**Haptic Device and Software Development**

- Examined the affordances and constraints of two haptic devices, Sensable PHANTOM Omni® and the Novint Falcon.
- Currently, we are developing activities using the H3D SDK, which combines haptic X3D models and python scripts.

**Haptic Embodiment Activities**

- A haptic embodiment is a force that is already identifiable to a user (e.g., “breaking point”, “impact”, “balance”).
- Simple experiments to investigate what haptic experiences matter to children and undergraduate students.
- Each activity has a set of predefined variations, which alter the haptic environment (“on the fly” e.g., turn off visualizations, add viscosity, change viewing angle).

**Research Questions**

- What types of new or enhanced learning experiences can be effectively integrated into elementary and undergraduate classrooms using the proposed technology?
- What are the perceived benefits of haptic technology in addition to visual technologies and how can we investigate and evaluate these benefits?
- How can the technology and associated activities be integrated both practically and effectively into mainstream curriculum?

**Broader Impact**

- The project aims to allow more accessible roots for a wider range of students to explore mathematical concepts in advanced learning environments, while assessing the practical and educational costs and benefits for wider dissemination.
- We will work with under-represented groups from the University’s mathematics and engineering programs as well as schools with low to middle achievement levels.
- We will build on an existing concentration of Sketchpad users and evaluate the impact of engineering programs as well as schools with low to middle achievement levels.
- How do children express themselves mathematically?

**Proof of Concept Study**

- Conducted with a 6-year-old and a 13-year-old.
- Examine the possible adaptation of a dynamic geometry activity to incorporate a haptic device.
- Participants interacted with a dynamic triangle by moving a cursor, via the haptic device, to one of the four hotspots (A through D).
- Area of the triangle is proportionally linked to the force-feedback of the device when a hotspot is selected.

**Year 1**

- Developed and created dynamic geometry curriculum units incorporating haptic devices.
- Investigate the value-added benefits and constraints to learning using haptics and dynamic geometry.

**In the Field**

- This spring, experiments using the haptic embodiment activities will be implemented in informal and formal settings with elementary and undergraduate students in three economically and ethnically diverse, educational establishments.

**Plans for the Future**

- Investigate the value-added benefits and constraints to learning using haptics and dynamic geometry.
- Build a prototype of Geometer’s Sketchpad® integrated with Sensable’s PHANTOM Omni®.
- Develop and create dynamic geometry curriculum units incorporating haptic devices.
- Design and run a main study with undergraduate students and early learners using curriculum units.
- Report on the effectiveness, practicality and dissemination possibilities of haptic devices in dynamic geometry curriculum.

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**Haptic Space**

**Reference Field**

**Curriculum Space**

**Haptic Embodiments**

**Impact Activities**

- **Escape the Shape**: Students are asked to trace the circle with the haptic device, exit the circle, and trace the circle again.
- **Shapes in Things**: Students are asked to trace shapes with the haptic device on both sides of the dividing line.
- **Falling Off**: Students follow three paths on a deformable surface.
- **Sphere Matrix**: Students can hold the stylus in place for 30 seconds while the device “pulses.”

**Breaking Point Activities**

- **Sensible PHANTOM Omni®**: Students are asked to hold the stylus in place for 30 seconds while the device “pulses.”
- **Novint Falcon**: Students are asked to trace the circle with the haptic device, exit the circle, and trace the circle again.

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**Dynamic Triangle Activity with a 6-year-old**

- Space is filled with a matrix of haptically rendered, spherical objects.
- Students navigate from one corner of the matrix to the opposite corner as quickly as possible.
- During the task, the spheres act as obstacles for the students’ movements.

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**Sphere Matrix**

- Space is filled with a matrix of haptically rendered, spherical objects.
- Students navigate from one corner of the matrix to the opposite corner as quickly as possible.
- During the task, the spheres act as obstacles for the students’ movements.