Assignment 02: Interactive System Case Study and Analysis – MR-based Interactive Milling Machine

Course: Designing for Interactive Systems (DES205)

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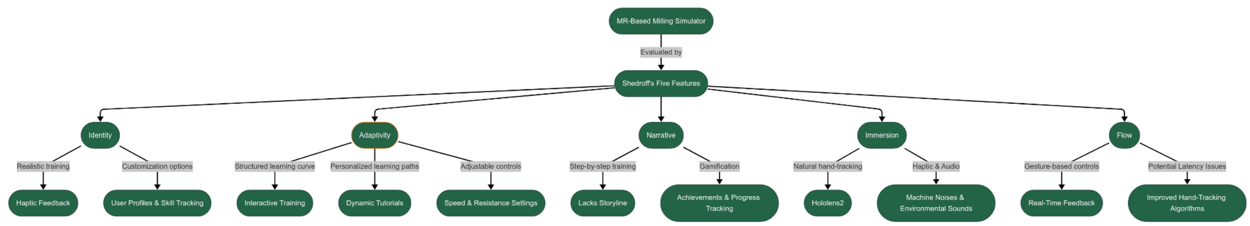
The MR-based milling simulator provides an interactive and immersive training experience for machinists, combining mixed reality (MR) and haptic feedback. It enhances skill development while addressing traditional training challenges like high costs, safety risks, and limited resources.

1. Evaluating the MR-Based Milling Simulator Through Shedroff's Five Features



Analysis using Shedroff's Framework

Nathan Shedroff's five features—Identity, Adaptivity, Narrative, Immersion, and Flow—offer a framework for assessing how engaging an interactive system is. This analysis explores how the MR-based milling simulator aligns with these principles, highlighting both its strengths and potential improvements.

1.1 Identity

Identity in interactive systems refers to how well users connect with the experience and whether it feels authentic. The MR-based milling simulator delivers a realistic training experience, mimicking a physical milling machine with haptic feedback that lets users feel cutting forces. This enhances immersion and makes learning more hands-on.

However, authenticity extends beyond realism—it's also about personal connection. The simulator could benefit from customizable settings, allowing users to modify machine configurations, materials, and control responsiveness. Additionally, integrating user profiles with skill progression tracking would personalize the experience, making it more engaging for learners at different expertise levels.

1.2 Adaptivity

A truly adaptive system accommodates users with varying experience levels and learning styles. The MR simulator currently offers interactive training with a structured learning curve, along with real-time feedback to help users identify mistakes and improve their skills.

To enhance adaptivity, the system could introduce personalized learning paths that adjust difficulty based on user performance. A dynamic tutorial system could guide beginners step-by-step while allowing advanced users to skip repetitive instructions. Adding adjustable speed and resistance settings would further refine user control, ensuring the simulator remains beneficial for both novices and experienced trainees.

1.3 Narrative

A compelling narrative enhances engagement by providing context and purpose. While the MR-based milling simulator follows a step-by-step training structure, it lacks an overarching storyline to connect the learning experience.

Introducing story-driven scenarios, such as real-world industrial challenges or troubleshooting tasks, could increase engagement. Additionally, gamification elements like achievement badges, progress tracking, and skill milestones would encourage users to stay motivated. A structured learning journey with performance-based rewards could make training feel more dynamic and rewarding.

1.4 Immersion

Immersion determines how effectively a system captivates users and transports them into the interactive environment. The MR simulator achieves a high level of immersion through its Hololens2-based environment, which supports natural hand-tracking and interactive gestures. Haptic feedback further enhances realism by simulating milling forces.

To elevate immersion further, the simulator could benefit from improved graphical fidelity (higher-resolution textures, better lighting) and spatial audio cues that mimic machine noises and surrounding environmental sounds. Additionally, enabling more dynamic environmental interactions, such as manually adjusting machine parts within the virtual space, would make the experience feel even more lifelike.

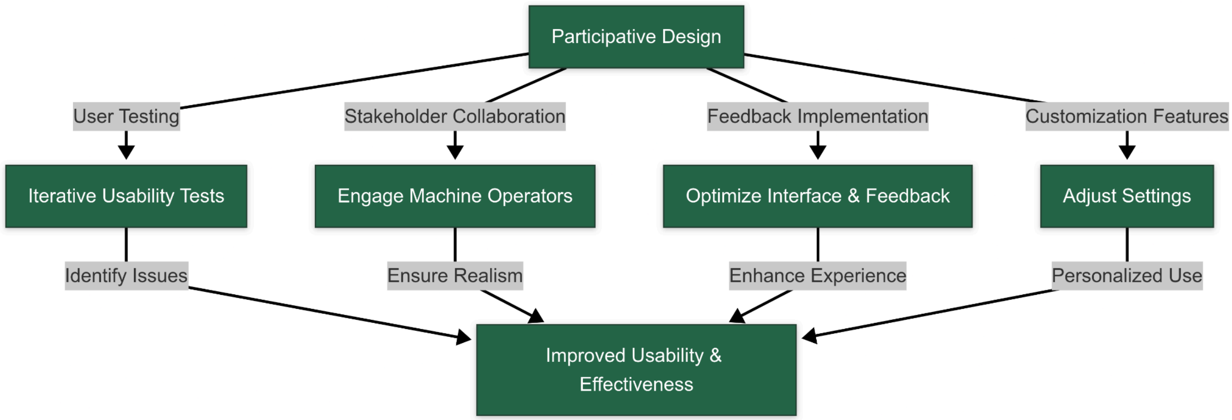
1.5 Flow

Flow ensures smooth, uninterrupted engagement as users progress through training. The MR simulator offers a fluid workflow with gesture-based controls and real-time feedback. However, some latency issues in gesture recognition can break immersion and cause frustration.

To enhance flow, improvements such as predictive hand-tracking algorithms, refined gesture recognition, and a more intuitive control layout would be beneficial. A progress indicator could also visually represent a user’s training journey, reinforcing engagement and motivation.

2. The Role of Participative Design

The development of the MR-based milling simulator did not involve direct user participation in its early design stages. Applying participative design principles—which emphasize stakeholder engagement and iterative user testing—could have improved usability and overall effectiveness.



The Role of Participative Design

Potential benefits of participative design include:

- *User Testing: Conducting iterative usability tests with real trainees, instructors, and industry professionals to identify usability issues.*
- *Stakeholder Collaboration: Involving experienced machine operators to ensure the training environment accurately reflects real-world scenarios.*
- *Feedback Implementation: Using user suggestions to optimize interface responsiveness, haptic feedback accuracy, and interaction methods.*
- *Customization Features: Allowing users to adjust settings, such as control sensitivity, interface layout, and feedback intensity, to match their preferences.*

3. The Design Process

3.1 Conceptual Design

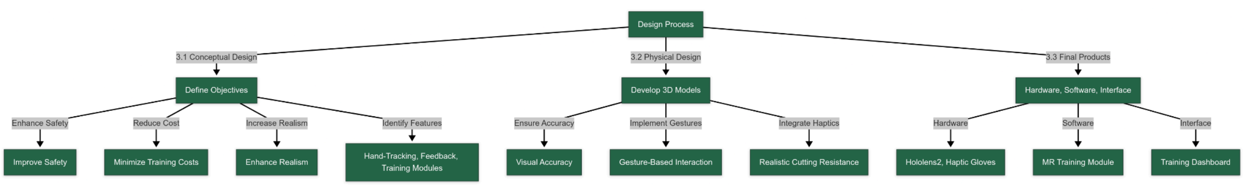
- *Defining the objectives of the MR simulator, including safety enhancement, cost reduction, and realism.*
- *Identifying core features such as hand-tracking, real-time feedback, and structured training modules.*

3.2 Physical Design

- *Developing 3D models of the milling machine for visual accuracy.*
- *Implementing gesture-based interactions and MR visualization using Hololens2.*
- *Integrating haptic feedback mechanisms to simulate realistic cutting resistance.*

3.3 Final Products

- *Hardware: Hololens2 headset, potential haptic gloves.*
- *Software: MR-based interactive training module.*
- *Interface: A training dashboard featuring machine operations and progress tracking.*



The Design Process

4. Heuristic Evaluation

Evaluation Against Usability Heuristics:

1. *Visibility of system status: The simulator provides real-time feedback on the milling process.*
2. *Match between system and real-world expectations: The MR interface closely mimics a real milling machine.*
3. *User control and freedom: The system lacks an undo/redo function, which could be added for error recovery.*
4. *Consistency and standards: Uses standard MR interaction techniques, but training navigation can be improved.*
5. *Error prevention: Implementing predictive feedback before mistakes occur would enhance usability.*
6. *Recognition rather than recall: Clear labels and instructions improve usability, but tooltips could be added.*
7. *Flexibility and efficiency of use: Adjustable difficulty levels would make the system more efficient.*
8. *Aesthetic and minimalist design: The MR interface is clean, but additional customization features could be beneficial.*
9. *Help and documentation: Step-by-step tutorials help, but interactive guides could enhance learning.*

5. Questionnaire Design

For this Design We are using with methodology from course Research Methodologies in social science and design, is crucial for assessing the sense of presence and usability of the MR-based milling simulator. The questions below aim to capture users' experiences, difficulties, and suggestions for improvements.

Sense of Presence Questions

1. *On a scale of 1-10, how present did you feel in the MR environment?*
    - *(1: Not at all present – 10: Completely present, as if inside the environment)*
    - *Please describe any factors that contributed to your rating.*
2. *Did you feel as though you were operating a real milling machine? (Yes/No)*
    - *If no, what elements made it feel artificial or lacking in realism?*
3. *How realistic was the haptic feedback in simulating the milling operation?*
    - *(Scale: Poor, Fair, Good, Very Good, Excellent)*
    - *Did you feel a strong, weak, or inconsistent force feedback? Explain your experience.*
4. *Did you experience any distractions or breaks in immersion?*
    - *(Yes/No)*

    - *If yes, specify whether they were caused by visual inconsistencies, lag, discomfort, or other issues.*
5. *How engaging did you find the simulation compared to traditional training methods?*
    - *(Scale: Not engaging, Slightly engaging, Moderately engaging, Very engaging, Extremely engaging)*
    - *What specific aspects enhanced or reduced engagement?*
6. *Did you feel in control of the milling machine's operations? (Yes/No)*
    - *If no, describe what aspects of the interaction were challenging.*

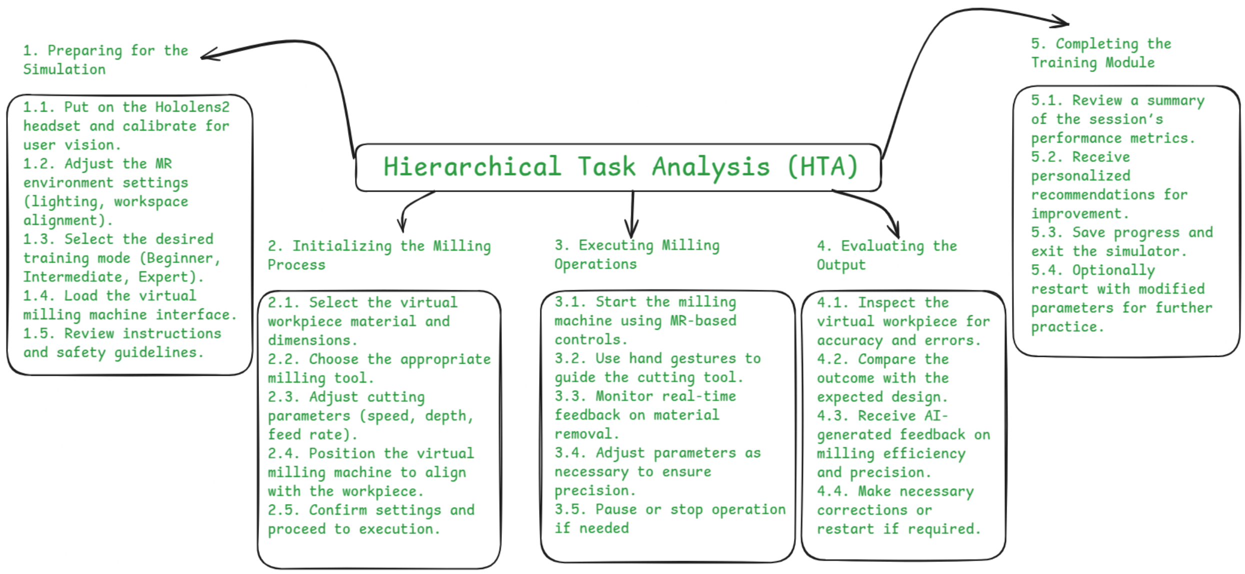
Usability Questions

1. *How easy was it to navigate the MR interface? (1-10 scale)*
    - *(1: Very difficult – 10: Very easy)*
    - *Did you require assistance, or was it intuitive to operate?*
2. *Were the instructions and feedback clear and understandable? (Yes/No)*
    - *If no, what parts of the instructions or feedback were unclear?*
3. *Did you experience any difficulties in hand-tracking interactions?*
    - *(Yes/No)*
    - *If yes, describe whether the system misinterpreted gestures, had lag, or required excessive effort.*
4. *How would you rate the responsiveness of the system to your gestures and commands?*
    - *(Scale: Poor, Fair, Good, Very Good, Excellent)*
    - *Did you feel there was a delay, or was it immediate and natural?*
5. *Did the MR system provide sufficient feedback when you made an error? (Yes/No)*
    - *If no, what kind of feedback would have been helpful (e.g., visual, auditory, haptic)?*
6. *Would you recommend any improvements in controls and gestures?*
    - *(Open-ended)*
    - *Suggestions may include improved gesture recognition, alternative input methods, or additional controls for ease of use.*
7. *Did you find the color scheme, icons, and buttons intuitive and easy to distinguish? (Yes/No)*
    - *If no, what improvements would make the interface clearer and more user-friendly?*
8. *What aspects of the MR simulator made it feel user-friendly, and what aspects made it difficult to use?*
    - *(Open-ended)*
9. *Would you prefer additional training or onboarding before using the simulator?*
    - *(Yes/No)*
    - *If yes, what format would be most helpful (tutorial video, interactive guide, walkthrough, etc.)?*
10. *If you could change one thing about the MR milling simulator, what would it be and why?*

- *(Open-ended response)*

6. Hierarchical Task Analysis (HTA)

Hierarchical Task Analysis (HTA) is a structured approach used to break down complex tasks into smaller, manageable steps. The HTA for the MR-based Milling Simulator helps analyze the sequence of actions required to complete a milling task in the simulator and identify areas for improvement.



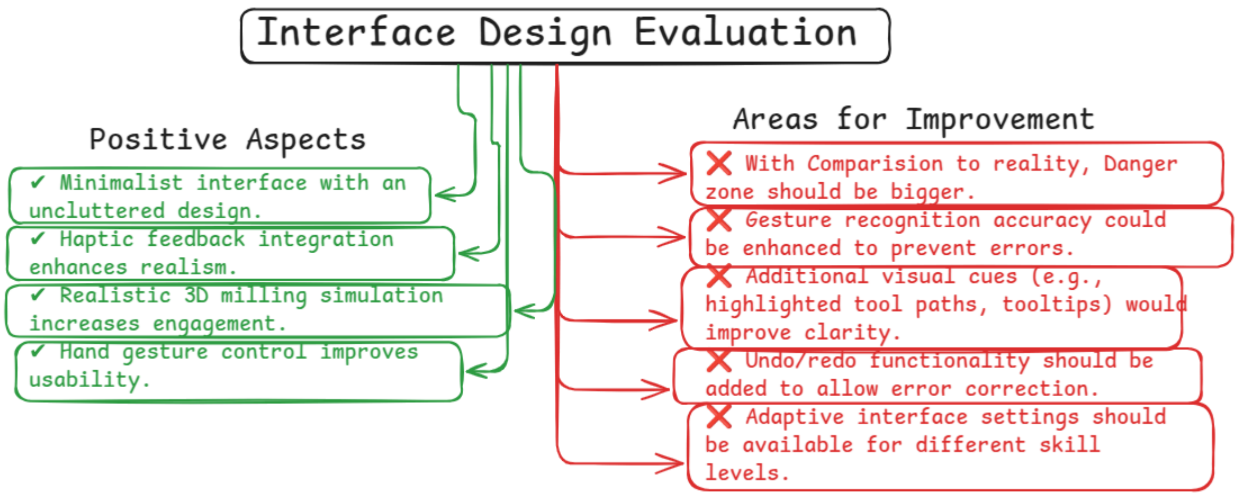
Hierarchical Task Analysis (HTA)

The MR-based milling simulator provides an innovative and immersive training environment by leveraging mixed reality technology. Through structured Hierarchical Task Analysis (HTA), the simulator guides users step-by-step, from initial setup to the execution of milling operations, ensuring a smooth and engaging experience. The system incorporates hand-tracking gestures, real-time feedback, and customizable settings to enhance usability and adapt to different skill levels. Additionally, a well-structured questionnaire evaluates user presence and usability, helping to refine interface elements, haptic feedback accuracy, and overall system responsiveness. By addressing minor usability challenges such as gesture misinterpretation and feedback inconsistencies, the simulator can offer a more refined and effective learning experience.

Despite its strengths, there are areas for potential improvement. The HTA analysis highlights the need for better gesture recognition, undo/redo functionalities, and enhanced tutorial systems to aid users in mastering the milling process efficiently. The inclusion of AI-generated feedback further helps users correct mistakes and improve performance dynamically. By refining the interface layout, incorporating additional learning modes, and optimizing gesture-based controls, *the MR milling simulator can become an even more powerful tool for training industrial professionals, reducing real-world hazards, and improving cost efficiency.*

7. Interface Design Evaluation

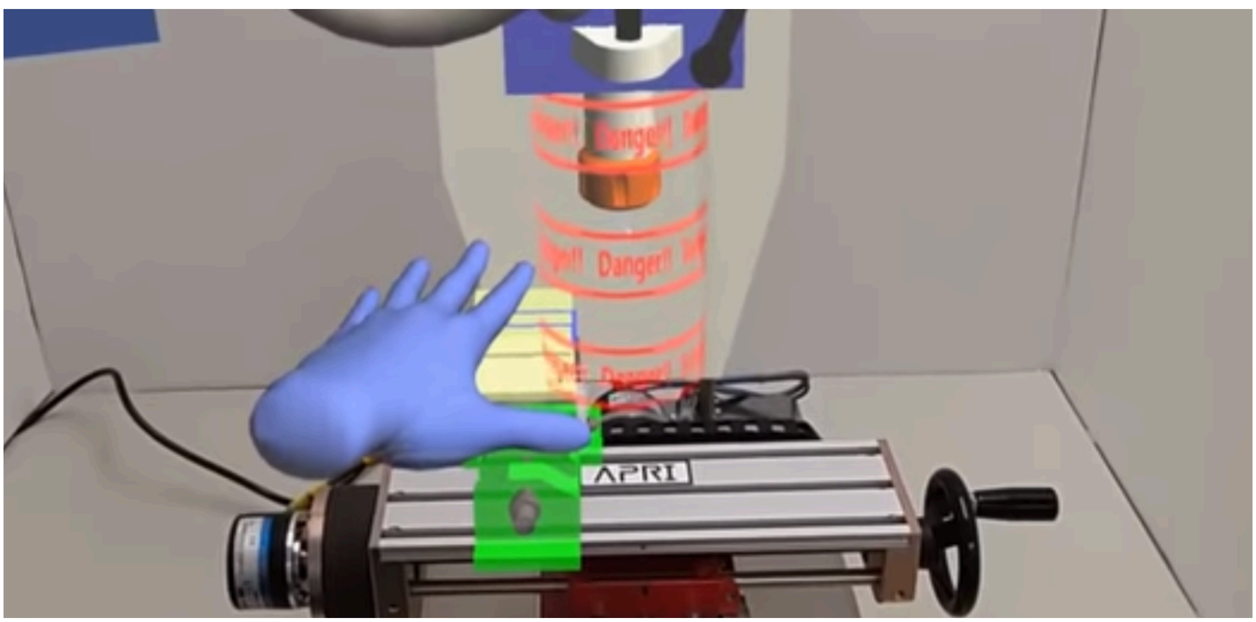
Minimalist interface with an uncluttered design. Haptic feedback integration enhances realism. Realistic 3D milling simulation increases engagement.Hand gesture control improves usability.



Interface Design Evaluation

Gesture recognition accuracy could be enhanced to prevent errors.Additional visual cues (e.g., highlighted tool paths, tooltips) would improve clarity. Undo/redo functionality should be added to allow error correction. Adaptive interface settings should be available for different skill levels.

Metal Flakes showing big vulnerabilities (Real_MillingMachine.mp4)



Small Indication of Zone of Metal Flakes showing big vulnerabilities (MR-MillingMachine.mp4)
Could be Improvised by special measures suggested

Conclusion

The MR-based milling simulator is a valuable training tool that enhances safety, minimizes material waste, and provides a hands-on learning experience. However, engagement and usability could be improved by:

- *Incorporating participative design principles to refine usability and responsiveness.*
- *Enhancing gesture recognition and predictive tracking to create a smoother experience.*
- *Improving adaptive learning mechanisms to cater to different skill levels.*
- *Upgrading immersion elements like graphical fidelity and audio design.*

By addressing these aspects, the simulator could offer a more engaging, personalized, and effective training experience for users across different expertise levels.