Haptic Methodologies for Guidance and Use in Virtual Environments

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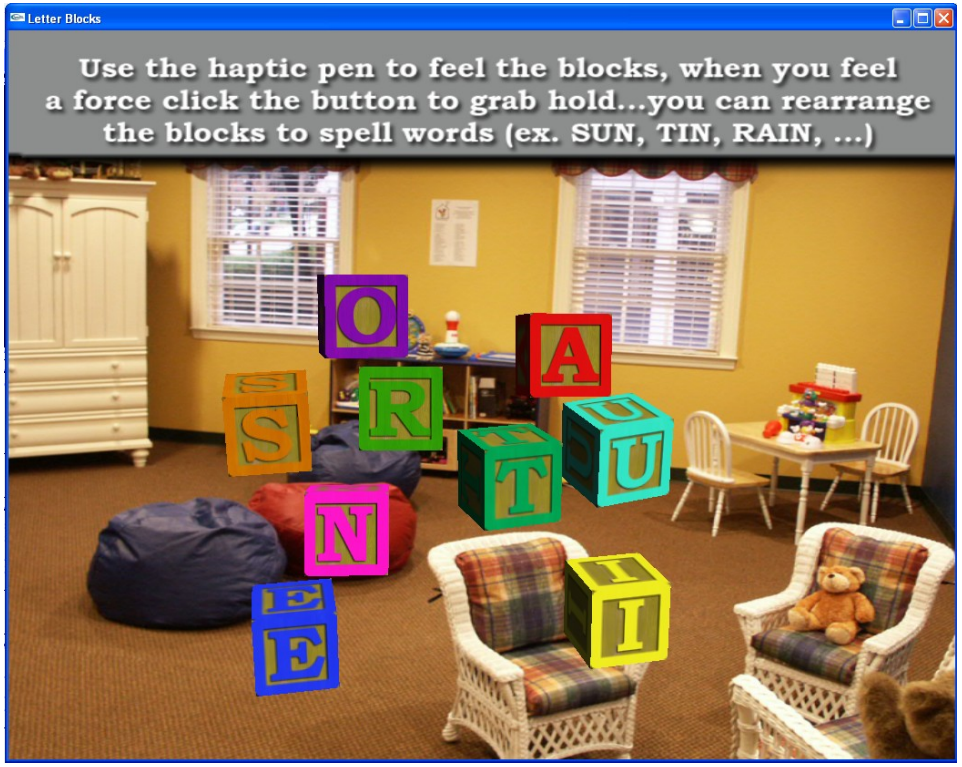
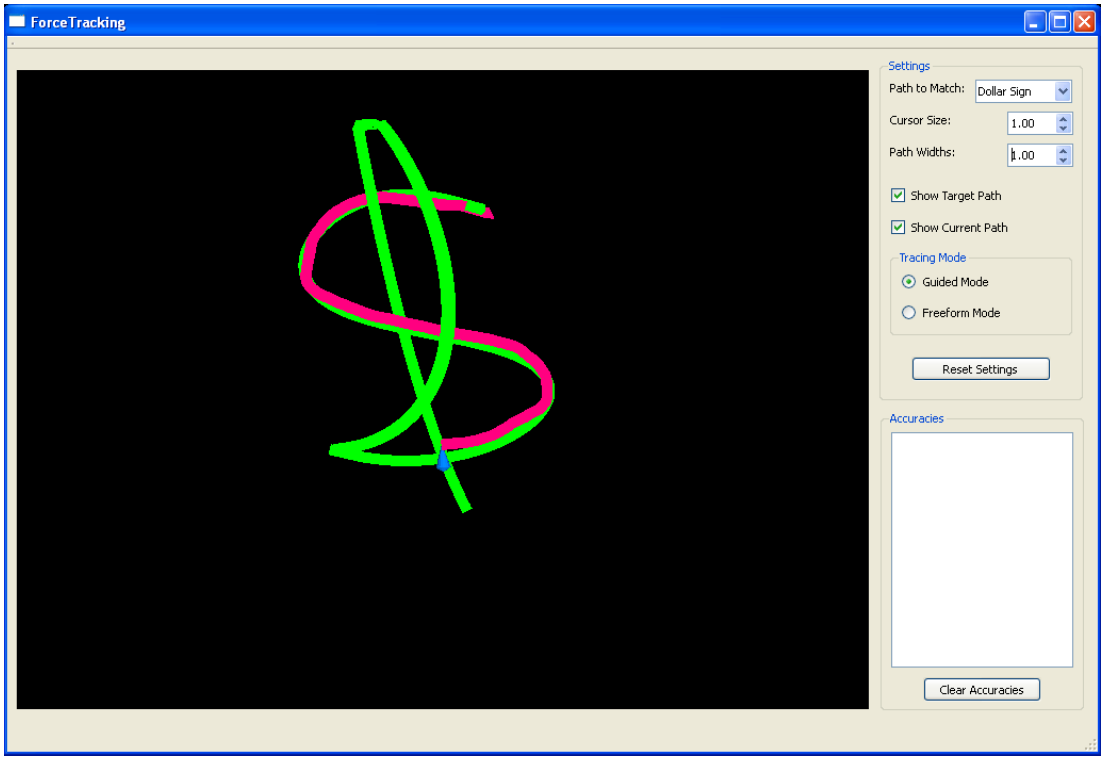
SensAble


HapticWorkbench


Letter Blocks
Use the haptic pen to feel the blocks, when you feel a force click the button to grab hold...you can rearrange the blocks to spell words (ex. SUN, TIN, RAIN, ...)


ForceTracking
Settings
Path to Match:
Dollar Sign
Cursor Size:
1.00
Path Widths:
1.00
Show Target Path
Show Current Path
Tracing Mode
Guided Mode
Freeform Mode
Reset Settings
Accuracies
Clear Accuracies

Laboratory for the Study & Simulation of Human Movement

Lynn Gerber, MD

Professor, College of Health and Human Services
Director, Center for the Study of Chronic Illness and Disability
George Mason University

Zoran Duric, PhD

Associate Professor,
Department of Computer Science
Volgenau School, George Mason University

Room 2005 Engineering Bldg
4400 University Dr
Fairfax, VA 22030

http://cs.gmu.edu/~vislab

Laboratory Personnel

- Graduate Students in Computer Science and Bioengineering
  - Kenneth Daffron, Ph.D. student
  - Ed Lawson, Ph.D. student
  - Michael O'Malley, Ph.D. Student
  - Cody Narber, Ph.D. student
  - Matthew Revelle, Ph.D. student
  - Gene Shuman, Ph.D. student
  - Nalini Vishnoi, Ph.D. student
- Lab Alumni
  - Younhee Kim, Ph.D., Former Lab Manager
  - Michael Sullivan, Ph.D. at UT Austin

Laboratory Core Goals

- <u>Study of Human Movement:</u>
  - Building a library of functional movements performed by normals and disabled people
  - Combine movement measurements:
    - Position/Rotation data from EMS, Accelerometer, & Video Capture
    - Muscle activity measurement from EMG
    - Force/pressure measurements
  - Build generative/predictive models for various functional movements

- <u>Simulation of Human Movement:</u>
  - Programming haptic devices to train people in performing functional movements
  - Design computer displays and engaging graphic-user interfaces from which to model and simulate human motion

Current Projects

- Development of New Instrumentation to Measure Upper Extremity Motion for Research and Teaching in Rehabilitation Science, Bioengineering and Robotics
  - NSF Grant CNS 0722575

- Application of Haptic Technology to Persons with Traumatic Brain Injury
  - To explore the role of multimodal visuo-sensory motor input learning using haptic devices.
  - To assess the acceptance of this approach as a therapeutic modality to persons with traumatic brain injury

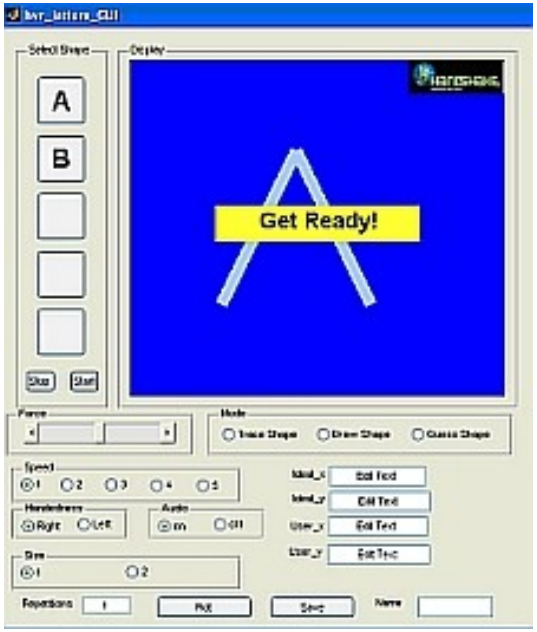
Haptic Technology

- Description:
  - Devices that provide vibration, force, or movement to provide proprioceptive feedback to the user

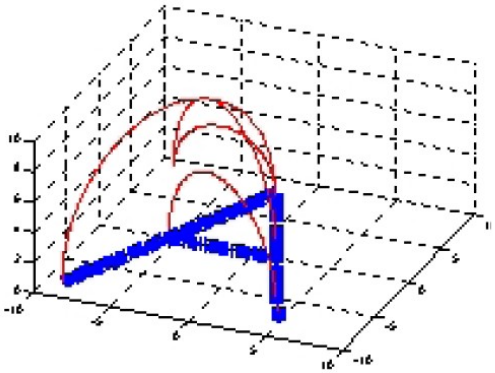
- Applications:
  - Enhance remote control of machinery/devices
  - Used for virtual object manipulation
  - Aid in creating a more immersive virtual environment
  - Aid in human rehabilitation
- Challenges/Difficulties:
  - Device motors can only provide a specific amount of force.
  - Some people tend to resist the force provided by the device.
  - Making the effects feel as “natural” as possible.

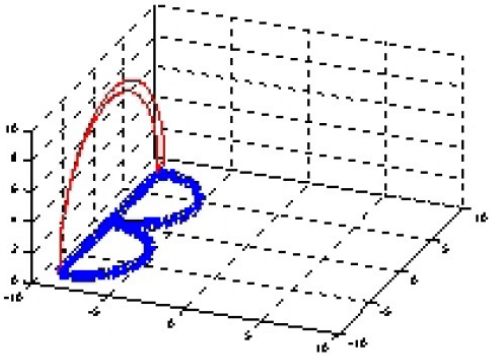
Letter Writing

- Designed a virtual hand-writing teaching system for children with handwriting difficulties



- <u>Features:</u>
  - Utilizes Handshake API
  - Use of Letter Primitives
  - Adjustable Modes
  - User-Friendly Interface
  - Quantitative Reports
- <u>Issues:</u>
  - Guidance force-control was handled behind the scenes.
  - Constructing primitives of free-form movement was time consuming.





** "Teaching Letter Writing using a Programmable Haptic Device Interface for Children with Handwriting Difficulties", Y. Kim, Z. Duric, N. L. Gerber, S. Palsbo, A. Palsbo

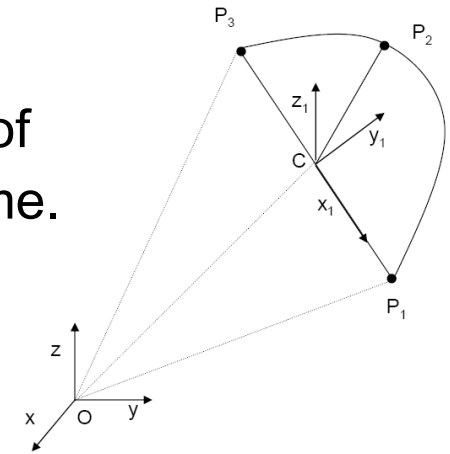
Free-Form Movement Translation

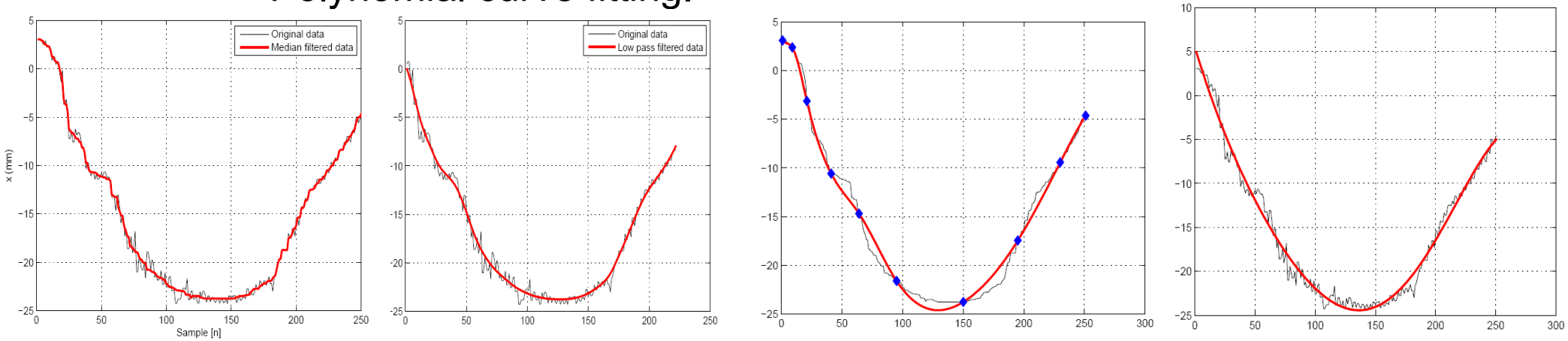
- <u>Motivation</u>
  - Rehabilitation of people experiencing difficulties with upper extremity is a complex and challenging problem since:
    - It is unconstrained
    - Patterns of movement are varied
    - Incorporate 3D movement
- <u>Goal</u>
  - Present a novel approach of haptic training using the ‘free form’ movement of a ‘normal’ person recorded by a motion tracker and then translating it to the haptic workspace.

**“Guiding Hand: A Teaching Tool for Handwriting”, N. Vishnoi, Z. Duric, N. L. Gerber

Free-Form Movement Translation

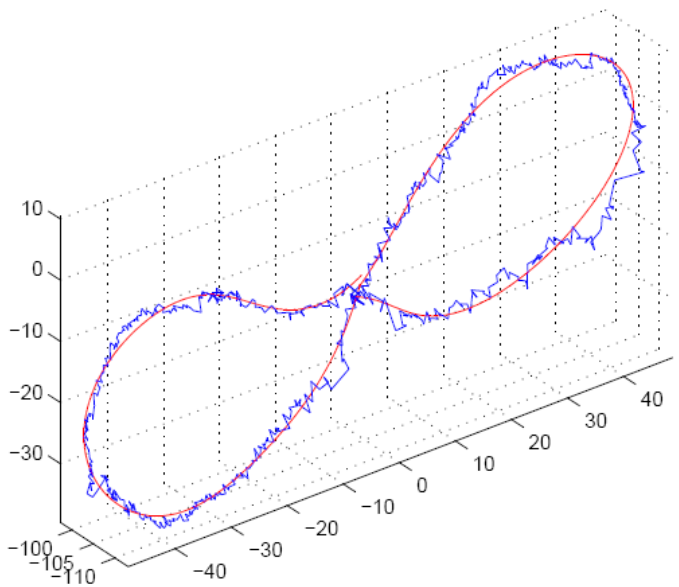
- <u>Process:</u>
  - Converted the data from the MotionStar Wireless Flock of Birds to haptic workspace by use of an intermediate frame.
  - Data from EMS was noisy due to its limitations, thus needed to be smoothed:
    - Median filtering
    - Low-pass filtering
    - Cubic splines fitting
    - Polynomial curve fitting.

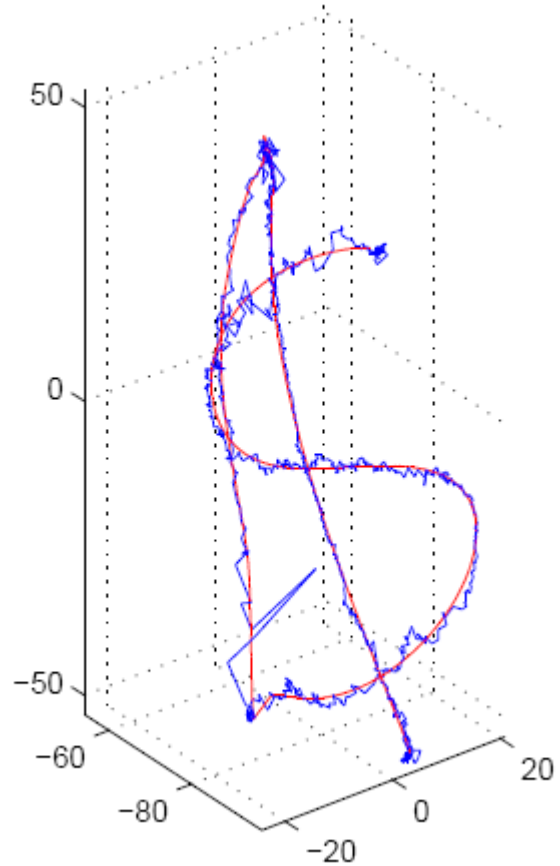




Free-Form Movement Translation

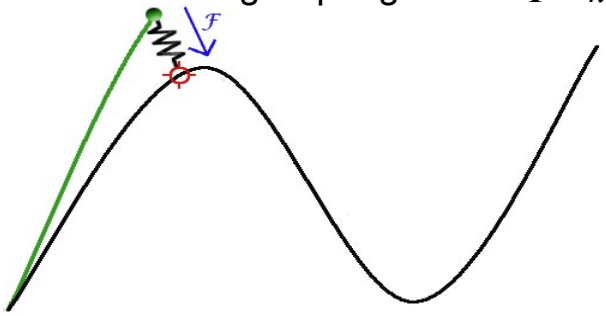
- <u>Future Work</u>
  - Automated stroke separation
  - Extracting accurate velocities and accelerations to be used for the haptic's force control

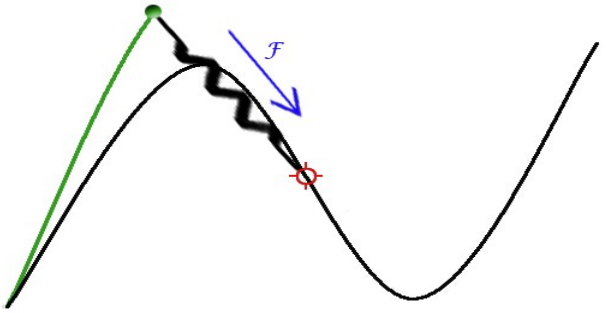




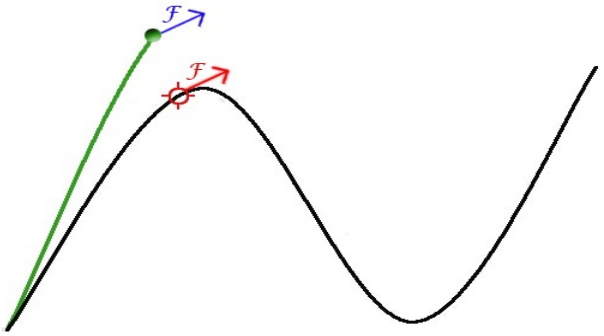
Haptic Force Control

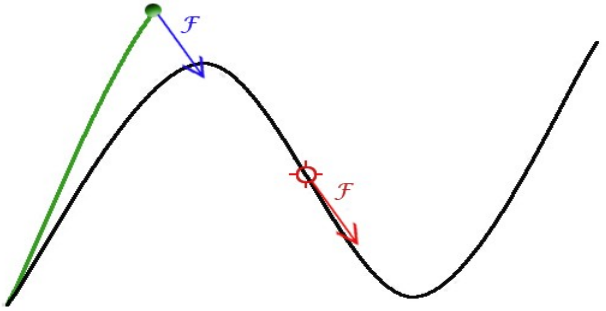
- <u>Motivation:</u>
  - Haptics provide proprioceptive cues, which can be used in conjunction with visual cues to aid the user in reconstructing a movement.
- <u>Previous Work:</u>
  - Haptic Guided Position (used for letter writing)
    - Created through Spring Force: $F = k\,d$





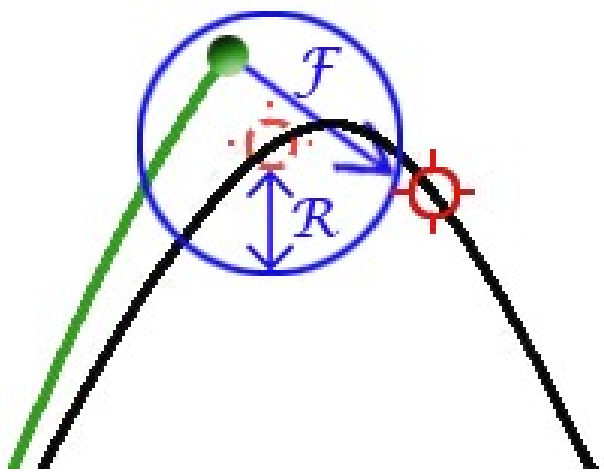
  - Haptic Guided Force

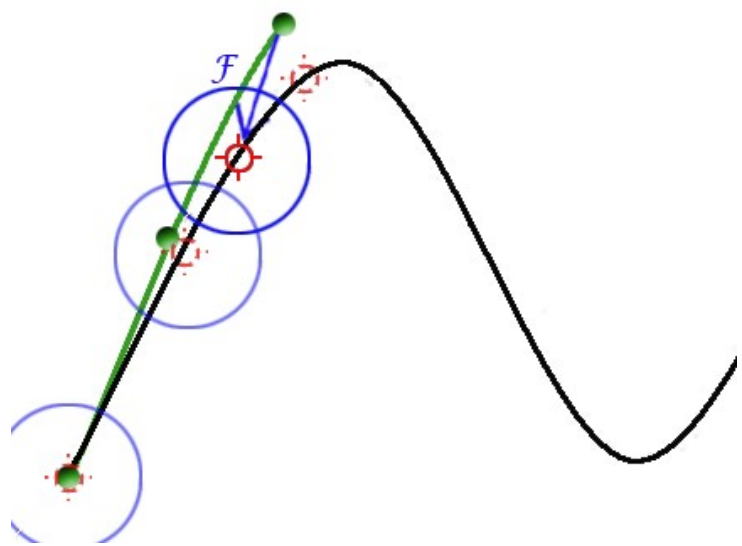




Haptic Force Control

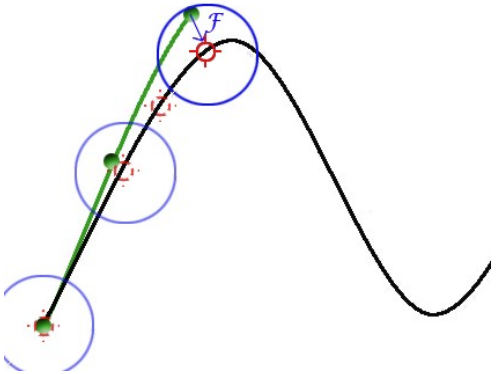
- Goal:
  - To develop the force equation that will provide the best training assistance to the user/patient, while feeling “natural” and engaging.
- Process:
  - Redefine how the target position is updated.
    - Previous updated very next sample.
    - Update to next next position if within bounds



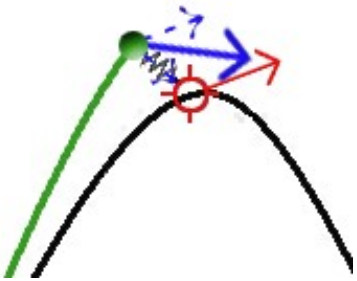


Haptic Force Control

- <u>Process (cont):</u>
  - The new target is determined by the speed at which the pen is moving
    - Assumes that speed changes are relatively small between samples
    - Haptic samples at 1000 Hz
    - Interpolate the target position

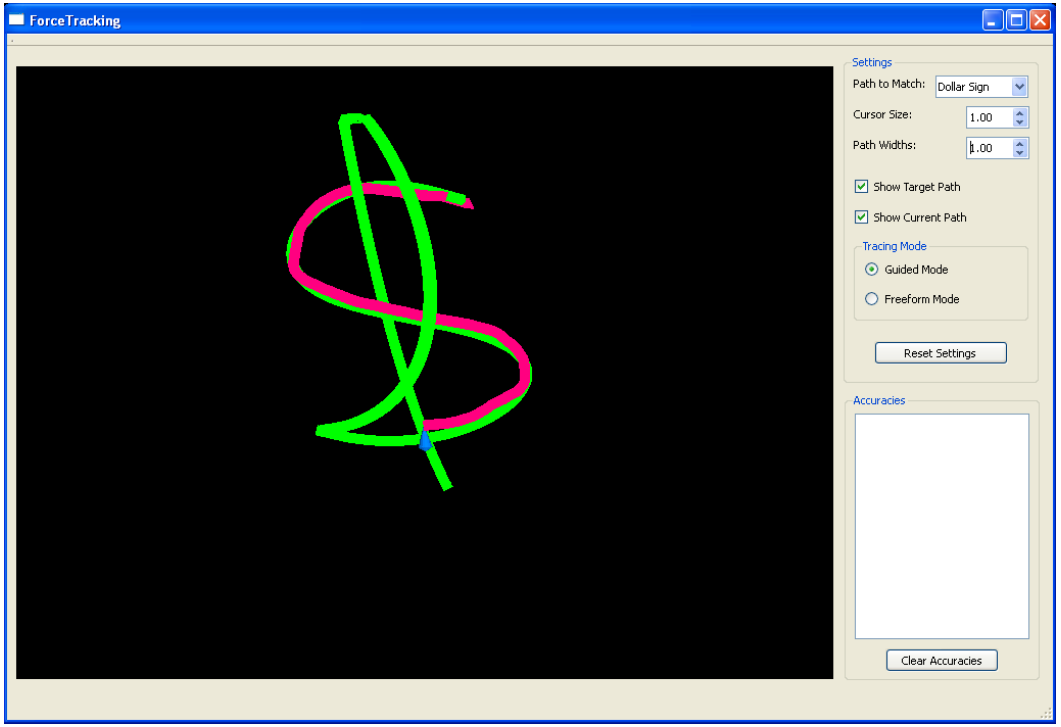


  - Mixture of forces between HGP and HGF. (i.e. match trajectory's position, velocity, acceleration).
    - Determine which features are more important at different times:
    - Hypothesized that position must be within a certain performance before enforcing proper velocities and accelerations



Haptic Force Control

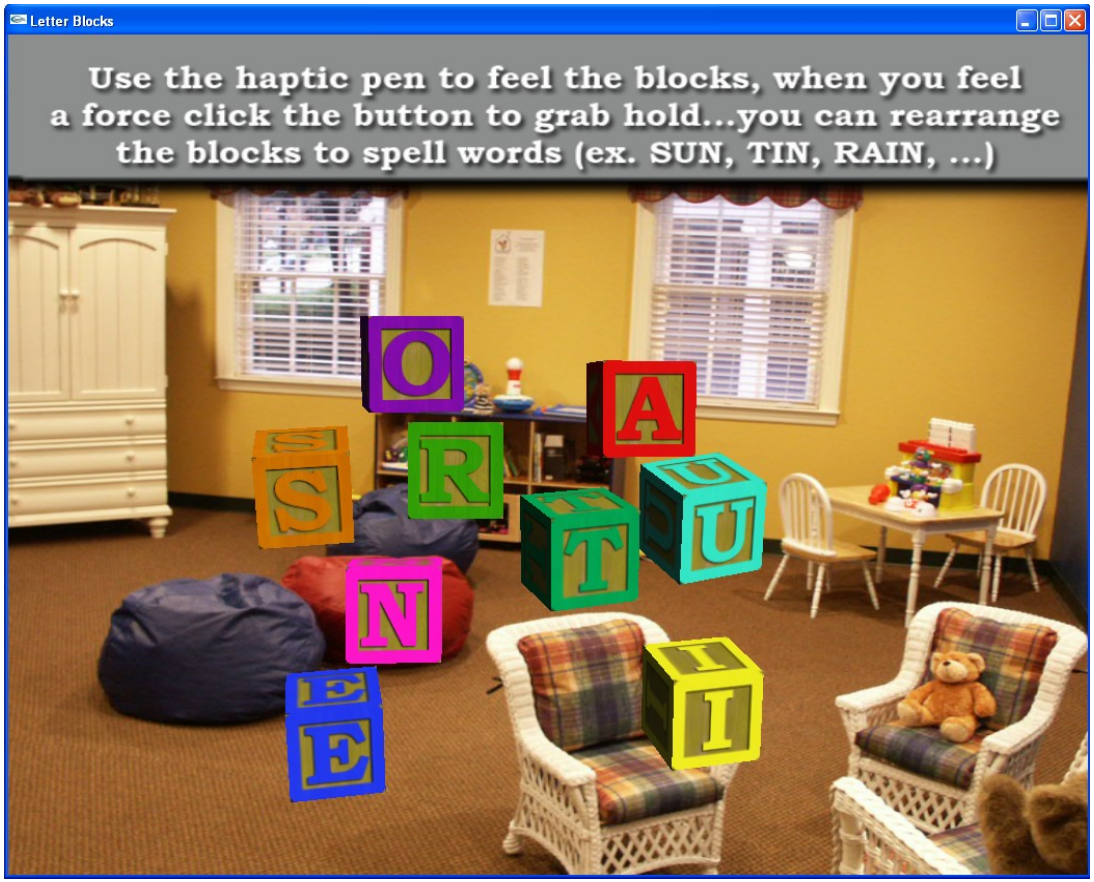
- Process (cont):
  - Adapt the force equation based on subject's performance
    - HGP vs HGF
    - Decrease guidance as subject improves



  - Performance measure needed (distance metric):
    - Hidden Markov Models (symmetric model comparison)
    - Longest Common Sub-sequence
    - Pairwise Euclidean Distance Measure

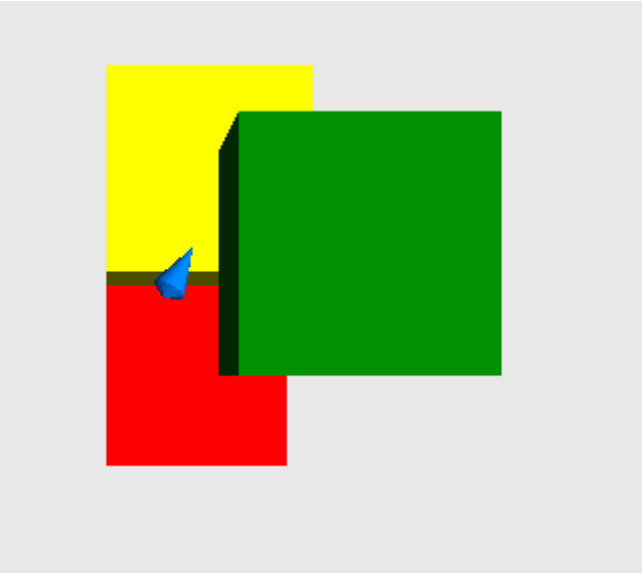
Virtual Environments

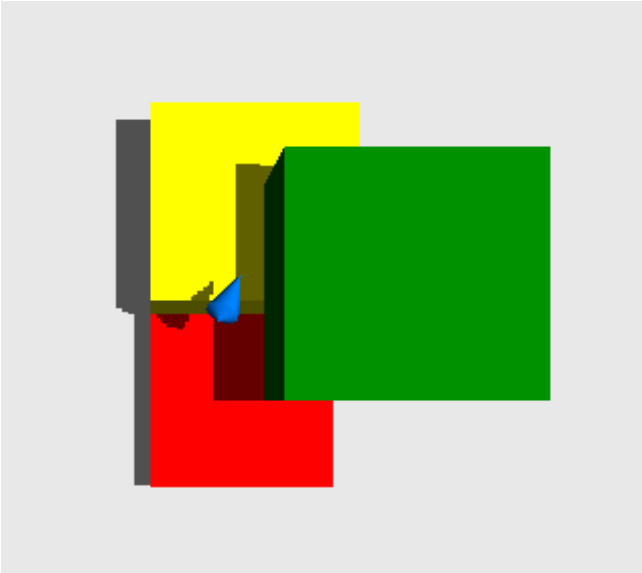
- Taste of Arlington
  - NSF area which was open to the public
  - Observations made about accessibility of software
  - Optimal age group: teen to middle-age



Virtual Environments

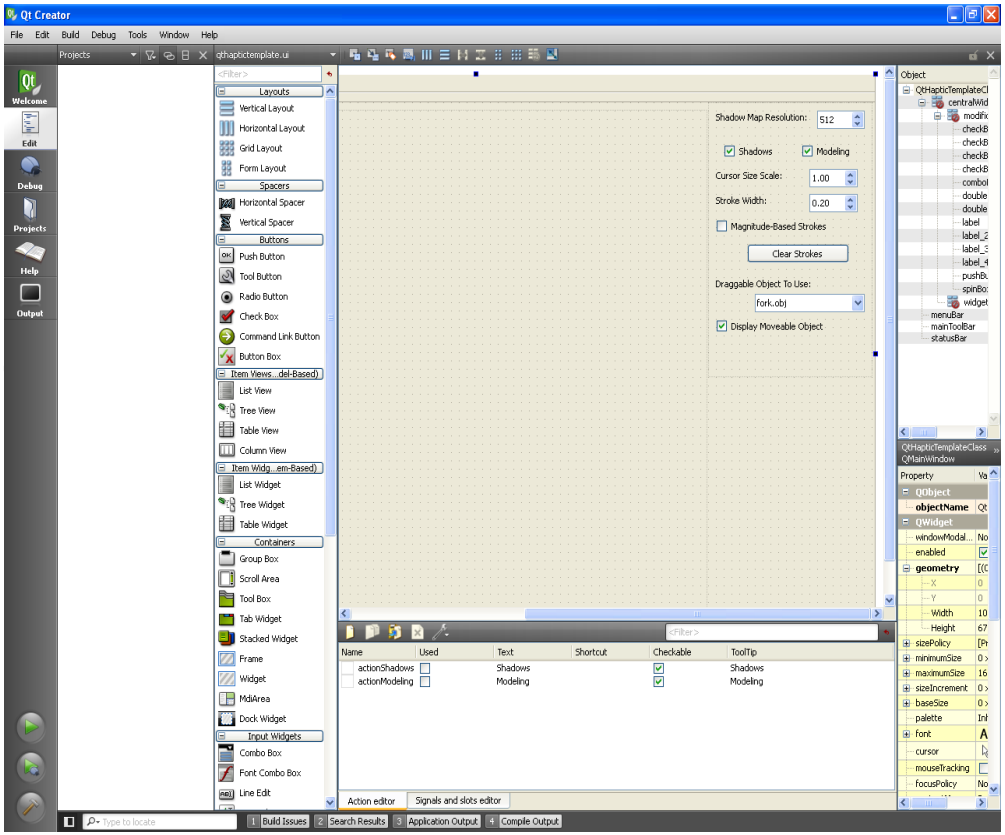
- Shadows
  - Needed for visual anticipatory cue
  - Created through the use of shadow mapping (as 3 passes)
    - Draw scene from light's POV
    - Draw scene as if completely shadowed
    - Draw lit sections determined from shadow map





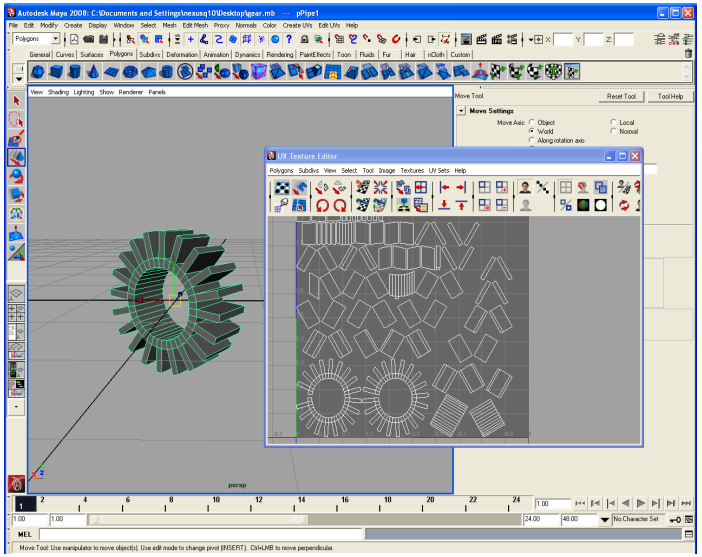
Virtual Environments

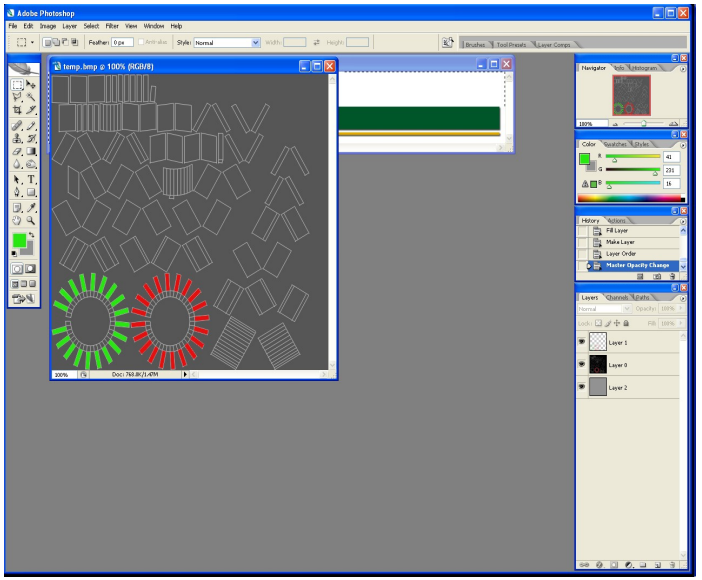
- Qt
  - A GUI development package was needed
  - Qt was chosen since it is multi-platform and well-documented
  - Easily build an interface for modifying settings for the environment:
    - Cursor Size
    - Color/Contrast/Brightness
    - Shadows On/Off
    - Various Force Settings (stiffness, spring constant, ..
    - …



Virtual Environments

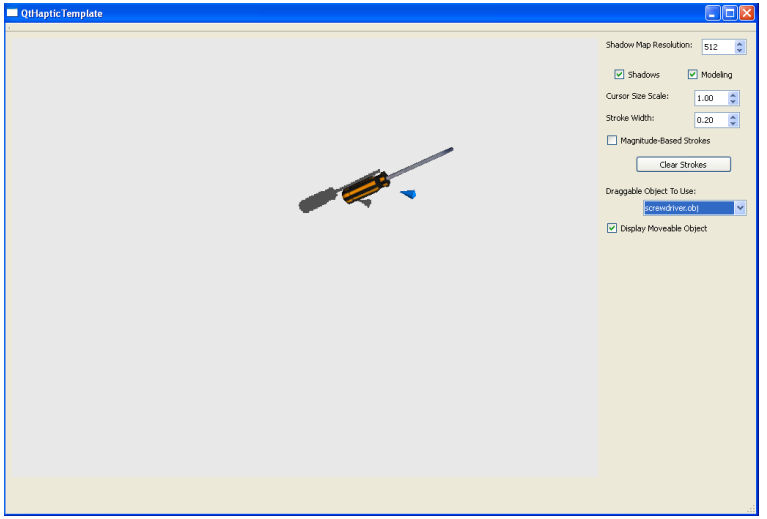
- Object Creation - Maya/Photoshop/GLM
  - Objects take a while to construct in OpenGL due to the explicit coding of vertices.
  - **Maya**:
    - Allows for expedited object creation
    - Allows for custom UV texture mapping
  - **Photoshop:**
    - Create compatible textures for objects
    - Allows for multiple layers, which ease in modifying textures quickly
  - **GLM:**
    - External code that imports .obj files and simplifies drawing them
    - Modified for Multi-texturing
    - Original Author: Nate Robbins

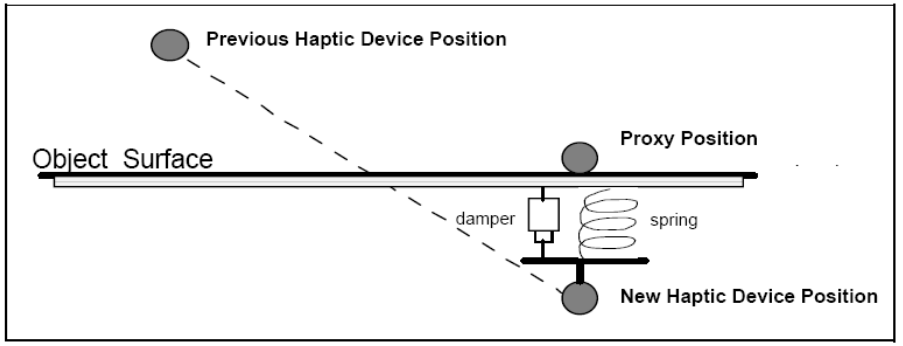




Virtual Environments

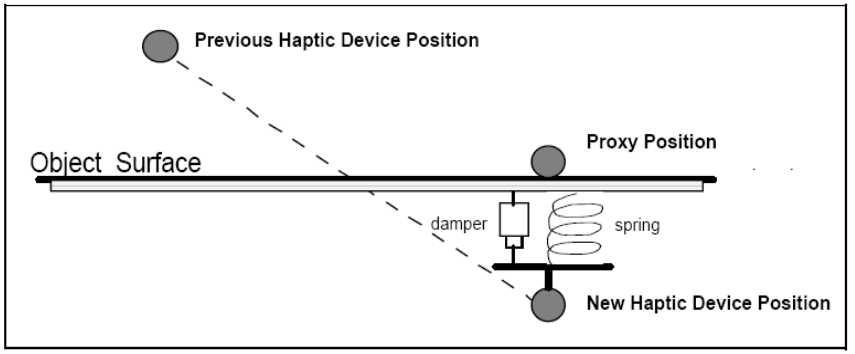
- Haptics
  - OpenHaptics Toolkit (SensAble)
    - HDAPI (Haptic Device API)
      - Consists of the *Device* and the *Scheduler*
      - *Synchronous* vs *Asynchronous*
    - HLAPI (High-Level API)
      - Shape Rendering
        - Stiffness
        - Damping
        - Static and Dynamic Frictions
      - Effect Rendering
      - Touch vs Constraint





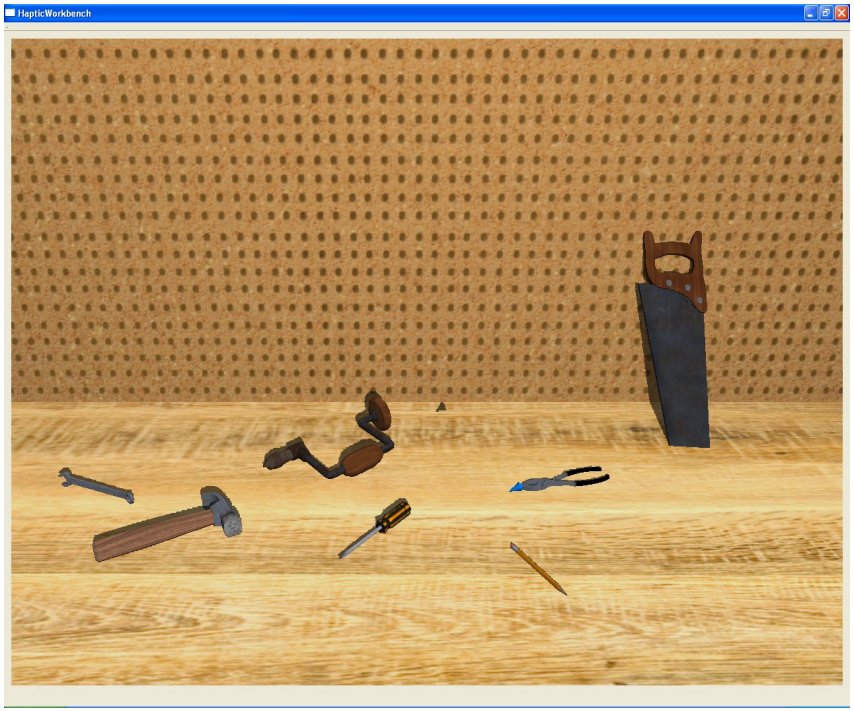
Virtual Environments

- Collision Detection
  - Objects magically going through back wall = BAD
  - Solid 3.0 Collision Library Used
    - *Broad Phase* – Compare Axis-Aligned Bounding Boxes (AABB)
    - *Complex Phase* – Compare objects composed of many complexes/primitives for hit
    - *Exact Phase* – Find intersection points, and depth vectors of intersecting primitives
  - Upon collision, depth vector found is used to compute an effect force
  - The object and proxy must be translated to appear on the outside of the colliding object
  - The translation and force is computed in much the same way as HLAPI computes the proxy's force and position upon contact:



Virtual Environments

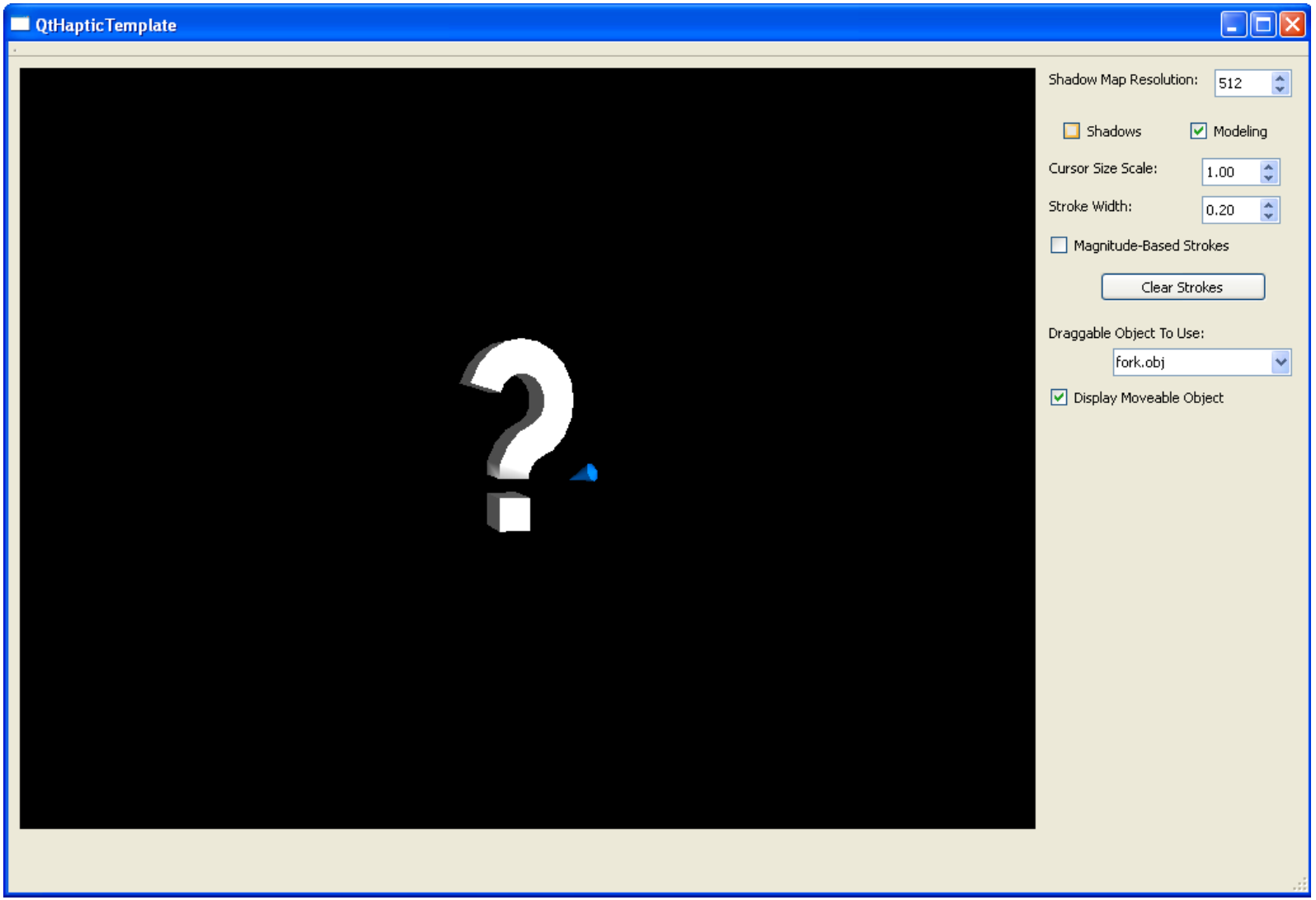
- Haptic Framework
  - Several C++ classes were written
  - Utilizing object-oriented programming, the QGLWidget was extended and given haptic, collision, and model capabilities on top of what Qt provides
  - Objects were written to be either generic, touchable, movable, and/or collidable.
  - All Objects are managed by a Scene Class
  - Documentation is being constructed so that future coding can be achieved quickly and effectively.



Traumatic Brain Injury

- Motivation
  - Virtual reality has been applied to both the evaluation and treatment of persons with TBI.
- Goals
  - Develop engaging virtual environments that provide different cues additively or subtractively to accomplish a task
    - Visual
    - Auditory
    - Proprioceptive
  - Develop several simluations/tasks that test a person's ability to accomplish said task
    - Cognitive abilities
    - Motor skills
    - Sensory deprivation

Questions?


QtHapticTemplate
Shadow Map Resolution:
512
Shadows
Modeling
Cursor Size Scale:
1.00
Stroke Width:
0.20
Magnitude-Based Strokes
Clear Strokes
Draggable Object To Use:
fork.obj
Display Moveable Object