Survey of work

PHeT Simulation #3

Introduction

Facilitating hands-on learning is particularly important for students participating in STEM related courses such as chemistry, biology, and physics. STEM educational tools have been explored in the virtual reality domain (Smedley & Higgns 2005) with programs allowing people with disabilities to participate in science experiments and activities (Inman, 2004) such as learning to drive their motorized vehicles in a safe environment using the Internet to practice in a shared virtual space. Simulations are less expensive and more widely available to quote Helsel (1992), allowing students to move through an experience and make repeated choices to learn concepts.

In general, highly illustrated materials with animated graphics are being preferred for instruction over largely text-based presentations primarily because of newer technologies of instructions becoming available (Lowe 2003). In the same paper, the contention is that “very specialised dynamic subject matter having a high degree of visual complexity may actually have negative consequences for learners who are novices in the depicted domain, because they are so demanding for them to process.” This aspect of learnability is explored in the study to examine a) minimising split-attention effects in processing b) direct depiction of change interpreted c) by students from the animation to build higher-quality mental models.

They study how animations incorporate:

a) Form changes (‘Transformations’) that involve alterations to graphic entities with respect to properties such as size, shape, colour and texture;

b) Position changes (‘Translations’) that involve the movement of whole entities from one location to another and can be perceived with respect to the border of the animation or other material within the animated display; and

c) Inclusion changes (‘Transitions’) that involve the appearance or disappearance of entities (either fully or partly) according to Lowe (1999a).

The study quoted here goes on to observe the “visual complexity” and context for animation/interactivity which is not relevant to this study. The main finding however is that “the potential of animation as a tool for learning is unlikely to be fully realised unless the design of these presentations gives proper attention to supporting learners’ extraction of domain-relevant information and its incorporation into existing knowledge structures.” In the case of PHeT simulations, as learning tools we can safely posit it is supported in the classroom. In an extended study we can ***categorize simulations*** and study these categories of changes in animation and their meaning to learners.

The retention of learning through visual animation and interaction is interestingly consistent for small groups and individuals. According to Stephens & Clement (2015) in no whole class/small group comparison did a small group show an advantage in visual support received over individual learners though there is a slight trend in favor of the students in the whole class condition. However, this activity is more complex for students with visual impairments as animations on interfaces are typically created with visual software elements using windows, icons, menus, and pointers (WIMP).

Alternative interactions: Gestures and haptics

With the challenges of skill levels, STEM concepts' learning requirements and emphasis on making web content accessible, we aim to explore controls like voice, haptic feedback and gesture to improve simulations. For the purpose of this study, we focus on the haptic and gestural control as the primary input mechanism:

1. Gestures serve as a critical means to obtain attention and to express ideas even for people with visual impairments (Bekker 1995)
2. Tang and Leifer studied a small group design session and found that sighted participants' use gestures associated with the actions of drawing graphs and making a list 65% of the time, and the rest to refer to an object in the workspace or enact simulations.
3. Frame's study also reported that, compared to sighted people, individuals with visual impairments felt less uncomfortable with the use of gestures while speaking.
4. Haptic technology enables users to obtain rich information through simulations of various characteristics of the objects and the environment, such as mass, hardness, texture, and gravitational fields (Kim et al 2013)
5. Lederman and Klatzky's model of hand movements (i.e., haptic exploratory procedures) supports the notion that people with visual impairments are able to perceive material (texture, hardness, and shape) assigned to prototyping artifacts to be identified by touch.
6. In addition, Hatwell et al. claimed that the sense of touch could also contribute to the perception of spatial properties, which play a critical role in perceiving and discriminating locations of stimuli in environments. Spatial properties include the following: localization, length, line, and orientation.
7. Sjostrom introduced four types of fundamental interactions between haptic technology and a user: (1) navigation in the virtual environment, (2) finding objects and overview, (3) understanding features of an object, and (4) discrimination of objects – driven mainly be a designed reference point in the physical workspace to trigger intended interactions with an interface.

Designing for gesture/haptics

Important considerations for design include knowing that when people with disabilities were allowed to make a decision on certain issues, these were often very different from those decisions made on their behalf (Mason 1992) which can be addressed by using participatory design approach through one of the four different design approaches - including cooperative design, contextual design, ethnographic field method (Wu 2005) and the Plastic Interface for Collaborative Technology Initiatives Video Exploration (PICTIVE) as explored by Muller (1993). Even sighted people perform different gestures without visual feedback (Kane 2010), and it is reasonable to assume that a person with visual impairments will react and perform gestures differently in response to auditory feedback.

3D Auditory Cursors

Screen-readers provide line by line information, a framework that does not meet the interactive experience of the simulations. Studies on auditory direct manipulation and the auditory interfaces mentioned in Winberg 2005, refer to "positioning a pointer to an object to be moved, picking it up, dragging it to a desired location and dropping it there." The UI involves a screen divided into 4 quadrants using pitch and panning adding overtones to the assigned tones. These were tested with two alternatives: a) high and low tones altered in parallel using pitch and b) sounds altered between left and right as users moved through panning.

To enable this set of actions, the interface uses auditory zooming or the ability to perceive changes in sound as changes in the state of manipulation. Quoting previous research from this paper, auditory cursors have been explored in:

1. The Mercator project (Edwards 1994) where the GUI used a hierarchical model of the interface objects coded logically using everyday sounds.
2. Spatial relations of the objects presented using a tactile devices in the GUIB project (GUIB consortium, 1995) and,
3. Auditory direct manipulation (Winberg 2001) through a sonification model for virtual drag and drop corresponding to the same resolution as a computer screen.

The study acknowledges the complexity of the sound environment in communicating easily to the participants. The motion of selecting, moving and releasing objects is further complicated by the number of objects and number of target points. The main takeaways from the Winberg study were a) provide the user with different ways of obtaining the same information, b) providing a continuous presentation of all objects did not require the user to leave the current position of interaction and c) participants clued into the sound design quickly though they were initially overwhelmed.

These aspects would possibly influence the sonified feedback to include number of objects and accurate placement of the objects in the intended target area. To develop an auditory cursor, we plan to study the gesture sets used by BLV participants in a 3D space.

Testing for gestures

One way to test the prototype is to use the gesture analysis technique, which is typically focused on the investigation of how frequently an individual uses gestures for certain purposes in design processes (Tang & Leifer) based on either a) a list of purposes (Bekker), b) gesture types that apply in a context (Frame) and c) Lederman's exploratory procedure list.

In contrast Dim et al., 2016 used an elicitation method in which blind users suggested gestures for controlling a television. The elicited gestures were seen to 1) mimic existing interfaces (legacy bias) such as the TV dial (a continuous rotating motion) or the remote control (a button press motion) and 2) that gestures should not require that the user find a specific location in space as nonspatial gestures were more common and rated as lower workload. In a study by Vatavu (2012) where sighted users defined gestures to control a television the compiled gesture set used symbolic and deictic gestures derived from metaphors. Some gestures were also performed with two hands and involved body movement (shoulders) at times. These suggest a need to understand the range of free-hand gestures preferred by non-sighted individuals and then proceed to feedback mechanisms.

Current Study Design (tasks)

The purpose of the present study is to understand how objects are manipulated using natural gestures in the absence of any cues - visual or auditory. We expect these gestures may be pantomimic as the elicitation is task-based where the participant will need to perform multiple low-level gestures of (i) grabbing an object, (ii) moving it, and (iii) releasing it again; or manipulation gestures used to guide movement of objects in a short feedback loop (Aigner et al). The study is designed to elicit free hand gestures towards:

1. Understanding the range of motion and expectations in movement
2. Understanding virtual objects as perceived by the user
3. Understand what cues are expected to signal interactions in terms of feedback

An alternative study for comparative performance could involve the use of verbal cues. Some ideas could be to cue:

1. Object placement and where they are located on/around a surface simulating a 2D model similar to the visual model on screen at present:
    a. Against the wall
    b. On a desk
2. Object size and shape characteristics with a single word description
3. Design the sound feedback to mirror cues using panning, pitch and loudness

The study will need to build up to checking retention and learnability in terms of the mental model created as mentioned in studies referred earlier in the document. This could form the scope of combining sound feedback, test exercises and questions by walking teachers through these interactions in retrospective interview methods.

Proposed Method of analysis

Interpretation of the observational findings can be coded using mind-mapping to cluster similar gesture sets apart from the quantitative coding activity from notes formats.

We plan to analyse the gestural inputs and set design based on several gesture elicitation studies leveraging participatory methods (Vatavu 2015). The statistical measures most applicable to gauge consensus among participants and the agreement rates in the elicitation studies quoted across the document are summarized below:

1. Computing agreement rates defined as the sum of squares of the percents of participants preferring various symbols (or gestures)
2. Evaluating user agreement for single-handed and bimanual gesture interaction
3. Preferences in fine finger gestures captured by the Leap Motion controller

4. Qualitative comparisons with legacy bias (eg. Windows-like graphical user interfaces) or charismatic technology influences (eg. sound being too attractive/emotional interpretations)
5. Cultural and technical experience influences on users' gesture proposals

Proposed Method

Participants will be ideally in the age group of 12 to 20 to ensure a close representation to students, yet maximize participation in terms of feedback as part of the think-aloud activity.

We recruit 5-10 participants with blind or low vision to perform the task.

They will be asked to "Move a certain object to a certain area in **three or more different ways** within your body frame or reach." The following set of observations will be noted:

- Manipulation - select, hold and release
    i. Size of object - small, medium, large
    ii. Size of targets - small, medium, large
    iii. Metaphors used
    iv. Body parts used
        - direction, number of fingers/hands
- Move several objects to a certain area. Observe metaphor for:
    i. Onto vs into;
    ii. shape/size of the objects
- Additional tasks
    i. Get a description of what I'm about to do
    ii. Get an overview of what I have in front of me

Once these activities are completed, the debriefing session includes feedback on Likert scale (1-7 = strongly agree):

- "The gesture I picked is a good match for its intended purpose."
- "The gesture I picked is easy to perform."

Each participant is asked to move their arms around to enable kinesthetic priming though they will remain seated at the desk for use of the LeapMotion device. The **current prototype** is focused on enabling drag and drop to test the auditory cursor. In the next iteration the prototype could include variables to handle errors and system overview triggers like the sliders, switchers and other navigation points to mirror the simulations. Once the simulations are categorized we will most likely find patterns that relate to selection, release and action confirmations. These will need to be added to the prototype.

Another aspect is integration with the sound design intended to be adapted to Web Audio - this would be important to test any alternative designs involving sound feedback appropriateness as a separate factor of learnability through sonified simulations.

Using LeapMotion

The cursor may need to adapt to a 3D orientation as well, so we capture coordinates to measure range of motion on a LeapMotion device to understand movements when participants are seated at a desk.

Case Study: The GRASP project funded by NSF and conducted in the University of Illinois at Urbana Champaign examines how students learn with simulations and how to enhance learning through gestures:

1. Students may develop gestures spontaneously in the course of an explanation, sometimes using gesture as a tool for thinking through physical actions
2. Sighted students watch their hands while describing the motion
3. For other students, gestures develop seemingly subconsciously, their hands constructing tentative representations of the ideas they are formulating.
4. In interviews, when researchers tried to make students aware of their hand use to develop it further, students reflect on and refine gestures to improve explanations.

Technology: They utilize Leap Motion for browser-based online simulations. Gesture control is not used to operate the computer's "widgets"—buttons, sliders, or checkboxes—but to manipulate the central actions and elements of the phenomena only.

http://mw.concord.org/modeler/

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