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RESEARCH ARTICLE

A SIMPLE AND UTILE APPROACH TO MANUAL GESTURE DECODING

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ABSTRACT

Manual gestures have been used as a medium of communication since time immemorial. Speech-impaired individuals extensively use manual gestures for communication. In addition, human-machine interfaces based on manual gestures are much more intuitive than those presently in use such as keyboards and mice. A manual gesture decoder could therefore simplify communication for a speech-impaired individual as well as serve as the backbone for an intuitive human-machine interface. Here, we have developed a manual gesture decoder which relies on a grid of infrared sensors and a switch for detecting and decoding gestures.

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INTRODUCTION

Since humans are social animals, the need and desire for communication is intrinsic to every human. Manual gestures are one of the means employed by humans for communication. However, each culture has its own set of manual gestures. Thus, the same manual gesture may be interpreted in different ways by individuals from different cultures. A device which can be programmed to map manual gestures to their corresponding symbols or words in a particular culture or language *i.e.* a manual gesture decoder, can be immensely useful as it could facilitate communication between individuals from different cultures. In addition, speech-and-hearing impaired individuals rely extensively on manual gestures for communicating with others. A speech-impaired individual is trained to use certain standard hand-gestures to communicate with others. These hand gestures may be difficult to comprehend for individuals who are untrained in using them. This may pose a communication barrier for a speech-impaired individual desiring to communicate with an individual who may or may not suffer from speech impairment.

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A manual gesture decoder would allow speech-and-hearing individuals to communicate more effectively and with less ambiguity. Manual gestures can also be used for intuitive human-to-machine communication in applications such as home appliance control and human-computer interfaces. Here, we describe the implementation of such a device along with one of its applications. In many cases, a speech-impaired individual may be hearing-impaired as well. We have devised a communication system to facilitate conversations between such an individual and a visually-impaired individual. This communication system incorporates the manual gesture decoder into a communication aid which is used by the speech-impaired individual. The manual gesture decoder decodes the manual gestures performed by the speech-impaired individual. The decoded gestures are then converted to textual representations and transmitted to an Android smartphone which is held by the visually-impaired individual. The smartphone is equipped with an application which is programmed to read aloud the messages received from the speech-impaired individual. Thus, the manual gestures performed by the speech-impaired individual can effectively be 'heard' by the visually-impaired individual. Similarly, the application is capable of converting the words spoken by the visually-impaired individual to text which is then transmitted to the communication aid held by the speech-impaired individual. The module then displays these. The speech-impaired individual can thus effectively 'read' the words spoken by the visually-impaired individual.

System Design

Most current approaches to manual gesture decoding rely on image analysis techniques (Yamato *et al*., 1992; Liu and Fujimura, 2004; Fang *et al*., 2007; Ren *et al*., 2011). Here, the manual gesture decoder relies on a grid of eight infrared transceivers to determine the positions of the fingers. This grid is mounted on a glove which is worn by the user. Each finger of the glove, excluding the thumb, has two transceivers mounted on it, one near the knuckle and the other near the base of the fingernail. The thumb has a switch fixed to it. It therefore has two possible positions –'0' and'1' corresponding to the ON and OFF conditions of the switch. A reflector is placed on each finger in between the two transceiver pairs. It provides indirect reflective coupling between the transmitter and receiver in the infrared transceivers mounted on that finger. When a finger is flexed, the strength of the reflective coupling changes appreciably for one or both transceivers on that finger depending upon the extent to which the finger is flexed. The position of each finger excluding the thumb is then mapped into one of three discrete values. We shall refer to these values as '0', '1' and '2' as shown in Figure 1.

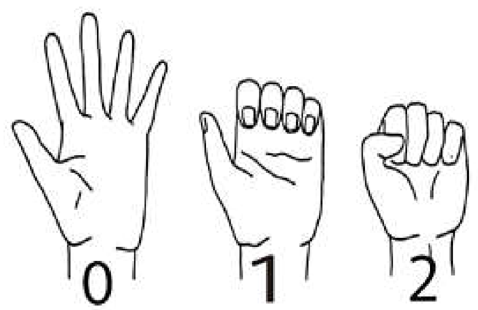

Figure 1. Positions of fingers

The indirect reflective coupling between the transmitter and receiver of both transceivers on a particular finger is maximum when that finger is held straight. This position is treated as a reference position and is used for calibrating the manual gesture decoder *i.e.* the values obtained from the ADC in correspondence to the IR receivers on the calibrated finger are used as threshold values. Once the manual gesture decoder has been completely calibrated for a particular user, the position of each finger can be determined. The manual gesture decoder then looks up the current combination of finger positions in a lookup table to get the currently performed gesture. In this way, the desired word is spelled out using gestures. Currently, the system has been designed to recognize predefined gestures for the lowercase Roman script letters from 'a' to 'z'. In addition, two gestures have been defined as space (' ') and full-stop ('.') in order to facilitate the forming of sentences in a conversation. In addition, the full-stop ('.') indicates the end of a message and triggers its transmission.

Hardware Development

The system requires a microcontroller which supports the following features:

- Serial communication via Universal Asynchronous Receiver/Transmitter (UART).
- Serial communication via Serial Peripheral Interface (SPI).
- Analog to digital conversion with at least 8 input channels.
- At least 16 bytes of non-volatile software programmable data memory.

A monochrome graphical LCD is used to display the User Interface (UI). It is interfaced with the microcontroller by SPI. Two switches are connected to the microcontroller for navigating the user interface, one for scrolling and another for selecting a particular option. Each of the eight infrared receivers in the transistor grid are connected in a potential divider arrangement with a resistors between the dc supply and ground. The tap points of the eight potential dividers are connected to the inputs of the ADC of the microcontroller. For the communication system application, the microcontroller is interfaced with a Bluetooth module by UART. The Bluetooth module connects it to the Android smart phone.

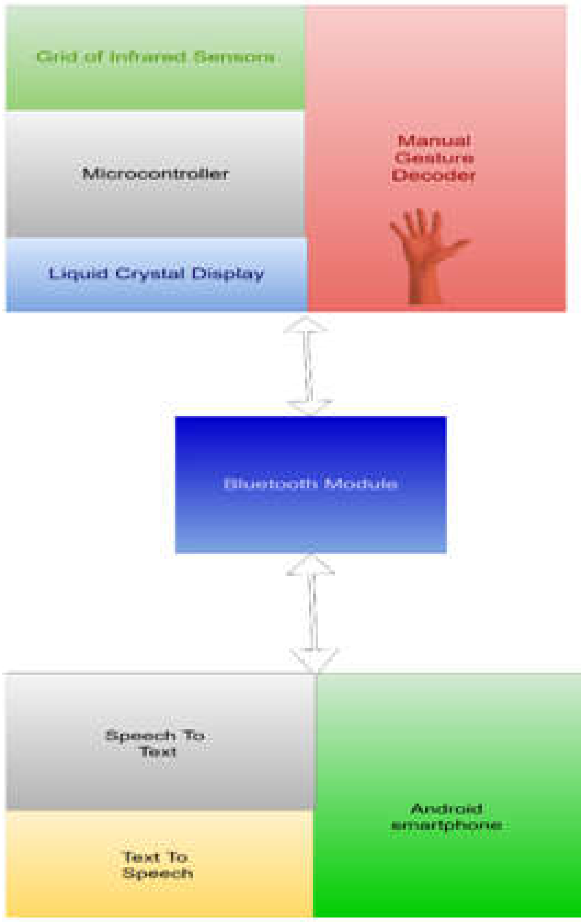

Figure 2. Block diagram of system

Software Development

Before the gesture decoder can be utilized for an application, it must be calibrated for the intended user. The calibration procedure is described below. For calibration of the system for a particular user, the finger is held in the position '0' and the ADC values corresponding to the IR receivers for that finger are stored to the non-volatile software programmable memory of the microcontroller for persistence. These values are treated as threshold or reference values and are used to determine the position of the finger in the future.

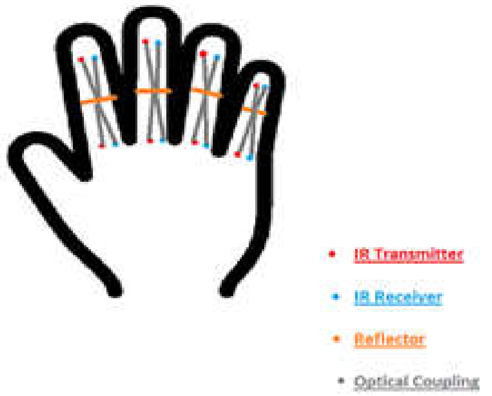

Figure 3. Placement of infrared sensors

If the ADC value from the lower receiver exceeds its threshold by a certain margin and that from the upper receiver is less than another certain margin from its threshold, the position of the finger is deemed to be '1'. If the ADC values from both the receivers lie within the predefined margins from their thresholds, the position of the finger is deemed to be '0'.

ADC Value Conditions		
Upper Sensor	Lower Sensor	Decoded Position
$V <= V_{th1} + V_{margin}$	$V <= V_{th2} + V_{margin}$	0
$V > V_{th1} + V_{margin}$	$V <= V_{th2} + V_{margin}$	1
$V > V_{th1} + V_{margin}$	$V > V_{th2} + V_{margin}$	2

Figure 4. Determination of a finger position

If the ADC values from both the receivers exceed their thresholds by the predefined margins, the position of the finger is deemed to be '2'. In this manner, the position of each finger is determined and the current combination of finger positions can be looked up against the pre-determined position combinations for standard hand gestures to infer the currently performed gesture. Figure 4 illustrates the relationship between threshold values (V_{th1} and V_{th2}), ADC output values (V) and the tolerance margins (V_{margin}). These relations allow us to determine the positions of all fingers. The manual gesture decoder is connected to a Bluetooth module for the purpose of serving as a communication aid for a speech-impaired individual. Words can be formed by sequentially performing the manual gestures for each letter of the desired words and appending them to the current message by pushing a button. The message is automatically transmitted when a full-stop (The Android Developer Guide) Is appended to the current message where they are readout aloud. These messages can be transmitted via Bluetooth to an Android smartphone. The Android operating system provides excellent Application Programming Interfaces (APIs) for speech recognition and speech synthesis from text 0. They are the Speech Recognizer class and Text To Speech class respectively. The words spoken by a visually-impaired individual can be converted to text and transmitted via Bluetooth to the communication aid used by the speech-impaired individual. The Android application relies completely on the accelerometer for user input so a visually-impaired individual can interact with it by merely shaking the phone.

System Analysis

The system relies on an extremely simple algorithm for the decoding of manual gestures. It therefore does not require powerful processing hardware as in the case of computer vision-based approaches. In addition, its operation is independent of the ambient lighting conditions. The components used are inexpensive and readily available. The manual gesture decoder has been used as a communication aid for a speech-impaired individual. The algorithm for decoding gestures is random-access based which means that the gesture for a specific letter can be performed directly instead of scrolling through a sequence of letters. This allows experienced users to use it at the same speed as a conventional keyboard. In addition, the same manual gesture decoder can be used by multiple users by calibrating it for each user. It does not need to be tailor-made for each user. The system does not require any imaging hardware. It relies completely upon the infrared transceiver grid and a switch for decoding manual gestures.

Conclusion

The advantages of the system are its cost-effectiveness, simplicity and speed. Potential improvements to the system include the addition of other sensors such as gyroscopes and accelerometers to increase the number of distinct manual gestures that the system is capable of detecting. Further, a word prediction algorithm implementation can speed up the formation of words and enhance its usability as a communication aid for the speech-impaired (Kapse and Shrawankar, 2013). The system could also be used as a computer input device if connected to a computer through a module which would accept the letters at its output and generate corresponding input events and dispatch them to the connected computer.

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