**Interactive Multimodal Virtual Display of 2D-Coordinates Plane**

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The aim of this research is to develop a studying aid for visually-impaired students to better understand mathematical concept of the coordinates plane. Since the coordinate system is usually drawn in visual representations, it is difficult to grasp what it is if it cannot be seen visually. We have developed an interactive multimodal interface, which includes three modules –haptic, sound, keyboard -. In these modules, haptic has a main role of replacing graphical property of coordinate plane and sound is for transferring the numerical information. In terms of haptics our application requires a haptic device, Phantom force-feedback device (Sensable, Inc.)

We established the following guidelines related to education before designing our application-: a) Simplification of coordinate plane into a grid plane is helpful to get started. It is considering only the specific part of math education related to function graph understanding. b) Providing a reminder of basic terms related to coordinate plane is helpful for understanding the whole concept. This covers for general mathematics education. c), User’s active participation with the studying tool (bidirectional) is more effective in education compare to those only providing passive receiving (unidirectional). Unlike the other two guidelines, this is targeted for multimodal interaction on education fields.

We developed our system based on H3D API [1], an extended version for usability of haptic rendering, from original X3D [2]. H3D API provided many functions, among which we used user-defined geometry creating, many kinds of surface properties, and force-feedbacks. By the guideline (a), we made 2-D grid plane of 9 by 9. In this part, three main components of grid plane - plane surface, grid lines, and coordinates points -were considered. We put certain degree of frictional surface effect on plane surface, and magnetic forces for grid lines. For points, we made constraining effects on them using some force-feedback functions in H3D, additionally putting sound information about the coordinate value. Each of three methods is for distinguishing and emphasizing each corresponding components. By this users are expected to combine each components concept, thus understand the coordinate plane well. To meet the guideline (b), we enabled haptic guidance for X, Y-axes. Choosing axes was from guess that axis concept is a basic prerequisite. Here we used ‘time function effect’ (sinusoidal function in time) and ‘position function effect’ (constraint on each axis) in H3D [1], resulting the effect of automatic movement of device which guides user on axis. Finally for the last (c), we abled point-pick and navigation activity on the grid plane. We made this function possible both by keyboard, haptic device.

We plan to perform a user study with students group who are visually impaired, and beginners in mathematical coordinate plane. We expect to get insights on some detailed process of learning the math concept, as well as optimal multimodal design for educating 2-D plane.

ACKNOWLEDGMENTS

This research was supported by

[1] The H3D API, http://www.h3dapi.org/

[2] The X3D standard, http://www.web3d.org/