The Georgia Institute of Technology

CS 6795 Introduction to Cognitive Science
Spring 2012 Homework Assignment 3

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Assignment

In class we discussed some of your ideas designing new products based on the principles of cognitive science, distributed cognition and cognitive offloading. The goal of this assignment is to develop those ideas in to designs. Note that a product here includes not only a physical object (like the Starbucks' coffee cup), but also physical, computational and social spaces, systems, tools, interactions, networks and services. Note also that you can build on the idea you shared in the class or start with a different idea.

For this assignment, you want to create a design portfolio. This portfolio should contain at least three things. Firstly, it should describe the problem you are trying to address. Now that we have completed Thagard's book, this part should also describe: a) how cognitive science motivates the problem statement; b) your understanding of distributed cognition; and c) the cognitive offloading in relation to the problem being addressed. Secondly, the portfolio should describe, perhaps pictorially, the design of your product for addressing the problem. The design should be detailed enough so that we can understand how it will work. Thirdly, your portfolio should include a critique of your design from a cognitive perspective (again, see Thagard's book).

1 Description of Problem

Today many children in the United States and around the world are deterred from pursuing careers in technological based fields such as engineering and the sciences because of the difficulty in grasping advanced concepts in science and mathematics. Cognitive science is the unified theory of understanding the internal workings of mind. From cognitive science, one may propose a solution to this problem by developing a system in which users who desire to learn these abstract concepts may have more access to this knowledge without direct instruction or without overly technical descriptions. This system will provide accessibility to users who might have otherwise been led to believe that such concepts were beyond their understanding or ability.

In 2005, Thagard states that distributed cognition is when, “thinking occurs not just in individual [mind] but through the cooperation of many individuals.” This problem utilizes the notion of distributed cognition in that multiple cognitive agents provide for the achievement of a single, unified goal: in particular, the goal of understanding. In a way, we are extending the boundary of the human system by adding an extension to one’s internal representation of a concept. The specific cognitive processes that are distributed are described in the following passage. The new system’s cognitive agents are defined as the user (in this case the humans) and the external processing unit. The processing unit will need to acquire representations of items external to itself via a camera and vision processing. It will also need to create inputs for the agent such as tactile or auditory feedback of virtually represented objects.

Dror and Harnad state that cognitive offloading is allowing other “brains” to do “brainwork” for you (Dror, 2008). The user of this system will be able to offload, to some degree, the cognitive processes, or functions, of **problem-solving** and **cognitive sequencing** and to a small degree **working memory** and **decision-making**. As described by Hollan Hutchins, and Kirsh, cognitive processes may be coordinated efforts performed with internal processes of the user and with computers or other external devices in a distributed cognitive system (Hollan, 2000). Problem-solving can be thought of as defining a problem accurately and then generating solutions and choosing the most relevant one. Cognitive sequencing is the ability to break down complex actions into manageable units and prioritize them in the correct order. Working memory refers to, according to Wikipedia, the internal system which allows for active manipulation of information for reasoning and comprehension.[8] Working memory involves cognitive processes such as executive and attention control of short-term memory for the sake of integration, processing, disposal, and retrieval of information. Decision-making, in terms of cognition, includes the ability to make decisions based on problem-solving, incomplete information, and on emotional considerations.

2 Design

2.1 Design Components

The design is a pair of augmented reality eye glasses to help visualize and perceive abstract mathematical or otherwise concepts. The glasses could also be accompanied with special gloves with tactile feedback to allow the user to feel the virtually manipulated objects. This idea augments problem-solving and cognitive sequencing by allowing the user to have visualizations that might otherwise have to be conjured up and performed internally. For example, a person utilizing the device could take an object in their visual space (such as a graph, a baseball, a chair, a person, etc.) and have the device recreate it in digital form so that the user may manipulate it and rotate it, throw it, bounce it, etc. Or perhaps the device could create visual representations of abstract concepts such as L1, L2, or L-infinite norms, the 3-dimensional derivative, any physics-related phenomenon, etc. Even simpler concepts such as basic arithmetic could be given a more visual representation to aid in understanding. Even further, the device could also assist in mapping by translating 2D maps into more realistic 3D representations.

The hardware needed for the device:

- Camera
- Processor
- Eye glasses with built-in see-through screen
- Tactile feedback gloves
- Speakers for auditory feedback

Figure 1: The figure above depicts a game called Butterfly Effect created by the Georgia Tech Augmented Environments Lab.[1]

Figure 2: Augmented reality location-ID[2]

The interface could be designed using DART, the Designers Augmented Reality Toolkit (ARToolkit) created by Blair MacIntyre at the University of Washington in 2004. DART was created to further the state of the art in augmented reality (AR) design. Figures 1 and 2 show examples of augmented reality that are already in use. The glasses would be similar to the Vuzix Smart Glasses, but utilize Planar's transparent electroluminescent (EL) displays (see Figure 3). Hand (or foot) tracking could be accomplished through current computer vision techniques to track a fiducial on the glove or the glove itself (A silly video representing this idea: http://tiny.cc/hmdz5). The glove could also be equipped with gyros and accelerometers to aid in determination of position in space.

Figure 3: Planar's transparent electroluminescent (EL) display[6]

Another key aspect of the device is to make its source code open source so as to facilitate innovation and encourage people of all ages and walks of life to develop applications, tutorials, or games for the device.

2.2 Examples

The device could be used in an introductory physics lab. Let us say that a user wishes to represent the kinematics of planar motion in 3-space. The glasses would present the user with a virtual ball in front of them. The user could reach out and “grab” the ball by balling their fist. The ball would stay attached to the users hand until they release their grasp. The kinematic equations could be presented on the glasses and show the force diagram affecting the ball. The user could apply the force, the force of gravity could be neglected to show Newton’s first law, or other artificial forces could be created as well.

There is further utility for such a device in introductory calculus classes. If the user was trying to gain a visual representation of a partial derivative in 3-space, a graph could be formed that the user is able to rotate and manipulate in some way just as many graphing calculators. The key distinction is that the user is given a more (literally) tangible form of such a concept. Perhaps the user is trying to conceptualize a differential equation describing simple fluid mechanics. The glasses could represent a pipe of two different color liquids flowing into a new container. The equation describing the situation and a pictorial illustration of what each term represents could be displayed to foster a deeper understanding of meaning.

Going beyond simple fundamentals, the device could shed light on more abstract subjects. Understanding the electromagnetics behind the operation of a transformer could be shown by diagrammatically presenting the electromagnetic flux flow as an electric potential is applied across it. Here as well, the relevant equations and their pictorial representations could be shown to further solidify the concept for the user’s understanding. The user could increase or decrease the separation between the coils to see the effects on the intensity of the field or some other manipulation.

Of course, visual representations of these concepts currently exist, however, this technology has the key advantages that the user has the ability to fully manipulate the visual representation in space and the device is completely portable. Another great advantage is that no additional hardware or tools are needed other than the device itself. This interactive cognition would allow for students of all ages to gain access to complex mathematical principles and could perhaps encourage children to pursue these scientific fields at a higher level. This device could inspire these children (and possibly adults) into seeking careers in science, technology, engineering, and mathematics fields.

3 Cognitive Critique

Clearly we are able to take advantage of the fact that a distribution of processes can result a greater complexity than any individual member of the cognitive system is capable of alone (Lintern, 2007). The fundamental idea behind this design considers the body as an extension of one's cognitive architecture creating a sort of unified cognitive architecture. Concepts of spatial relations are defined by our bodily perception. Our ability to interact with the world is dependent on our physical sensory input (Thagard, 2005). The device sends enhanced visual, tactile, and auditory inputs into the human's mind. From an imagistic standpoint, we are processing certain aspects of a concept and then displaying these concepts for the user to observe. Thagard describes an idea of *intentionality* to describe mental states that represent the world (Thagard, 2005). For example, one's belief that their toaster is in their kitchen is not just a mental representation, rather it is a relation between your toaster and your kitchen, two things that are in the world. We are creating an enhanced or perhaps artificial form of intentionality by creating artificial objects in the world that the user need not create internally. We are playing on the idea that humans have the ability to learn by manipulating objects in their environment without the need for forming an internal representation of the object.

The design has no need to account for certain cognitive features such as societal aspects of cognition or consciousness since we are primarily concerned with representing things external to the mind. Internal representations of external things, however, play a key role in the implementation of the device. Much of the processing of the conceptual phenomenon is performed through the augmented reality glasses, the user need only to understand the representation that the glasses are presenting to them. Some contradictory information could be perceived from a logic or rule-based cognitive standpoint. Objects in the virtual form do not need to conform to rules the person associates with objects in the real world, such as gravity. One might argue that this is a disadvantage of the device since misconceptions may be formed about the idea being presented. The best way to counter this is for designers to take caution in the programs they design so that these misconceptions are kept to nil or a minimum.

4 References

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