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Proud Hands: An Android-Based Hand Gesture Recognition and Conversion System Using Image Processing, Image Segmentation and Feature Extraction

Bucad, Maria Graciela Ramos

Batangas State University JPLPC-Malvar, Malvar, Batangas, Philippines
Instructor, College of Engineering and Computing Sciences
E-mail: gracerbucad@gmail.com

Abstract: The process of human communication has evolved, with many path-breaking inventions and discoveries heralding revolutions or a lift from one level to another. The main purpose behind the project is to provide persons with speech, mobility, and with physical impairments another means of communication using android-based technology, image processing (such as image acquisition, edge detection and token detection) and human computer interaction techniques. An android application that recognizes hand gestures and then convert it into its corresponding speech output.

Descriptive developmental design was used as the design model in developing the application. Using such, respondents can be depicted in a more accurate way, assessments can easily be known through numeric marks. Since the application is developed for an android platform and has highly volatile requirements, the Agile Development Model as software methodology was used. The proponent used Android Development Studio as the main IDE, Java as its programming language and MySQL Lite as the database.

The application was assessed by IT professionals and end-users, who are persons with speech, mobility and physical impairments, their parents and caregivers. Purposive sampling and availability techniques were used in choosing the respondents. A validated survey questionnaire was used to evaluate the application.

Based from the survey results, respondents strongly agreed that the application has performed all the tasks required from it. The proponent also concluded that the respondents had a positive assessment on the application, that it will improve ways on how people with speech, mobility and physical impairments communicate with other people.

Keywords: Android Technology, Human Computer Interaction, HCI, Assistive Technology, Image Processing, Hand Gesture Recognition.

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Introduction

Over the years, technology has significantly changed the way people communicate. Originally, the telephone replaced the telegraph. Using technology in communication has become a necessity, it's now part of our lives. Now cellphones, email and the Internet top the

list of preferred communication methods. As more businesses, educational institutions and other areas that affect the way people live use technology to communicate, society seems to have accepted, if not embraced, the increased role technology now plays in everyday life. These improvements have resulted in the advancement of the science of communication to a new level.

The process of human communication has evolved over the years, with many path-breaking inventions and discoveries heralding revolutions or a lift from one level to another. Communication technologies support many types of messaging and information sharing in organizations and even ordinary individuals. Organizations use communication technology to support and drive their day-to-day business activities. The predominance of communication technologies in organizational life means it is vital that employees have the skills to use them. Technological changes do influence the world which we live in. Regardless of whether its influences are positive or negative, each technology changes how people communicate and interact. These influences are especially evident when it comes to relationships. People often use technology and communication with others for specific relational reasons. Most technologies–digital and electronic–enable interaction to take place and quite frequently are the actual basis for interaction. That enabling power of technology to improve communication applies to all types of people–normal or even to those with special needs and disabilities.

Mobile devices like phones or tablets are now very common to people of all age. They are connected with network and provide seamless communications through internet, cellular, programs and application services. These assistive technologies can be a big help for people who are not able to communicate properly and even in emergency conditions. There are indeed many different ways disabled people can benefit from everyday technology.

Most individuals with disabilities can and do benefit from technology. Incorporating technology increases the motivation of individuals with disabilities to socialize and communicate. Even the most severe and profound disabilities can use assistive technology to live an almost normal life, and their potential can be reached in ways we didn't have before. As human beings, we interact with one another through many modalities: gaze, touch, gesture, and speech. Large interactive art installations often use vision, albeit a primitive version of that acute human sense, as their main input modality. Vision liberates the human participant to use movement in order to interact; it is also the domain of surveillance and attention, two key themes in contemporary society. The sensing capability of technology is indeed unimaginable.

For persons with disabilities, communication occurs non-verbally. Non-verbal communication is a particular case of human-to-human communication where the means used to exchange information consists of nonverbal behavioral cues such as movements, hand signals and gestures. This is appealing from a technological point of view because non-verbal cues must necessarily be accessible to our senses (in particular sight and hearing) and this makes them detectable through microphones, cameras or other suitable sensors. In other words, nonverbal behavioral cues (such as gesture) are the physical, machine detectable evidence of how persons who's unable to speak shares his thoughts and communicate-an ideal point for technology and human sciences to meet.

Everyone "talks" with their hands at least sometimes. Some people's hand-talking or gesturing matches their message well. But for those with disabilities, it is actually thru hand

gestures that they communicate. It's actually their first language. Hand gestures are really a powerful aspect of communication, from both the speaker's and the listener's end, especially for persons with disabilities and people who takes care or look after them.

Gestures can originate from any bodily motion or state but commonly originate from the face or hand. Gesture recognition can be seen as a way for computers to begin to understand human body language, thus building a richer bridge between machines and humans. Gesture recognition enables humans to communicate with the machine and interact naturally without any mechanical devices. Gesture recognition can be conducted with techniques from computer vision and image processing.

Gestures of the hand are read by an input sensing device such as mobile or computer. It reads the movements of the human body and communicates with computer that uses these gestures as an input. These gestures are then interpreted using algorithm either based on statistical analysis or artificial intelligence techniques. The primary goal of gesture recognition research is to create a system which can identify specific human hand gestures and use them to convey information. By recognizing the hand symbols of a man it can help in communicating with other people. Several approaches have been made using cameras and computer vision algorithms to interpret sign language produced by hand gestures.

A real-time method for hand and finger gesture recognition was used by Zhi-hua Chen *et al.*, (2014). The authors highlighted the use of background subtraction method to efficiently and effectively grasp the hand and segment the finger images of the user. A normal camera is used to capture the vision information of the gesture. No special gloves or device was used to detect the hand region (Zhi-hua Chen *et al.*, 2014).

In recent years, research efforts seeking to provide more natural, human-centered means of interacting with computers have gained growing interest. A particularly important direction about perceptive user interfaces, where the computer is endowed with perceptive capabilities that allow it to acquire both implicit and explicit information about the user and the environment was given emphasis for better image acquisition (Zabulis *et al.*, 2009). Vision has the potential of carrying a wealth of information in a non-intrusive manner and at a low cost, therefore it constitutes a very attractive sensing modality for developing perceptive user interfaces. Proposed approaches for vision-driven interactive user interfaces resort to technologies such as head tracking, face and facial expression recognition, eye tracking and gesture recognition. Most of the complete hand interactive systems can be considered to be comprised of three layers: detection, tracking and recognition. The detection layer is responsible for defining and extracting visual features that can be attributed to the presence of hands in the field of view of the camera(s). The tracking layer is responsible for performing temporal data association between successive image frames, so that, at each moment in time, the system may be aware of "what is where". Moreover, in model-based methods, tracking also provides a way to maintain estimates of model parameters, variables and features that are not directly observable at a certain moment in time. Last, the recognition layer is responsible for grouping the spatiotemporal data extracted in the previous layers and assigning the resulting groups with labels associated to particular classes of gestures.

On the other hand, an algorithm for extracting and classifying two-dimensional motion in an image sequence based on motion trajectories was proposed for easier classification. First, a multiscale segmentation is performed to generate homogeneous regions in each frame. Regions between consecutive frames are then matched to obtain 2-view correspondences.

Affine transformations are computed from each pair of corresponding regions to define pixel matches. Pixels matches over consecutive images pairs are concatenated to obtain pixel-level motion trajectories across the image sequence. Motion patterns are learned from the extracted trajectories using a time delay neural network. The said algorithm was applied to recognize 40 hand gestures of American Sign Language. Experimental results show that motion patterns in hand gestures can be extracted and recognized with high recognition rate using motion trajectories (Yang *et al.*, 2002).

In addition, a paper that describes the study of the threshold techniques in image segmentation was developed for images with complicated structure (Bhargavi, 2014). The segmentation process for images with complicated structure is one of the most difficult problems in image processing and has been an active area of research for several decades. Segmentation divides an image into its constituent regions or objects. Segmentation of images is a difficult task in image processing. The paper highlighted the wide application of image segmentation in many applications. He specifically dwelled on a non-contextual segmentation technique which is known as thresholding. Thresholding is the simplest method of image segmentation. This method is based on a threshold value to turn a gray-scale image into a binary image.

A design and implementation for Automatic License Plate Recognition (APLR) using Matlab was developed for faster and more accurate license plate reading. ALPR plays an important role in terms of Security and surveillance which also provides cumulative application access control, traffic control and detection of stolen vehicles. The project is OCR driven, it is divided into different stages of image manipulation to provide an accurate output of processed license plate number (Bhat and Mehandia, 2014). Visual Basic .Net is used as the face of the system for the signal and notification controls of authorization and is linked to OCR in Matlab.

A study on the recognition of Logosyllabic Han writing system such as Cantonese for Chinese, Hiragana and Katakana for Japanese and Hangul for Korean from a camera-captured image using image processing algorithms: Peripheral Direction Contributivity and 3-level matching, 2D Array and Recursion methods was developed by Filipino authors. In order to improve performance and to reduce memory usage of a mobile device, a remote web server has been used to communicate information from the user to the server and vice versa using Simple Object Access Protocol. Experiments were conducted to test the accuracy of the application such as capturing the same image several times, checking the percentage of the features of the text in the captured image, and capturing text from images in different circumstances such as low lighting and skewed images (Aragon *et al.*, 2014).

Synthesis

Visual information is the most important type of information perceived, processed and interpreted by the human brain. One third of the cortical area of the human brain is dedicated to visual information processing. Digital image processing, as a computer-based technology, carries out automatic processing, manipulation and interpretation of such visual information, and it plays an increasingly important role in many aspects of our daily life, as well as in a wide variety of disciplines and fields in science and technology, with applications such as television, photography, robotics, remote sensing, medical diagnosis and industrial inspection. Image processing indeed has shown great contributions and application in diverse areas of life.

Objectives of the Study

General Objective

The proponent would like to develop an android application that recognizes hand gestures, hand signals and simple hand motions and then convert it into its corresponding text-character or speech output.

Specific Objectives

Specifically, the proponent seeks to attain the following:
1.1.1 To apply the concept and techniques in Human Computer Interaction (HCI) in the designing the application.
1.1.2 To develop an android application that will recognize hand signals and gestures then convert it into its corresponding speech output;
1.1.3 To assess the application using ISO 9126 software evaluation criteria in terms of:
1.1.3.1 Functionality
1.1.3.2 Efficiency
1.1.3.3 Usability
1.1.3.4 Reliability
1.1.3.5 Maintainability

Scope and Limitation

The application can only recognize signals and gestures performed by a single-hand. Furthermore, it can only perform conversion of gestures that are stored on the database. Basis for the hand-gestures is the American Sign Language (ASL) and Filipino Sign Language (FSL) as those are the predominant sign-language of Deaf-Communities in US, Asia and in the Philippines.

Distance of the user from the camera may affect the quality of the image acquisition. The recommended position and distance of the user from the android camera depends on the size of the hand and screen of the android phone. All fingers and hand edges need to be captured in the screen to better perform hand token process, thus, having distorted and incomplete fingers may cause the application not to work properly. Lighting, background, completeness of the fingers, quality of the camera, screen size of the android phone affects the image acquisition process. The least recommended screen size is 4.0 inches.

The application will run on Android OS version 2.3 up to the latest as the application requires media framework and higher API level.

Materials and Methods

A system or an application that can recognize human signals or gestures could provide a new way for people with physical disabilities to interact with computers and other individuals as well. The first step in the developed application is the image acquisition or image capturing thru an android or mobile camera. The camera will capture the hand signal carried out or acted by the user. It will then be processed using image processing techniques such as edge detection, feature extraction and tokenization. Once an image has been formed and recognized, matching process with the pre-defined signals/gestures will be performed by the application. The equivalent speech of the recognized image will be spoken out by the application. Images below exemplifies concepts and the operations of the developed application.

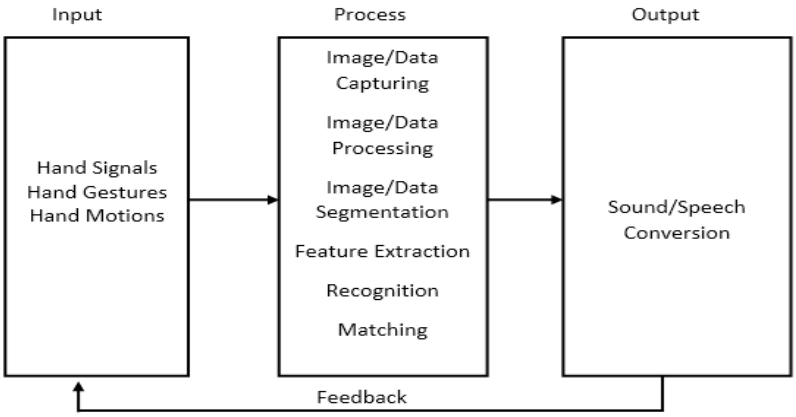

Figure 1. Input-Process-Output Model

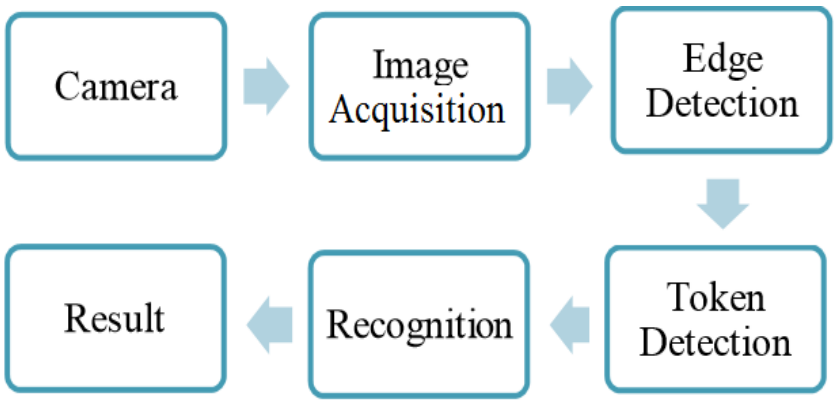

Figure 2. Block Diagram

Before any image processing can commence, an image must be captured by a camera and converted into a manageable entity. This is known as image acquisition, the first step in this project. Gestures of the hand are read by an input sensing device, in this project, it is the android phone's camera. The camera reads the movements of the end-user's hand and communicates with the device that uses these gestures as an input. The captured imaged will then be converted to its digital form.

The digital image's edges need to be detected as it will define the boundaries of different hand signals. Edges are significant local changes in the image and are important features for analyzing images. By finding the edge in an image, some amount of data is reduced but the image's shape is still preserved. Then, some kinds of features are extracted to describe specific hand gestures and signals. Edge detection undergoes three steps: (1) Filtering, where noises in an image are reduced; (2) Enhancement, where it emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude; and (3) Detection, wherein determining which points are edge points, usually those with strong edge contents are identified. Token detection comes next where the program converts the image into a neuronal network usable form is, that the cosinus and sinus angles of the shape represents the criteria of a recognition pattern. Figure below shows image with tokens. Each square represents a point on the shape of the hand image from which a line to the next square is drawn.

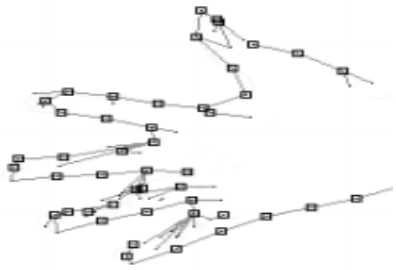

Figure 3. Generated token of the image

System Requirements

Hardware Requirements

Component	Specifications
Android Phone / Tablets	At least 4.0”

Software Requirements

Component	Specifications
Android OS	Version 2.3 up to the latest
OpenCV	Latest version

Data Collection Methods

Series of interviews with parents and caregivers of the main beneficiary of the application were conducted. The discussion revolved around ways and difficulties on their communication process. A semi-structured questionnaire was used by the proponent to administer the interview. The proponent gathered data from two different groups: the end-users that include persons with speech, mobility and physical impairments, parents and care givers of individuals with impairments and the researchers who can be information technology enthusiasts or information technology professionals.

A survey questionnaire was also devised to assess the functionality, efficiency, reliability, maintainability and usability of the developed application. Series of questions and other prompts are contained in the questionnaire for the purpose of gathering information from the respondents and assessing the application. The criteria in evaluating the application is in the scale of 1 to 5; 5 as the highest score and 1 as the lowest.

Software Methodology

Highly volatile requirements of mobile applications require adaptive software development methods Agile methods represent a relatively new approach to software development, becoming wide-spread in the last decade. The ideas behind these methods originate from the principles of Lean Manufacturing (in the 1940s) and Agile Manufacturing (1990s), which emphasized the adaptability of enterprises to a dynamic environment (Salo, 2006). Agile development is defined as the ability to move quickly and easily; relating to a method of project management that is characterized by the division of tasks into short phases of work and frequent reassessment and adaptation of plans. The practices of agile development simplify mobile app development so that the resulting mobile apps are adaptable after release.

Agile SDLC model is a combination of iterative and incremental process models with focus on process adaptability and customer satisfaction by rapid delivery of working software product. Agile Methods break the product into small incremental builds. These builds are provided in iterations. Each iteration typically lasts from about one to three weeks. Every iteration involves cross functional teams working simultaneously on various areas like planning, requirements analysis, design, coding, unit testing, and acceptance testing. At the end of the iteration a working product is displayed to the customer and important stakeholders.

Figure 4. Agile Development

Results and Discussion

Application of Human Computer Interaction Techniques in the development of the application.

Gesture recognition has been a research area which received much attention from many research communities such as human computer interaction and image processing. The increase in human-machine interactions in our daily lives has made user interface technology progressively more important. Physical gestures as intuitive expressions will greatly ease the interaction process and enable humans to more naturally command computers or machines.

Developing an application or any software requires human computer interaction (HCI) techniques. This "interaction technique" starts when the user does something that causes an electronic device to respond, and includes the direct feedback from the device to the user. HCI is a design that should produce a fit between the user, the machine and the required services in order to achieve a certain performance both in quality and optimality of the services. Determining what makes a certain HCI design good is mostly subjective and context dependent.

In the case of the developed application, the end-user needs to perform hand signals or gestures so that the application will perform necessary speech conversion–such is an exemplification of an interaction between a device and a human. The proponent designed and developed the application that tailored the requirement of its end-users, who are with speech, mobility and physical impairments. The application did not only provide ease of use but also new interaction techniques for supporting user tasks, providing better access to information, and creating more powerful forms of communication.

Ability of the application to recognize hand gesture and perform conversion process

Utilizing different image processing techniques, program codes, algorithms and android phone camera as an input device, the application was able to perform gesture recognition and speech conversion processes that will assist persons with physical and mobility disabilities to communicate.

The first step in the developed application is the image acquisition or image capturing thru an android or mobile camera. The camera will capture the hand signal carried out or acted by the user. It will then be processed using image processing techniques such as edge detection, feature extraction and tokenization. Once an image has been formed and recognized, matching process with the pre-defined signals/gestures will be performed by the application. The equivalent speech of the recognized image will be spoken out by the application. A built in speech API (Application Programming Interface) was utilized to execute speech output.

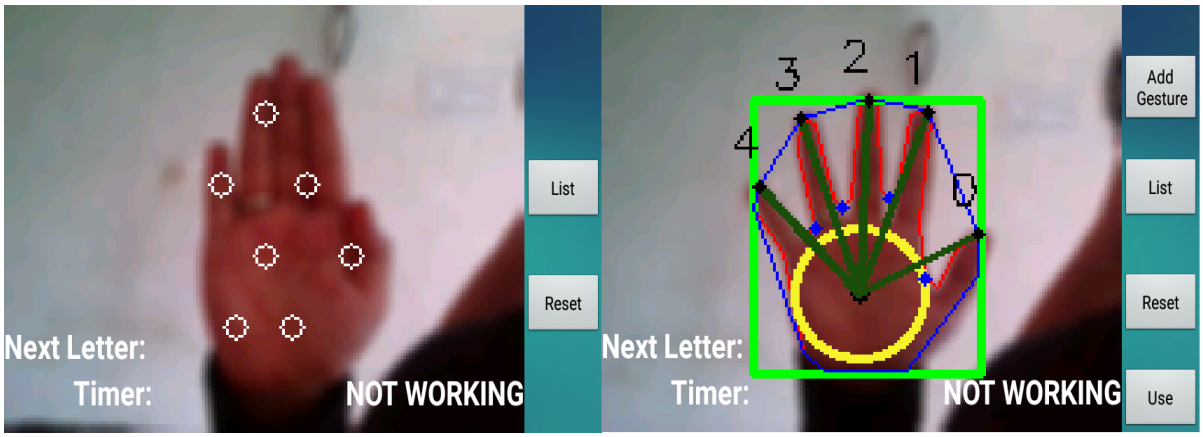

Figure 5. Recognition of hand gesture

Assessment of the respondents' responses in terms of Functionality, Usability, Efficiency, Reliability and Maintainability

The data gathered during the research, through the use of survey questionnaire that was sent out to the respondents is analyzed, interpreted and presented. The analysis is presented:

Table 1. Respondents' Assessment in terms of the Application's Functionality

Functionality	W1	V1	W2	V2
The app is capable of detecting hand signals/ gesture.	4.80	SA	4.76	SA
The app provides accurate conversion of hand signals to speech.	4.50	SA	4.50	SA
Overall, the app performs the tasks required from it	4.50	SA	4.60	SA
Average Weighted Mean	4.60	SA	4.62	SA

Legend: W1=weighted mean of end-users, W2 = weighted mean of IT professionals/enthusiasts, V1=verbal interpretation for W1, V2= verbal interpretation for W2; SA-Strongly Agree, A-Agree, N-Neither Agree nor Disagree, D-Disagree, SD-Strongly Disagree;

Based on data presented in Table 1, where the respondents' assessment in terms of the applications' functionality was recorded, the average weighted mean computed for end-users and IT professionals' responses are 4.60 and 4.62 respectively. Both results are interpreted

verbally as Strongly Agree. It just means that the developed application is capable of performing the tasks required from it which is basically to detect hand signals and convert it to its corresponding speech output that will assist the end-users in their communication process.

Table 2. Respondents' Assessment in terms of the Application's Usability

Usability	W1	V1	W2	V2
Screen layout is clear and is easy to interpret.	4.90	SA	4.76	SA
Icons that are used to assist navigation is clear and intelligible.	4.80	SA	4.76	SA
The user can use the app without much effort.	4.80	SA	4.80	SA
Average Weighted Mean	4.83	SA	4.77	SA

Legend: W1=weighted mean of end-users, W2=weighted mean of IT professionals/enthusiasts, V1=verbal interpretation for W1, V2=verbal interpretation for W2; SA-Strongly Agree, A-Agree, N-Neither Agree nor Disagree, D-Disagree, SD-Strongly Disagree;

Table 2 presented the respondents' assessment of the developed application in terms of its usability. Average weighted mean computed for the end-users' and it professionals' assessments are 4.83 and 4.77 respectively. The results show that both groups strongly agreed that the application is easy to use, can be used without too much effort and is easy to understand.

Table 3. Respondents' Assessment in terms of the Application's Efficiency

Efficiency	W1	V1	W2	V2
The app responds within a reasonable time	4.20	A	4.10	A
The app utilizes resources efficiently.	4.20	A	4.26	SA
Average Weighted Mean	4.20	A	4.18	A

Legend: W1=weighted mean of end-users, W2=weighted mean of IT professionals/enthusiasts, V1=verbal interpretation for W1, V2=verbal interpretation for W2; SA-Strongly Agree, A-Agree, N-Neither Agree nor Disagree, D-Disagree, SD-Strongly Disagree;

Data seen on Table 3 presented the respondents' assessment of the developed application in terms of its efficiency. Average weighted mean computed for the end-users' and it professionals' assessments are 4.20 and 4.18 respectively. The results show that both groups agreed that the application is has shown efficiency in terms of its performance.

Table 4. Respondents' Assessment in terms of the Application's Reliability

Reliability	W1	V1	W2	V2
The user is offered useful feedback if he/she gets something wrong.	4.80	SA	4.90	SA
The user is provided with help (instructions on how to navigate/use the app).	4.90	SA	4.90	SA
Average Weighted Mean	4.85	SA	4.90	SA

Legend: W1=weighted mean of end-users, W2=weighted mean of IT professionals/enthusiasts, V1=verbal interpretation for W1, V2=verbal interpretation for W2; SA-Strongly Agree, A-Agree, N-Neither Agree nor Disagree, D-Disagree, SD-Strongly Disagree;

Table 4 presented the assessment of the respondents in terms of the applications' reliability. As shown, the computed average weighted mean for the end-users' response is 4.85 with a verbal interpretation of Strongly Agree. While for the IT professionals' response, the computed average weighted is 4.90 with a verbal interpretation of Strongly Agree. The results show that the application is indeed reliable since users are well guided on how to use the application and what happens on each of the actions taken.

Table 5. Respondents' Assessment in terms of the Application's Maintainability

Maintainability	W1	V1	W2	V2
The user is capable of adding new gestures / signals.	4.70	SA	4.66	SA
The app can easily be updated.	4.70	SA	4.46	SA
Average Weighted Mean	4.70	SA	4.56	SA

Legend: W1=weighted mean of end-users, W2=weighted mean of IT professionals/enthusiasts, V1=verbal interpretation for W1, V2=verbal interpretation for W2; SA-Strongly Agree, A-Agree, N-Neither Agree nor Disagree, D-Disagree, SD-Strongly Disagree;

With the results gathered, the developed application has proven its characteristic of being maintainable. End-user's average weighted mean is 4.70 which is verbally interpreted as Strongly Agree. Similarly, IT Professional's response got an average weighted mean of 4.56 which is also verbally interpreted as Strongly agree. The application has shown ease with which the component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment.

Conclusions

Based on the findings of the study, the proponent has drawn the conclusions about the developed application:

4.1 Recognizing gestures is a complex task which involves many aspects such as motion modeling, motion analysis, pattern recognition and machine learning. The developed application presented hand gestures as conversational and communicative gestures, specifically for persons with disabilities. Considerable effort has been put towards developing intelligent and natural interfaces between users and computer systems, such as the developed application. This is done by means of a variety of modes of information either used individually or in combination. The use of gestures as means to convey information is an important part of human communication. The automatic recognition of hand gestures enriches Human–Computer Interaction by offering a natural and intuitive method of data input.

4.2 Image processing methods such as image acquisition, feature extraction, edge and token detections made ways to provide an effective assistive technology, an application that is able to recognize hand gestures and consequently convert it to its equivalent speech. Gesturing is one means of interaction, and there are some important issues in gesture communication, looking from a technological viewpoint, as well as a user viewpoint such as the learning rate and ergonomics. These issues were taken into consideration by the proponent. The procedure proposed and utilized in the way the developed application recognizes, reads and converts hand gestures were based user and technological viewpoints.

4.3 Information can come from a range of sources. The proponent collected all necessary information and materials needed in the development of the application. Responses from IT professionals (technological viewpoint) and end-users (user viewpoint) were solicited and provided the following results:

4.3.1 In terms of functionality, it was proven, through the marks given by the respondents, that the developed application is able to perform the tasks required since it was able to recognize hand signals and convert it to its corresponding speech output.

4.3.2 As for the application's usability, or the characteristic of being user-friendly, almost all of the respondents agreed that the application can be used without much effort and users can easily understand how the application actually works. The design of the interface contributed to high ratings in this criterion.

4.3.3 In terms of application's efficiency, majority of the respondents, both end-users and it professionals agreed that within the recommended setting, the developed application responds within a reasonable time frame. The application also exhibited its capacity to utilize the resources since it allows new gestures/signals to be added in the application.

4.3.4 As for the application's reliability characteristic, adding help or instructions on how to use the application contributed to making the application demonstrates its being reliable. Another factor is the immediate feedback that the user gets whenever an input is made.

4.3.5 For the maintainability, allowing the application accommodate and accept new signals/gestures made most of the respondents agree that the system is certainly maintainable. The proponent also considered the ease of the end-users in updating the system, thus including sign-in feature contributed to high marks given to this criterion

These principles are important for the entire interface that the gestures are used in the developed application.

In future work, the proponent aims to implement an application that recognizes gestures and hand signals of both right and left hands. Recognition of other non-verbal gestures and signals such as eye, lips and head movements can also be incorporated in the developed application, thereby requiring additional set of algorithms. Providing an option to use Filipino language and other dialects as speech output can also be very helpful.

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