Haptic motion during virtual simulations. In a motor role the haptic device can augment unwanted user motions such as in the case of virtual mechanisms. In its sensory role the user can learn about the environment.

Haptic devices can provide a sensory or motor function: haptic simulations.

Research into methods of haptic rendering and creation of interactive virtual environments has yet to be fully exploited and requires further development. Haptics uses the sense of touch to augment virtual simulations.

SimMechanics was used to design the mechanisms and to connect the haptic interface point to the coupler by a virtual spring and damper. Matlab and Simulink were used to interface with the haptic device and graphical user interface.

Traditional methods for learning about mechanism design is limited to calculations and visual representation. Physical manipulation of mechanisms has a potential effect of increased the quality of student learning.

Motivation:
Visualization of the trajectory and inertial properties of mechanisms is unintuitive. Traditional methods for learning about mechanism design is limited to calculations and visual representation.

Haptic Rendering of Virtual Mechanisms

Implementation:
Matlab and Simulink were used to interface with a Novint Falcon and to implement force generation.

Application areas:
• Surgery
• Flight simulation
• Education
• Industrial manipulation

Haptics-Augmented Designs With Pre-computed Force Map

Motivation:
Haptic rates should exceed 1000 Hz for realistic feedback, thus calculations must be very short for immediate response. Without proper optimization geometric models can be too computationally intensive.

Implementation:
Matlab and Simulink were used to interface with a Novint Falcon and to implement force generation.

With Pre-computed Force Map

Potential Fields Technique
Force is max at wall and decreases linearly as distance increases.

\[ F = F_{\text{wall}} - k \times x \]

F = Force
k = Constant
x = Distance

Haptic Simulation Training

Motivation:
Simulations require incorporated visual and haptic feedback for realistic user interaction. It is often necessary to use 3D meshes in the form of CAD models or medical data for graphical representation.

Implementation:
H3D, an open source haptics software, was used to facilitate graphical and haptic simulation.

Future Work

Implementing new forms of force control for haptic simulations.

Development of advanced tutorials using C++.

Creation of robust surgical and biological simulations.

Integration of a 5 Degree of Freedom device within H3D for enhanced manipulability.

Acknowledgment
This project has been funded by a National Science Foundation Research Experience for Undergraduates and Zimmer Research Award.

Graphical User Interface

Diagram changes shape dependent on input parameters
Feedback Design
The haptic interface point is connected to the coupler by a virtual spring and damper.

Tracing a Sphere

Choose two-, four-, or fivebar mechanism, link lengths, and individual masses
Trace trajectory of mechanism
Note the average error with and without feedback

Example Trajectory

Parallelogram Fourbar

Feedforward Design

Depicts user’s trajectory after tracing the output
Apply an additional vertical force component or change spring-damper parameters

Procedure

Initial:
• User inputs 2D design
• Computer generates force map

Run:
• Haptic device position mapped to force
• Force sent to haptic device

Virtual Fixture Example: Tracing a Sphere

Motivation: Straight and precise incisions are necessary for minimally invasive surgery.

Task: User traces haptic device one revolution about a complex surface.

Results: Deviation about the central plane show significant error without the haptic fixture.

User Build Phase

Generated Force Map

Colors denote force direction

Graphical User Interface

Choose two-, four-, or fivebar mechanism, link lengths, and individual masses

Trace trajectory of mechanism

Note the average error with and without feedback

Future Work

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Application areas:
• Industrial manipulation
• Education
• Flight simulation
• Surgery

Haptics-Augmented User Interaction

Automation, Robotics, and Mechatronics (ARM) Lab

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Simulation Training

Visualization of the trajectory and inertial properties of mechanisms is uninteresting. Traditional methods for learning about mechanism design is limited to calculations and visual representation.

Physical manipulation of mechanisms has a potential effect of increased the quality of student learning.

Matlab and Simulink were used to interface with a Novint Falcon and to implement force generation.

Integration of a 5 Degree of Freedom device within H3D for creating robust surgical and biological simulations.

Development of advanced tutorials using C++.

Creation of advanced force control for haptic simulations.

Integration of a 5 Degree of Freedom device within H3D for enhanced manipulability.