Haptic Methodologies for Guidance and Use in Virtual Environments

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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, ...).
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http://cs.gmu.edu/~vislab
• 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
• **Study of Human Movement:**
  - 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

• **Simulation of Human Movement:**
  - 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

- Features:
  - Utilizes Handshake API
  - Use of Letter Primitives
  - Adjustable Modes
  - User-Friendly Interface
  - Quantitative Reports

- Issues:
  - Guidance force-control was handled behind the scenes.
  - Constructing primitives of free-form movement was time consuming.

• **Motivation**
  – 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

• **Goal**
  – 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

- **Process:**
  - 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.
Future Work
- Automated stroke separation
- Extracting accurate velocities and accelerations to be used for the haptic's force control
Motivation:
- Haptics provide proprioceptive cues, which can be used in conjunction with visual cues to aid the user in reconstructing a movement.

Previous Work:
- Haptic Guided Position (used for letter writing)
  - Created through Spring Force: $F = k \cdot d$
- Haptic Guided Force
• **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
Process (cont):
- 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
• 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
• **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, ...)
    - ...
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
- **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
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:
• **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.
• **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 simulations/tasks that test a person's ability to accomplish said task
    - Cognitive abilities
    - Motor skills
    - Sensory deprivation