



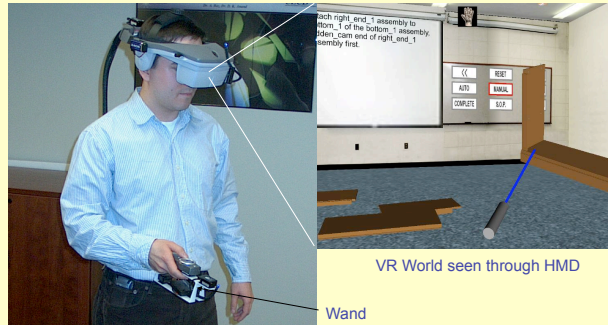
A Virtual Environment-Based System for Simulating Mechanical Assembly Operations

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Sponsor: NSF, CECD, and NSWC-IH

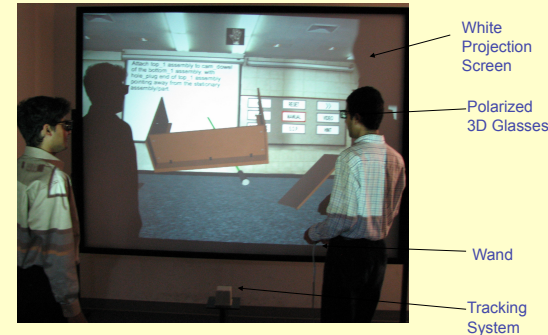
Motivation

- Reduce need for physical models in visualizing and analyzing assemblies
- Provide immersive experience for enhancing the understanding of the assembly process
- Provide an environment where users can safely make mistakes and learn from them
- Reduce the time needed to generate assembly instructions

A Virtual Environment for Assembling Mechanical Parts



Head Mounted Display Setup for Immersive Experience



Projection Screen based Setup for Collaborative Immersive Experience

Project Goals

- Develop a low cost virtual environment for simulating assembly operations
- Develop computational foundations to provide interactive speeds and immersive experience at low cost
- Enable generation of training instructions without any programming
- Develop features to offer assistance to users by pointing out mistakes on-the-fly and tailoring training for them based on their skill level
- Conduct user studies to determine the effectiveness of the virtual assembly technology

- **Virtual Workspace** module provides basic environment for the user to interact with the virtual parts
 - Simulates the adequate level of realism to support training and includes dynamic animation and plan completion
 - Supports 3D Animation, Video, Audio, Text, and Interactive Simulation

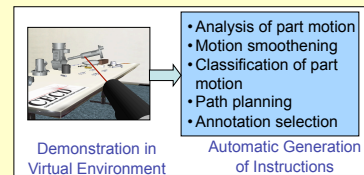


Interactive Simulation Mode

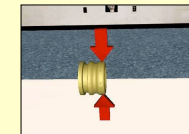


Video Mode

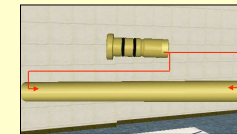
- **Virtual Author** module enables the trainer to generate instructions by performing a demonstration in the virtual environment
 - The system records, cleans, and generalizes trainer's actions automatically translating them to text
 - No programming is required



- **Virtual Mentor** module assists user during interactive sessions by monitoring actions and reporting mistakes
 - Use part symmetries declared to allow alternate positions and orientations
 - Provide hints
 - Insert additional details into animation instructions



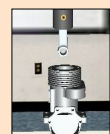
Insert details into animation instructions to clarify detected problem areas



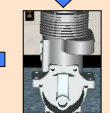
Multiple possible insertion locations and orientations

Instruction Generation

- Detailed text instructions and 3D animation are automatically generated for the engine maintenance procedure by analyzing demonstration of the procedure in our system



Piston assembly is aligned



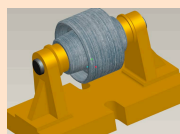
Piston assembly is placed into cylinder

Sample Virtual Author Output

- Align piston assembly with engine case.
- Insert piston assembly into engine case until connecting rod contacts the bottom of the engine case.

Design for Assembly

- A designer is interested in assessing assembly difficulty of a new pulley mount
- The designer simulates the assembly steps in our system and discovers that shaft cannot be inserted into the bracket without changes in the design



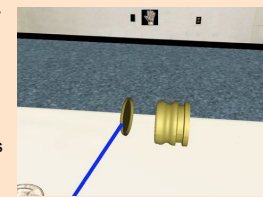
Pulley Mount Assembly



Screen shot of virtual assembly process

Virtual Manufacturing

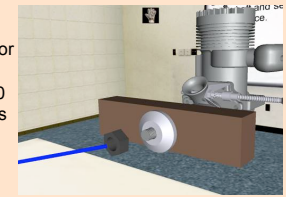
- An assembly operator needs to practice assembly operations for a rocket motor to pass the certification test
- User studies involving 30 users show 94% success rate in transferring the skills acquired using our system to physical assembly tasks



Screen shot of an assembly step during rocket motor tutorial

Virtual Maintenance/Service

- A maintenance engineer needs to learn how to perform a specialized maintenance operation for an engine
- User studies involving 30 users show 97% success rate in transferring the skills acquired using our system to physical assembly tasks



Screen shot of an assembly step during engine maintenance tutorial