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E322 - Homework 4

Enhanced Human Machine Interaction project

Section 1:

Individual contributions:

Alexander

-Researched references [1], [2], [3], [4]

-Contributed toward the project discussion and written report, also organized the document

Jiaren

-Team Leader, provided summary and workable scopes of the project

-Researched reference [5] [6]

Shinji

-Contributed toward the project discussion and written report, reviewed document

-Researched references [7] [8]

Gwenn

-Contributed toward written report and provided documentation review

-Researched references [9] [10] [11]

	Jiaren Li	Shinji Sato	Alexander Thieke	Gwenn Flores
Percentage of effort toward this assignment	25 %	25 %	25 %	25%

Section 2:

Our goal for this project is to design a device that enhances the interaction between human and machine, as described in the past assignments. To further limit this objective into a workable scope for potential Senior Design project, the team decided to work on the most major component in the concepts and temporarily suspend all other concepts as described in the previous assignments. In essence, for this project, the team will aim to design a glove-like computer input device used to record human hand movements.

One problem to the design of this setup is how to allow the hardware to effectively communicate with software interface. Among other difficulties, there are so many design choices with different benefits and disadvantages. For example, which middleware should be chosen to interface between the glove and the computer? What is the minimum requirements for software interface? How should the glove be designed electronically and mechanically? This assignment will attempt to answer some of these questions by researching the principles and ideas that potentially contribute to this project.

Looking at different existing prototypes, we found there are several different types of sensors that could be used for detecting hand motions. The simplest option was to have conductive nodes placed at each fingertip and parts of the palm, such that when the user touched two of these together they would send an input to the computer. [1] This allows for a fairly large number of unique and configurable inputs, but this does not really capture the motion of the user's hand. Another method which appears very promising is the usage of several accelerometers located at different points on the hand. This has been shown to be capable of recognizing many unique hands gestures and also allows for 3D motion tracking.

For example, one application of this technology was set up to detect and translate symbols from Vietnamese sign language. [2] With the measurements from six accelerometers, with one placed on each fingertip and one on the palm, these distinct hand figures were able to be distinguished:

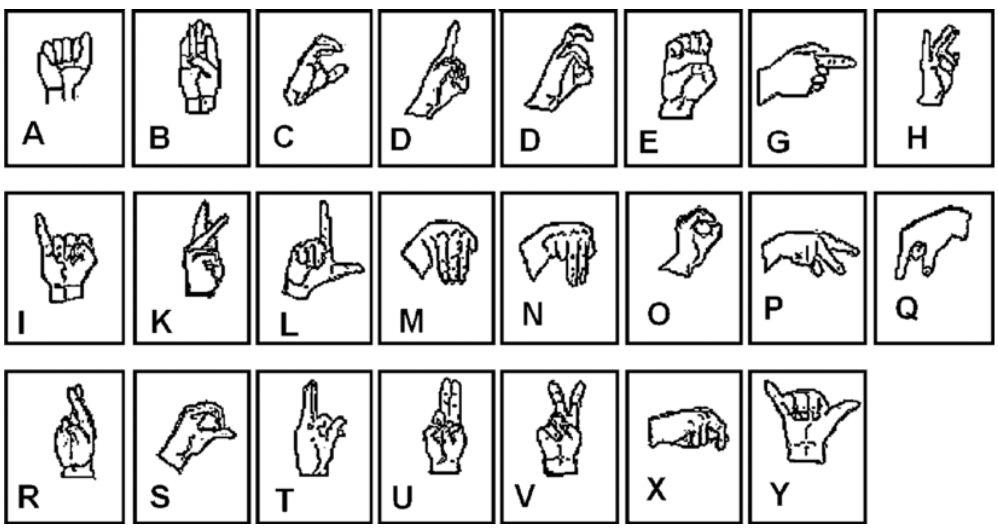

Fig. 1. Alphabet system in VSL. [2]

Their results state: "Twenty out of the 23 letters reached a 100% recognition rate." [2] This method seems very promising for accurate gesture recognition, but since the motion of the user's hand is also important to us, there is more we had to consider.

Another example we found during research used three tri-axis accelerometers attached to a glove (shown below) and tracked the hand in 3D using a digital model. Again, this application was successful in recognizing and even modeling hand shapes, but did not show the capability of measuring if the user moved his/her hand from one position in space to another. This paper even mentions, "Motion recognition is mostly done by video and motion sensor-based approaches." [3] So, perhaps the use of a camera in conjunction with a glove would be the most comprehensive option.

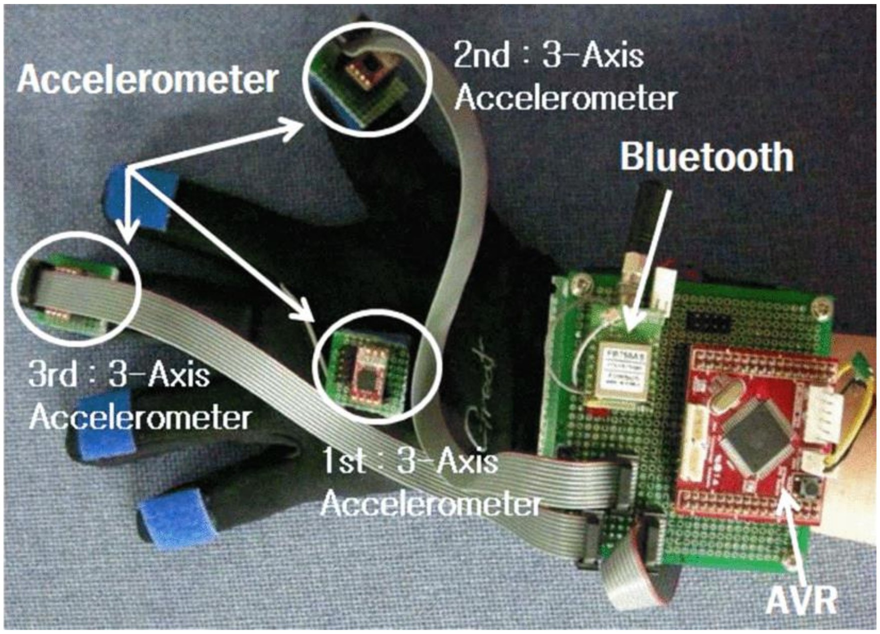

Fig. 2. The KHU-1 Data Glove [3]

An example of glove-less human-computer interaction used a vision based approach. By combining visual recognition system with real time hand gesture recognition, researchers were able to track hand gestures without a glove. Tracking gestures combined three approaches: thresholding, skin color detection, and edge detection (depicted below) [7].

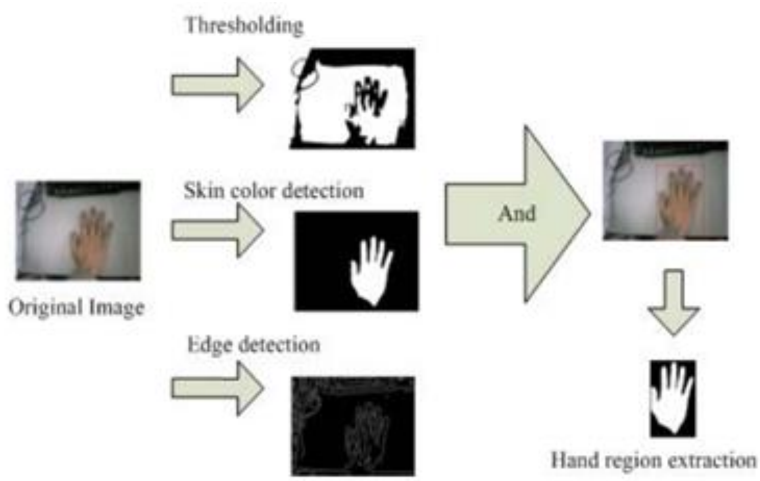

Fig. 3. The process of hand region extraction [7]

Tracking and comparing large sets of gesture data can become impractical for real-time speeds, but with the associative processor's similarity calculations it becomes possible [7]. However, even with real-time tracking in a set space this design fails to accomplish aggressive 3-D tracking.

Following gloveless design further, researchers took gesture recognition to full 3-D postures. Their technique starts with head and hands tracking through motion tracking and skin color segmentation [8]. Then through predicting human joint movement, which is minimal compared to other appendages, tracking is further improved [8].

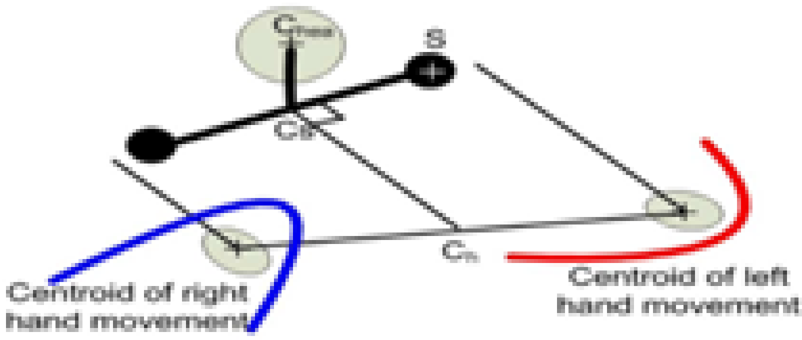

Fig. 4. Updated shoulder line orientations [8]

The study proved promising results varying from 85-100% accuracy depending on the gesture tracked. Perhaps integrating this concept will advance our 3-D hand gesture capabilities.

Other methods for gloveless human interaction also include orientation histograms and the use of a smart laser-scanner. The orientation histogram is a technique used as a feature vector for gesture classification and interpolation [9]. The method is simple and fast to compute and can be used to depict both “static” and “dynamic” gestures. A static gesture is a hand configuration and pose recognized by a single image, whereas a dynamic gesture is a moving gesture recognized by a sequence of images [9]. The orientation histogram implements a fast, real-time algorithm on a workstation and provides recognition relative to changes in lighting.

The smart laser-scanner is a physical alternative that is used tracking 3-D hand motion and interaction. It is a smart rangefinder scanner that restricts its scanning area, on the basis of a real-time analysis of the backscattered signal, to a very narrow window precisely the size of the target [10]. This prevents time and resources spent on continuously scanning over the full field of view. Without the need of markers, the system provides few constraints on the user/environment, full real-time non-imaging 3-D acquisition, and system on-chip integration.

Simultaneous tracking of bare fingertips [10]

More approaches to human-machine interaction and hand gesture recognition without the physical usage of a glove include soft computing based methods like artificial neural network, fuzzy logic, genetic algorithms, etc [11]. Even though the team has already decided on designing a glove-based device, other alternatives may be researched and taken into account for finding innovative ideas as well as for integrating different principles into an original prototype design.

All existing glove prototypes rely on fairly "bulky" accelerometer attachments to detect fingertip movements. One idea the team can potentially look into is incorporating piezoelectric devices to the glove structure itself, creating the "smart" structure in which movement detection and data voltage output are processed by one single unit, which has the advantage of being stable with a long life cycle [5]. In addition, fingertip movements can be accurately detected through the voltage difference in the bending of the fingers, glove, and piezoelectric materials. However, integrating piezoelectric components directly into gloves can be difficult, expensive, and unreliable, and we will have to look into alternatives that can reduce these flaws and limits.

Given the potential budgetary constraints and other technical limitations, the most accessible approach to accomplish such interfacing is by using an Arduino board. As a versatile, readily expandable, low cost, and efficient microcontroller, Arduino has the capability to read accelerometer data and provide some preliminary data processing and calculations. For example, an Arduino-based balancing robot was designed solely using processing power of Arduino and some basic accelerometers and gyrometers [6]. In the same way, we could simply wire accelerometers to Arduino board, and program the Arduino board in a way to take the voltage difference of the accelerometer raw input and output accelerations. This data would be picked up by computer interface to convert into hand movements. However, just the basic Arduino setup presents its own setbacks and limitations. The number of inputs Arduino can take before memory overflow is limited and Arduino's sampling rate and serial communication efficiency can often become problematic [6]. Accelerometers that are often directly compatible with Arduino are often inaccurate and inefficient to operate. If this setback can be overcome through an advanced hardware Arduino setup or better programming, then this method can be surprisingly efficient.

References:

[1] http://theperegrine.com/product/

A glove that sends signals when the user touches two metallic touch points together. Made as an alternative to keyboard commands and designed for gaming.

[2]http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=4154662&queryText%3Daccelerometer+in+glove

This talks about the usage of accelerometers in a glove to recognize hand gestures. In this project, they apply this technology to identify and translate Vietnamese sign language.

[3] http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=5221998&navigation=1

This tracks movement of a hand using a glove with three accelerometers, and uses a 3D hand model on the computer to show motion tracking. This also recognizes a few basic gestures.

[4]http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=5655123&queryText%3Dgaming+glove

A glove that uses optical linear encoders as sensors to measure finger position and

movement. This type of sensor used is the same that you would find in an optical computer mouse.

[5]http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=4775822&queryText%3Dpiezoelectric

This is an article on principles behind use of piezoelectric materials and how it can be integrated into devices creating "smart structure".

[6]http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6565146

This is an article describing an arduino-based self-balancing robot. The most useful information it contributes is regarding the combination of accelerometer and arduino or microcontroller board that can potentially be used for this project.

[7] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5234784

Article describing human-computer interactions through real-time hand gestures with a gloveless design.

[8]http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6054047

Article describing 3-D full-body posture and gesture recognition. Utilizes a "markerless" design.

[9]http://aimm02.cse.ttu.edu.tw/class_2009_2/CV/OpenCV/References/Orientation%20histograms%20for%20hand%20gesture.pdf

Article that describes hand gesture recognition through orientation histograms.

[10]http://delivery.acm.org/10.1145/1060000/1056851/p1138-cassinelli.pdf?ip=155.246.5.113&id=1056851&acc=ACTIVE%20SERVICE&key=C2716FEBFA981EF142FE614771876DFD3E849A5ACCB7F9AD&CFID=294815354&CFTOKEN=56605945&__acm__=1393005985_377570c04a53650a4d0bc7ff00c80395

Article that details human machine interaction through the use of a smart laser-scanner.

[11]http://arxiv.org/ftp/arxiv/papers/1303/1303.2292.pdf

Different approaches to human gesture recognition.