Project 01

Title: Haptic Rendering of Virtual Mechanisms

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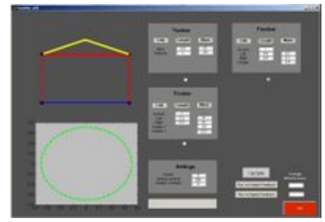


Overview

Haptics is an emerging field of robotics used to add the sense of touch to virtual applications enhancing the user-experience during training. Some of its applications include enhancement of flight-simulator and medical-simulator based training for complex procedures. Other applications bridge the gap between virtual dissection and physical procedures using camera tracking and magnetic sensors [1]. Cadavers are expensive, thus using haptics has proven to be an effective educational strategy due to a relatively low lifetime cost and high modularity for new procedures [2]. Therefore more hours of training can be provided without increased cost.

Significant research creating algorithms that can quickly calculate haptics forces on 3D volumes has been done. The Springer Handbook of Robotics provides adequate background on haptics [3].A Synthesis Lecture [4] on the topic documents current procedures for implementing haptic feedback.

An alternate method of control that I have developed parallels mechanism design. Using software such as SimMechanics it is possible to create complex mechanisms. These can be used to control a haptics device from linkage constraints. An introduction to SimMechanics can be found on my webpage [5]. A trajectory can be traced using multiple types of mechanisms such as a pendulum, double pendulum, and fourbar. Link lengths can be changed to vary the shape of the trajectory.

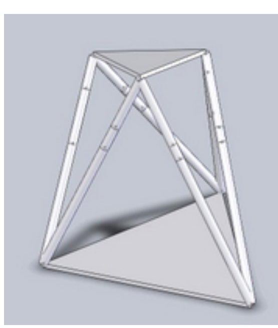
Research Goals

The goal is two-fold: develop a method for understanding linkage design and implement haptic control to demonstrate how the device can be confine using the linkages as constraints. The path of a mechanism is not always apparent; thus a graphical user interface (GUI) provides benefits. Mechanism design is important in the development of haptic devices, so the ability to introduce design and haptics with one application is useful to the user. My plan was to start by investigation into mechanisms, evaluate haptic rendering, and create an interface for learning and user control.

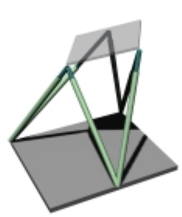
Outcome and Discussion

My work on haptically-augmented mechanism control started with an introduction to Solidworks, Visual Nastran, and Simulink/SimMechanics. These tools assisted me in modeling and control of articulated systems. I evaluated the software for their effectiveness in creation of varied designs. After investigating haptic control within Simulink they were used together to visually and haptically enhance the learning of mechanisms.

Using Solidworks and Visual Nastran I analyzed serial and parallel manipulators. For example I modeled a Stewart platform in Solidwork and created real-time haptic control within Simulink. A presentation I developed on QuaRC, a real-time hardware abstraction layer for Simulink, can be found at my website. Knowledge on serial and parallel manipulators is necessary for fundamental creation of mechanisms. My future work on a novel parallel haptic device will rely on this research.



(a)



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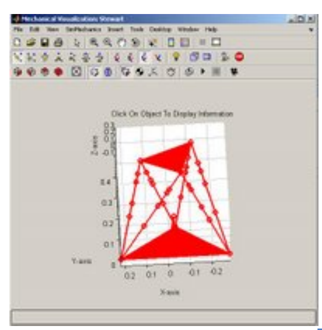

(c)

Figure 1: Stewart Platform (a) Solidworks (b) Visual Nastran (c) Simulink/SimMechanics

I developed a tool using Matlab/Simulink and Real-Time Workshop to visually and haptically evaluate the workspace and path of two-, four- and fivebar mechanisms. Along with this demonstration I developed an introductory tutorial I on using SimMechanics. This is also located on my website [6].

The intended use is as follows:

1. Edit parameters for select mechanism type.
2. Apply Settings such as gravity, Spring Constant, and Damper Constant.
3. Press “Update.”
4. Press “Run w/o Haptic Feedback.”
5. Press “Run w/ Haptic Feedback.”
6. Receive feedback via “Average distance away from trajectory.”

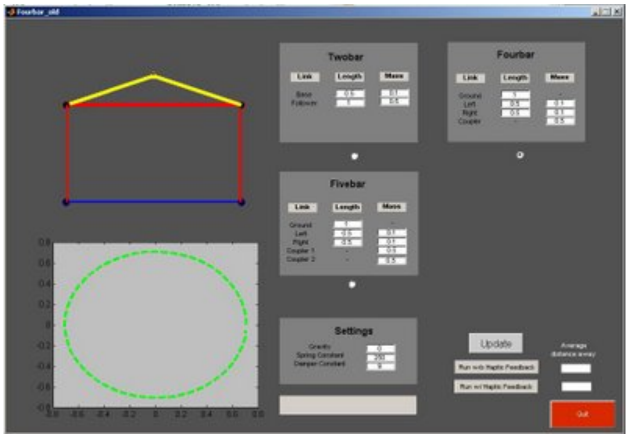

Figure 2 Virtual Mechanism GUI

By changing the link lengths the user can feel the change in trajectory. Additionally, for known trajectories the user can attempt to trace a path with and without haptic forces. An average distance from the path is shown to compare the accuracy of their two runs.

Haptic Rendering

Haptic rendering is employed using a mass-spring-damper model (Figure 3). This creates a linked relationship between the haptic device and the mechanism. If the device moves along the path then forces on the links causes it to move towards the device. If the device moves outside the range of the path then a force is calculated and applied to the haptics device to bring the end effector back on path.

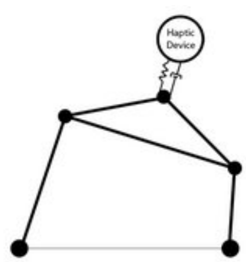

Figure 3 Haptic Fourbar Model

The spring and damper model applied in Simulink is shown in figure 3. The inputs are the position of the haptic device and the position of the mechanism end effector. All signals are vectors with <x, y, z> components. The concept is the same as a PD filter in control theory. The spring and damper values can be controlled on the user interface.

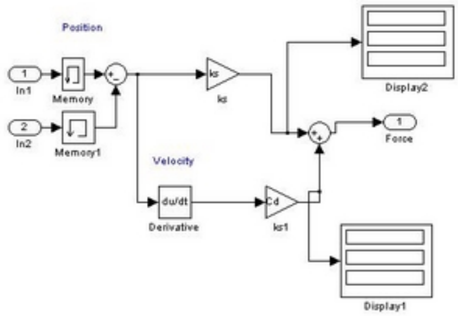

Figure 4 Spring and Damper Force Calculation

The following Simulink diagram describes the complete fourbar mechanism. The blue section contains a SimMechanics-designed fourbar. The gray section integrates a Novint Falcon haptic device. The Falcon is a relatively cheap ($100-200) 3 degree of freedom haptic device marketed at consumers.

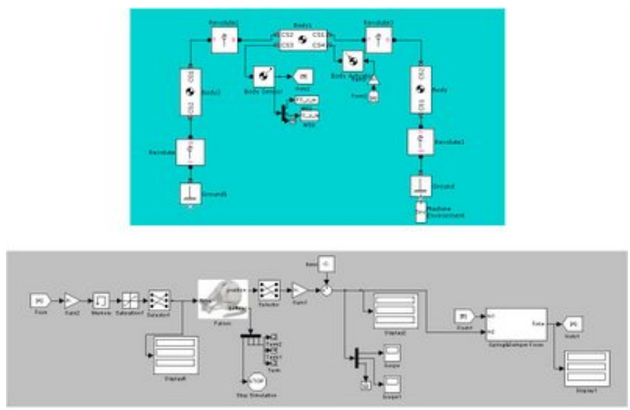

Figure 5 Simulink Block Diagram (Blue) Fourbar (Gray) Haptic Integration

The Falcon is implemented using QuaRC, a real-time hardware abstraction layer for Matlab and Simulink. Concurrently I developed a presentation on an Introduction to QauRC [6]. The spring and damper subsystem (figure 5) is located in the right section of the gray box. The output forces are sent to the end effector and haptic input.

Figure 6 Novint Falcon

Conclusion

My implementation of haptically-augmented mechanism control presents a method of haptic rendering beneficial to applications with specific known geometry (ex. Ellipses). Through the control of forces, it intuits a sense of form that the linkages can provide. With adaptable parameters, the user can modify both link lengths and masses. By developing this method I have concluded that for specific geometries the use of mechanisms can be easier to implement and possibly more accurate than other generic collision-based haptic algorithms. However, for many applications, including use i surgery where there are many shapes that must be simulated concurrently, the use of mechanized constrains is not effective.

References

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Appendix

Appendix A : Introduction to SimMechanics

Introduction to SimMechanics

Introductory Tutorial on SimMechanics

Creation of a Fourbar Mechanism

Appendix B: Introduction to QuaRC

QuaRC

Introduction to QuarRC

Real-time control of hardware devices

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