Navigation Ease:

   Most participants (63.6%) found it very easy to navigate through the VR training environment.

7. **Clarity of Instructions:**

   100% of participants found the instructions clear and easy to follow.

8. **Realism and Immersion:**

   All participants (100%) agreed that the visuals in the VR training environment were realistic and immersive.

9. **Sound Effects:**

   Participants were generally positive about sound effects, with 45.5% strongly agreeing and 45.5% agreeing that they enhanced the realism.

10. **Difficulty Encountered:**

    18.2% of participants reported some difficulty during the project.

11. **Comfort Level:**

    The comfort level varied, with 36.4% rating it a 9 and 36.4% rating it a 10.

12. **Motion Sickness or Discomfort:**

    45.5% rated their comfort level regarding motion sickness or discomfort as a 10.

13. **Guidance and Instructions:**

    90.9% felt there was sufficient guidance, while 9.1% expressed a preference for visual animations over text tutorials.

14. **Suggestions for Improvement:**

    No specific suggestions were provided, and one participant praised the project as "next level."

15. **Final Thoughts:**

    Most participants had no specific comments, with one noting issues when using glasses with the Meta Quest 3

## 6.4 – Analysis

The usability test for the app has yielded predominantly positive feedback, with participants praising the clarity of instructions, realistic visuals, and effective use of diagnostic tools. However, some users faced minor difficulties, particularly those wearing glasses. Addressing these issues in further iterations could potentially enhance overall user satisfaction.

The app's immersive experience and positive reception indicate promising potential for success. Notably, the absence of specific feature requests suggests a well-designed and complete user experience.

Moving forward, the next phase involves a systematic approach to improve user experience. This begins with a thorough analysis of user feedback and quantitative data from the initial test. Prioritizing identified issues allows for a focus on the most critical problems affecting the majority of users. Careful selection of changes is crucial to avoid introducing new problems, and swift implementation is emphasized for immediate benefits.

Following the implementation phase, retesting and iterations are planned to validate the effectiveness of the changes made. This iterative design process aims to continuously refine the app. Clear communication of results, meticulous documentation of the entire process, and celebrating successes along the way are highlighted as crucial aspects of this approach. This comprehensive strategy ensures that the VR app evolves based on user feedback, maintaining a commitment to delivering an optimal user experience.

# 7 - Future Work

The future work for our VR app involves an array of enhancements to solidify its position as a cutting-edge industrial training tool. These include advanced scenario customization, adaptive learning algorithms, real-time data feedback integration, expanded platform compatibility, collaborative training environments, AI-driven virtual instructors, continuous content expansion, accessibility features, integration with Learning Management Systems, and a long-term impact assessment. By focusing on these areas, we aim to provide a highly personalized, realistic, and inclusive training experience, ensuring sustained effectiveness and addressing evolving industry needs.

# 8 - Acknowledgment

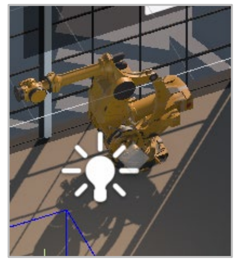
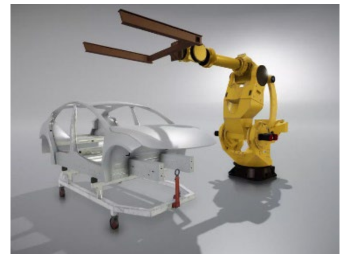
We would like to express our sincere gratitude to Dr. Pierre Boulanger for contributions to this project.

# 9 - Conclusion

This project (Developing A Training VR Environment to Repair Robots in a Factory) is a forward-looking initiative designed to address the evolving needs of the manufacturing industry. Utilizing cutting-edge VR technology, the project aims to empower technicians with the skills necessary for modern industrial robot repair, aligning with the demands of Industry 4.0. By leveraging Unity 3D, the Meta Quest 3, and digital twin technology, the proposed project seeks to offer a cost-effective and scalable training solution. Ultimately, it aspires to enhance the skills and readiness of technicians, ensuring their proficiency in the dynamic landscape of industrial robot repair.

# 10 – Appendix

## 10.1 – App Environment and HMD

## 10.2 – Client and team

**Client:** Name: Dr. Pierre Boulanger Email Address: pierreb@ualberta.ca

**Team Member's Contact Information**

| Member name | Student ID | E-mail |
|---|---|---|
| **Morteza Mogharrab** | 1830256 | mogharra@ualberta.ca |
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# 11 - Resources

The following resources have the potential to be highly beneficial for the successful completion of this project.

- Unity VR Development Pathway: https://learn.unity.com/learn/pathway/vr-development
- Unity VR Documentation: https://docs.unity3d.com/Manual/VROverview.html
- Industrial Robot Asset: https://assetstore.unity.com/packages/3d/props/industrial/industrial-robotic-manipulators-bundle-140368