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Perceptual Computing, the Future of Computer Interaction

Introduction

It started with punch cards. From punch cards, it went to a keyboard and typing, and from typing it went to the mouse, clicking and dragging. From using a keyboard and mouse, we took a step further and went to swiping and tapping. We are at the next turning point in technology where we take the next step: perceptual computing. This next step in the evolution of computer interaction is breaking away from the one dimensional surface and pushing through to the three dimensional space. Perceptual computing is an umbrella that encapsulates facial tracking, close-range finger tracking, close-range gesture tracking, speech recognition, augmented reality. With this newly developing technology, we will be able to enhance and redefine what we think of entertainment, accessibility, education, medical, and business.

From the Start: Fuzzy Logic

Perceptual computing draws its roots from Lotfi A. Zadeh's theory of Fuzzy Logic and Computing with Words. Zadeh's theory involves computation and reasoning with words rather than numbers. One of the draws towards this theory is that it is utilized when uncertainties and variances to be matched with a number counterpart. Additionally, these same variances and uncertainties may be employed to fit into a semblance of normalcy and tractability with a low solution cost. Words are labels of a granule, which is defined as a fuzzy set of points with an association with the fuzzy set conforming to a role of a variable's fuzzy constraint. Constraint propagation from premises to conclusions is essential to computing with words. Words may be considered composite, which is established and older, or they may be considered atomic, younger and new. Denotations of words may be of various order predicates.

Typically, logic we utilize is known as crisp sets; this being a set of well-defined, unordered lot of things that are unique and identifiable. An example of this is that there are three primary colors: red, green, and blue. Primary colors = {Red, Green, Blue}. Crisp sets are relations from a domain to a binary value. This issue with crisp sets comes into play in such cases: Premise 1: There is a collection of 500 marbles. Premise 2: The collection losing one marble is still a collection. However, after some time, there ceases to be a collection of marbles. As we can see, there are issues with traditional logic.

It may help if we had conceptual vagueness, a softer model to work with, and degrees of set membership. In fuzzy logic, the boundaries of a set are more malleable and allow for change, the degrees of a set are measured as real numbers between one and zero, and the set membership is graduated. Unlike in crisp sets where relations are from a domain to a binary value, fuzzy sets are relations from a domain to real numbers. Computers prefer discrete approximations over continuous functions. Additionally, fuzzy logic has well defined logic as like in crisp logic. Fuzzy logic utilizes, IMPLIES, AND, OR, NOT for operators. Transitions can be made from crisp logic to fuzzy logic and also form fuzzy logic into crisp logic. The transition from a fuzzy set to a crisp value is known as defuzziification. The transition from a crisp value to a fuzzy set is known as fuzzification.

When combining logical operators and fuzzy sets, crisp outputs are typically generated by crisp inputs. A fuzzy logic system has inputs that pass through a fuzzifier, traverse to an inference engine that utilizes a rule base, and then passes through a defuzzifier to produce outputs. This allows for a large scope of problems. Such problems in particular relevant to the subject are human decision making and image processing. A large issue with these is that the large variances in human behavior.

For example, let's say we are examining a motorcycle. A motorcycle could include two fuzzy systems such as a gear selection and driving style. Gear selection is computed on fuzzy judgment of driving style and collected sensor data. Driving style is collected by average driving style; everyone drives

differently. Starting with the fuzzifier, we input the average driving style of a driver, and then this is sent to the inference engine and control system, and this selects the gear for the motorcycle. The motorcycle now sends accelerator, resistance, speed, and variations in speed to the fuzzy classifier to recomputed the driving style. Simultaneously, the motorcycle sends speed, engine load and speed, and throttle information to the control system to be recalculated for the appropriate gear.

Because there isn't one identical driving style due to the large quantity of variables involved in the entire process, the need for fuzzy logic is clear. The previous example is known as an adaptive fuzzy system, and it gradually adjusts the fuzzy sets in order to dictate the outcomes of gear selection in order to create a smooth and safe driving experience. Most people do not think of the previous example to be related to perceptual computing, but we can see that fuzzy logic is integral to perceptual computing. People do associate perceptual computing with image processing, however. For example, we want to identify the regions of an image. This image depicts a blood cell, and we would like to identify the chromosomes, the mitochondria, the nucleus, and the cytoplasm while classifying the outer skin.

In this example, there is a set number of classes: n(4). We must initialize fuzzy descriptions per each class, and we must find the lowest overlap set of fussy descriptions n. The fuzzy descriptions may be as the following: the chromosomes in black and red, the cytoplasm being green, the mitochondria blue, and the nucleus being yellow. This allows easy distinguishable parts, and if you were to have many blood cells in an image, it is still possible to identify many of the individual parts of the cells. As we can see, this is extremely useful when ambiguity of uncertainty exists. It also depicts a fairly easy to understand paradigm.

Onward, to the future: Utilizing Perceptual Computing

Now that we have a basic background of perceptual computing, let's move to the technology utilized today and upcoming in the future. One use of perceptual computing is for entertainment and for

learning. At the AWE 2013 Conference, Barry Solomon of Intel demonstrated their Intel Perceptual Computing SDK 2013. The demonstration utilized a HD webcam, an IR depth sensor, and dual-array microphones. The demonstration revolved around a child's book; the book's cover art was placed in front of the hardware where it was recognized by the camera and IR depth sensor. Once recognized, the display on screen responded to gestures made in front of the book. 3D images on the screen brought moving visualizations to viewer. The demonstration made use of the book as a window, the book acting as a looking glass, and per position, showing different views as if looking through at different heights; the book was placed on a desk, and the 3D real time camera identified the table and generated a virtual surface where a character from the book moved off of the canvas and interacted with real world (virtualized) objects.

As for the medical and accessibility uses of perceptual computing, we have Victor Mateebitsi's SpiderSense. SpiderSense revolves around gestures to accomplish its work, and it was a class project developed at the University of Illinois at Chicago for a Human Augmetics class at UIC. Sensing the invisible was the premise; for example, radiation is invisible. It doesn't have taste, sound, odor, but it is deadly. Using sensor modules and a control box, the project allows a user to detect approaching objects such as people, walls, and other obstacles from a 360 perspective using only the device. The user is not using sight or audio. The sensor module has a pressure arm, a servo motor, and an ultrasonic sensor. The ultrasonic sensor detects approaching objects.

The servo motor allows movement for the pressure arm. The closer the user gets to an object, the more pressure is asserted by the pressure arm. The sensors emit pulses, receive a reflection, send the reading to the control box, where it is processed and calculates the servo arm angle. The servo arm angle is then sent to the next sensor and the previous sensor to repeat the process. This can allow for those with missing senses or dysfunctional senses such as those with difficulty hearing or with visual

issues. This is only a developing technology, the design clunky and not particularly user-friendly. However, this is an amazing use of the technology, and there will only be progress made upon it in the future.

There are also uses in the business, such as Corning's interactive glass surface known as the MultiTaction or the Microsoft Surface. These devices allow for recognition of devices placed on them, fingers touching the table tops to utilize gestures, and much more. The MultiTaction surface is built from an interactive cube constructed of Gorilla Glass, embedded projective capacitive touch, and a film that allows for holographic pixel formation. It provides interactivity and an image that lets real time data on systems or customized information to be manipulated for various uses. These can be utilized to provide functionality and efficiency to business meetings, displaying and manipulating charts and information with ease.

There are many ingenious takes on perceptual computing, and it does seem rather incredible and futuristic. It seems that whenever there is a futuristic display depicted in a book, movie, commercial, etc., it is a holographic display that is manipulated in such fashions as stated previously in this paper. There is a large draw for this technology because as a matter of fact, it's flashy, edgy, and cool. Google has taken steps into augmented reality with their Google Glass prototype, as well as Microsoft with their take in the way of the HoloLens. While this may be exciting and may seem like a possible step in the next evolution of computer interaction, there are draw backs.

Issues with the Technology

To start, when computers moved to keyboard and mouse interaction, people had issues with their posture and its effect on their health. With the current attempts at utilizing this technology, the user is standing and raising his/her arms to interact with the computer. This causes the users arms and back to become sore over time. Most people are not used to waiving their hands and arms around all

day during a work day, unless the person is a conductor or hairdresser; even then, one can imagine how tiresome that would become. Since this technology is not entirely mainstream or developed, there have not been studies on how this affects the user over time.

In addition to health concerns, due to the nature of the interaction with the computer, there is no tactile feedback. There is something to be said, for a great many people, to feel the press and release of a keystroke or the click of a button. It is a big change in the way in which we interact with our computers, and there will be many who are hesitant to make the transition to this technology that lacks such things. The tactile feedback that we have always known when interacting with computers may be too much to give up. While this is but a concern for some, there are also additional concerns to consider.

With the current stage of technology, there is not quite yet the precision required for a great many tasks unless the technology utilized for the entire process is more upscale and advanced. For the average user, using the technology for more than simple tasks and entertainment is just not there as of yet. Additionally, it is rather difficult to perceive where the user's hands are in virtual environment. With a mouse and keyboard, we can see the cursor and have a mouse to push around the cursor as well. However, with using just one's own body for manipulation, it is curiously complicated to get a natural feel for connection between the user and the computer.

In addition to not having the tactile feedback we are used to and the orientation we are used to, there is a concern revolving around the disconnected relationship between the user and the computer. Matti Bergstrom, a neuroscientist has researched and formulated the concept of "finger blindness". He states that the density of nerve endings in our fingertips is enormous. "The discrimination is almost as good as that of our eyes, if we don't use our fingers, if in childhood and youth we become "finger blind', this rich network of nerves is impoverished - which represents a huge loss to the brain and thwarts the individual's all-around development. Such damage may be likened to blindness itself. Perhaps worse,

while a blind person may simply not be able to find this or that object, the finger-blind cannot understand its meaning and value". (Svanteson)

This concern may be demonstrated through the trials of youth. Children can figure out touch devices relatively easy such as a tablet. If children utilize these devices more and more as they grow, they lose sense of their connection with objects and can become finger-blind. Instead of the visceral feel of handling an object - picking up a rock, feeling its texture, temperature, and weight the muscles pulling to lift it, and throwing it. Without the feeling of release in our muscles, seeing it fly, and hearing it land and possibly feeling the reverberations in the ground upon impact, it can really cause a loss for human beings. We take our physical connection with our surroundings for granted, but we all enjoy feeling the world around us. I believe that we really need to understand how people really are and how technology is going to mold the future around us.

Why Research This Topic?

I chose to pursue this topic as it is a trending aspect of technology, and I believe it to be one possible future for the way in which we interact with our computers. I have learned a substantial amount during my research into the subject. I found fuzzy logic particularly interesting, as well as the drawbacks that are current and predicted. A new way to interact with computers besides a mouse and keyboard is particularly interesting. To think of people sitting on their couch and using a large screen for work and for entertainment without any sort of controller or other peripheral device seems entirely too futuristic. While I believe in the progress of technology, I can also understand that not all new paths we forge are worth taking. In order to progress as a species, make the most use of our environment, and take the next steps to humanity’s future, there are bound to be avenues that are not worth pursuing.

Ever since I first heard of perceptual computing a couple of years back, I thought it was incredibly interesting. There are developers who are using the technology by incorporating it into

various gameplay styles for video games, but my real interest lies with the uses that will benefit people in education, medical, and business. While I have been known to relax and enjoy a video game or two, I firmly stand behind the advancement of the technology towards the aforementioned areas to be crucial. One of the reasons that the technology field particularly attracts me is that it is going to be our first steps into the future. All that I can wonder about the future is that of technology: what will computers evolve into, how will we interact with them, will we take on cybernetic implants for more connectivity, what are the drawbacks and complications that these things may or may not bring?

I was curious as to how the technology was utilized, and I had not a clue of how in depth the field actually was developing into. I had heard about perceptual computing being used for entertainment purposes, but I had never heard of the SpiderSense experiment or much in the way of useful advances in the technology. Learning about the Intel Perceptual Computing SDK 2013 was also rather fascinating, and they sell a kit with all that one would need to start the development and testing process for approximately $150. The SDK itself is free to download and experiment with. However, to really get the most out of the package, one would need the equipment.

Fuzzy logic of which perceptual computing relies on so heavily, was also an important and interesting learning experience. To start, I had never even heard of fuzzy logic, but I now understand the basics and hold an idea of what it may be useful for. The motorcycle example shows a good glimpse of how fuzzy logic is utilized in extremely common circumstances that we often do not consider. While I did not have any clue that fuzzy logic would be applied to a non-computer science discipline, I am personally more interested in the image processing adaptation as it is more closely related to the field of study I hold an interest in. In regards to future research, I will be looking into additional projects and uses for the technology, and I will be certain to look for it in technology news.

I can only wonder and fantasize about where this technology will lead. There are simply a wide variety of uses and possibilities that this technology can be utilized towards. While the groundwork is being laid, it is an excellent time to draw up some concepts and ideas so that, once the technology has grown and is more well-defined and commonplace, there may be a higher chance of these goals being achieved. I would think that fuzzy logic and perceptual computing could be used in order to reach higher levels of artificial intelligence. With a device having the ability to recognize objects around it, the device could identify objects, interact with them, stay away from danger, and much more. With having these abilities, perhaps they can be harnessed and used in creating more advanced robotics that can aid in survival rescue and towards exploration of space and sea.

My research into the subject of perceptual computing certainly allowed me a brief glimpse into the technology, how it works, a variety of uses, and possible futures that the technology may produce. I was curious as to how a computer could have the decision making abilities to recognize the environment around it, and now I have a basic understanding of how it does so. I realize that I am far from completely understanding the subject and that there is much more to learn about it, but it is fascinating all the same. I also was not certain what kind of physical components would be utilized to make the software portion of the technology function except for a camera. Certainly, different tasks require different hardware to accomplish a particular task at hand, and the SpiderSense project definitely illustrates that.

Since my research into the subject had only gone so far, there are plenty of questions that are left unanswered. For example, since the technology required to perform higher level tasks requires more advanced and powerful technology, what level of hardware is required to perform these lofty tasks such as artificial intelligence? The examples that I had encountered during my research were not terribly advanced in regards to super computers, and I would be interested in seeing a scaled up version of the technology. I was delighted to find out that fuzzy logic is utilized in the technology behind the

traffic lights that make signal decisions based on the number of cars that coming and crossing the intersection. If fuzzy logic is utilized in such a simple task, and I was not aware of it, how many other technologies that I encounter everyday utilize this branch of logic?

Conclusion

Perceptual computing has a variety of applications, from entertainment and learning to medical and professional use. Fuzzy logic is the backbone for perceptual computing, and it allows for the technology to really strive and evolve. Technology around us already utilizes fuzzy logic and perceptual computing, and we do not even notice. There exists a free SDK from Intel that I plan on utilizing myself in the future to get my feet wet in the subject. More common uses for the technology is for image processing, which allows computers to visualize and understand the world around them, and it will lead to the next evolution in computing as we know it. There are large companies such as Microsoft and Intel that are researching this technology, and they have plans to get their products to the market first with their own groundbreaking products. Fuzzy logic and perceptual computing have already proved themselves incredibly useful in technology around us today, and I cannot wait to see what it transforms into.

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