



The Impact of Computer Simulated Haptic Force Feedback on Learning

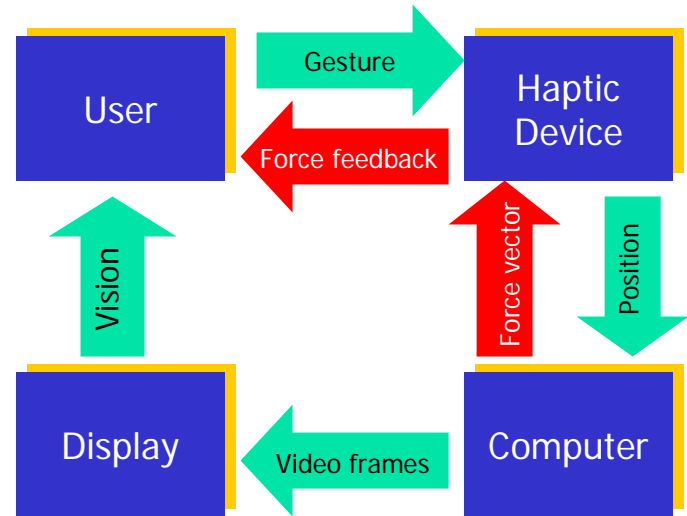
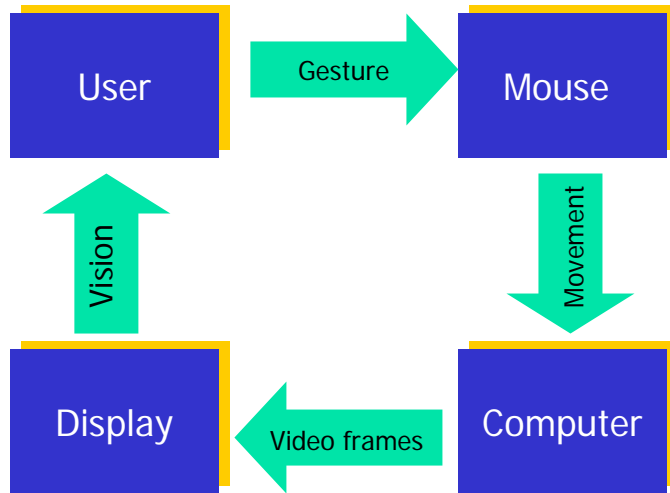
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Introduction

- Human Computer Interaction (HCI)
 - Display elements: windows manipulation, toolbars, menus, and 3D virtual objects.
 - Interaction hardware: mouse, keyboard, motion capture system, cyber glove, wand, head tracker, and natural language.
 - Display system.
- Haptics in HCI
 - Kinesthetic and tactile force feedback
 - New channel of information

Introduction (cont...)





An overview of the impact of haptics on learning

- Haptics technologies allow users to feel force, pressure, and temperature while interacting with a virtual environment.
- Haptics has been largely used as a learning tool for motor skill training such as surgical simulation, molecular docking, and virtual prototyping (Wagner et al., 2002; Gunn et al., 2005; Ström et al., 2006).
- In motor skill training, haptic force feedback is used to reproduce expert's skill in the form of tactile and kinesthetic perceptions using expert's temporal position, velocity and force information.
- Although considerable number of research has been done on how haptic force feedback improves human motor skills, to date, little research has been done on how haptic force feedback affects the learning of abstract scientific concepts.

Haptics and Physics Concept Learning

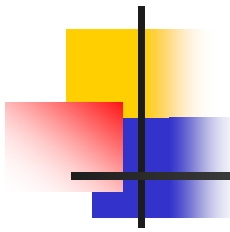


- In his seminal article, Ivan Sutherland (1965), the father of computer graphics, predicted that mathematical and physics concepts which never before had any visual and haptic representations can be shown and felt allowing us to learn them as the same way as we learn our own natural world.
- We think that the current advances in computer graphics, display and haptics technologies have already brought us “the ultimate display” that Sutherland (1965) predicted over forty years ago.
- So, we want to answer the following question:
 - Is there any evidence that shows involvement of haptic force feedback in exploration of physics concepts enhance learning of those concepts?



The impact of haptics on learning abstract concepts

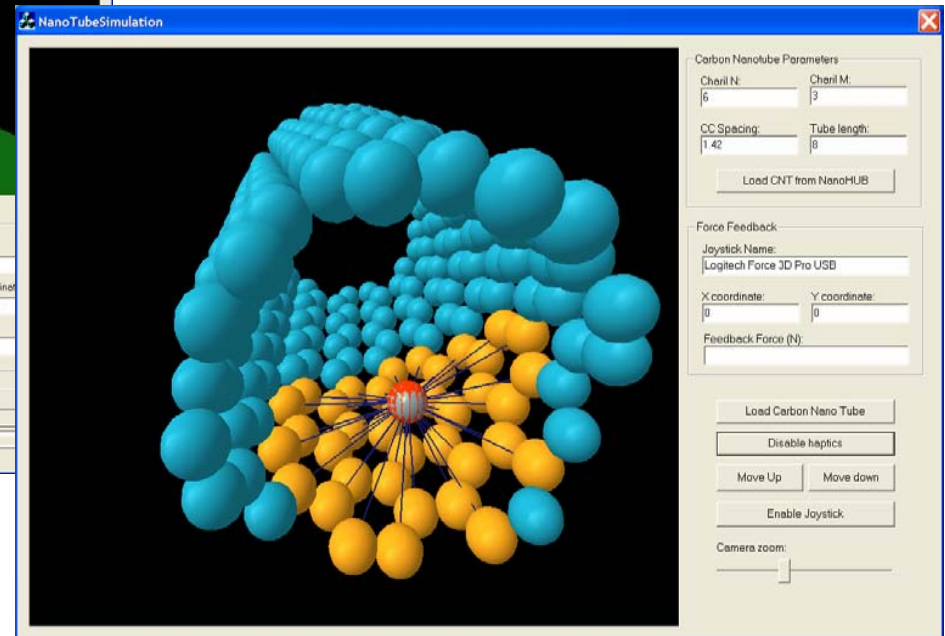
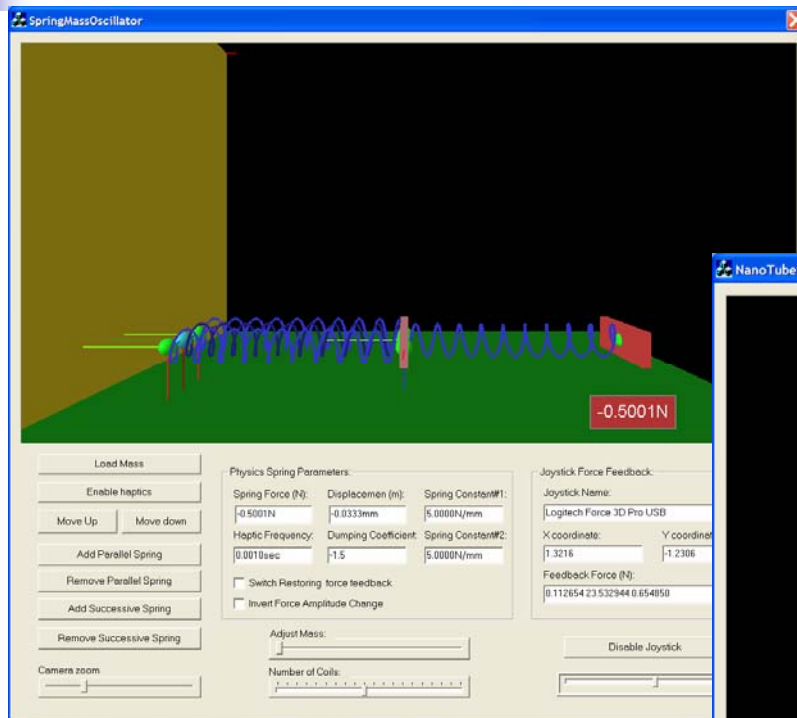
- Jones et al. (2004) conducted an experiment to examine haptic feedback in the context of an investigation of viruses and explore how and why hands-on haptic experiences may be effective.
- Harvey and Gingold (2000) developed a visio-haptic simulation for 3D representation of atomic orbitals that are traditionally difficult for chemistry students to conceptualize.
 - “With the aid of haptics, the conceptually difficult task of mentally integrating two or more images to create a complete representation of the orbital is replaced by a concrete, complete, and conceptually accurate physical experience” (Harvey & Gingold, 2000).
- Recently, Minogue et al. (2006) conducted a systematic research to examine the cognitive and affective impact of haptic feedback on students’ conceptual understandings of the structure and function of an animal cell.



The impact of haptics on learning physics concepts

- The fundamental concepts in physics are so unique that they often require the constructions of active mental models of their physical and mathematical models in the mind of the students.
- Human spatial cognition which provides us the ability to think quickly and to recognize complex mental models is an important building block to general cognition and learning (Bertoline, 1998).
- Multiple brain regions involved in spatial tasks are activated by multisensory inputs, suggesting convergence of information from different modalities in human spatial perception.
 - Further, this active information integration process was evident at neuron level with existence of bimodal neurons, which are activated both by visual and tactual stimuli, in a number of brain areas which are involved in reaching movements (Graziano & Gross, 1994).
 - Recent research conducted by Ernst and Banks (2002) showed that human nervous system combines visual and haptic information in a statistically optimal fashion.
- This suggests that inherently dual-modal stimuli such as variety of physics force (spring force, electro-static force, gravitation, etc,.) that require both spatial and haptic cognitions may be better understood when both modalities are involved in learning semantics of related physics phenomena.

Physics Concept Simulations





Bibliography

- Bertoline, G. R. (1998). *Visual Science: An Emerging Discipline*. In Journal for Geometry and Graphics, Vol. 2 (2), pp. 181-187.
- Ernst, M. O., & Banks, M. S. (2002). *Humans integrate visual and haptic information in a statistically optimal fashion*. Nature, Vol. 415(6870), pp. 429-33.
- Graziano, M. S. A., & Gross, C. G. (1994). *Mapping space with neurons*. Curr. Dir. in Psych. Sci., Vol. 3(5), pp. 164-167.
- Greca, I. M., & Moreira, M. A. (2002). *Mental, Physical, and Mathematical Models in the Teaching and Learning of Physics*. Science Education, Vol. 85(6), pp. 106-21.
- Gunn, C., Hutchins, M., Stevenson, D., Adcock, M., & Youngblood, P. (2005). *Using Collaborative Haptics in Remote Surgical Training*. Proceedings of the First Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems.
- Harvey, E., & Gingold, C. (2000). *Haptic representation of the atom*. IEEE International Conference on Information Visualization. Proceedings, pp. 232-235.
- Heller, M. A. (1983). *Haptic dominance in form perception with blurred vision*. Perception, Vol. 12(5), pp. 607-13.
- Jones, M. G., Andre, T., Kubasko, D., Bokinsky, A., Tretter, T., Negishi, A., Taylor, R., & Superfine, R. (2004). *Remote Atomic Force Microscopy of Microscopic Organisms: Technological Innovations for Hands-On Science with Middle and High School Students*. Science education, Vol. 88(1), pp. 55-7.
- Locher, P.J. (1982). *Influence of vision on haptic encoding processes*. Perceptual and Motor Skills, Vol. 55(1), pp. 59-74.
- Millar, S. (1999). *Memory in touch*. Psicothema, Vol. 11(4), pp. 747-767.
- Minogue, J., Jones, M. G., Broadwell, B., & Oppewall, T. (2006). *The impact of haptic augmentation on middle school students' conceptions of the animal cell*. Virtual Reality, Vol. 10(3), pp. 293-305.
- Power, R. P. (1980) *The dominance of touch by vision: Sometimes incomplete*. Perception. Vol. 9(4), pp. 457-466.
- Power, R. P. (1981). *The dominance of touch by vision: Occurs with familiar objects*. Perception, Vol. 10(1), pp. 29-33.
- Ström, P., Hedman, L., Särnä, L., Kjellin, A., Wredmark, T., & Felländer-Tsai, L. (2006). *Early exposure to haptic feedback enhances performance in surgical simulator training: a prospective randomized crossover study in surgical residents*. Journal Surgical Endoscope, Vol. 20(9), pp. 1383-1388.
- Sutherland, I. E. (1965). *The Ultimate Display*. Proceedings of IFIP Congress, Vol. 2, pp. 506-508.
- Wagner, C. R., Howe, R. D., & Stylopoulos, N. (2002). *The Role Of Force Feedback In Surgery: Analysis Of Blunt Dissection*. Proceedings of the 10th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, pp 73.
- Williams II, R.L., Chen, M., & Seaton, J. M. (2003). *Haptics-Augmented Simple-Machine Educational Tools*. Journal of Science Education and Technology, Vol. 12(1).