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The Development of Hand Gestures Recognition Research: A Review

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ABSTRACT

This paper contains a review of the literature published in the last five years that discusses the topic of hand gesture recognition. The focus of this paper leads the reader to see the development of research over the years in hand gesture recognition, mainly that discusses performance, methods, and datasets used in hand gesture recognition. Hopefully, this paper can attract researchers' interest in developing technology more deeply, especially in hand gesture recognition. Hand gestures are not only used as a communication medium for people with disabilities. Hand gestures can also be used to interact with a computer without special devices with the technology available today.

I. Introduction

According to content published by the Data Centre and Information of the Ministry of Health of the Republic of Indonesia, it was written that in 2019 the World Health Organization (WHO) estimated that around 466 million people in the world have hearing disorders, of which 34 million are children. As many as 360 million, or about 5.3% of the world's population, have deafness. The World Health Organization (WHO) also estimates that by 2050, more than 900 million people will have hearing disorders, or every one in ten people worldwide. Based on the results of Basic Health Research carried out by the Health Research and Development Agency of the Ministry of Health in 2018, the proportion of hearing disorders since birth in children aged 24-59 months in Indonesia is 0.11% [1].

People use sign language gestures as a means of non-verbal communication to express their thoughts and emotions, but ordinary people find it extremely difficult to understand [2]. While sign language is a bridge to communicate with each other, it still doesn't get too much attention [3]. Having a translator all the time for the deaf and dumb is not affordable. Also, writing notes or paper to communicate every time becomes unhandy for a disabled person [4].

The flexibility and efficiency of noncontact communication methods have led many researchers to consider employing them to support human-computer interaction. The gesture is a required noncontact communication method that forms a substantial part of the human language [5].

This study aims to provide an idea that today's technology, especially Machine Learning, can be utilized to develop systems that help us communicate differently. Many media can be used to communicate; one example is hand gestures or sign language. The difference between hand gestures and sign language is what they are used for. Sign language is a form of communication used by people with impaired hearing and speech [2]. Meanwhile, hand gestures, such as waving hands over the screen to unlock our smartphones, can generally be used. Hand gestures have various applications in the military, gaming, etc. [6]. Recognizing hand gestures and sign language is a big topic that will be discussed in this paper because computers can learn hand gestures and sign language with today's available technology, which means being able to help deaf and mute people to communicate with others. Furthermore, the development of computer vision technology has been a critical field of scientific research for nearly 50 years [7].

To support all of this, a total of 20 pieces of literature that discusses the topic of hand gesture recognition using Machine Learning have been collected. The key points are the focus of research, methods, problems and solutions, and datasets.

There are also research questions (or formulations) of issues that will be discussed in this paper, (a) what makes hand gesture recognition technology important? and (b) how capable is the ability of the current technology to recognize hand gestures with good results?

The analysis and findings will be divided into the following sections. Part 2 describes how to search for the literature and discuss important points obtained from the collected literature. Section 3 explains more about the important points and presents the findings followed by discussion. Section 4 is the conclusion.

II. Material and Method

Literature reference searches come from well-known portals such as Google Scholar, IEEE, Springer. There are five keywords that are used as references in searching for literature, they are Hand Gesture Recognition, Sign Language Recognition, Image Recognition, Human-Computer Interaction, and Neural Network. The five keywords were also translated and then searched in Indonesian. Searching the keywords in Indonesian is also done because in Indonesia there are two versions of sign language, they are formal and informal. Therefore, hopefully it will give an insight about the existence of sign language in Indonesian version.

The literature drawn is only the literature published in the last 5 years, or in other words the literature published between 2016 and 2021. After collecting literature that meets the keywords, a total of 27 literature was obtained. Of the 24 literature, four literature were excluded because their focus does not meet the objectives of this paper even though they are still in the same context, image recognition. The four literatures do not discuss the topic of hand gestures/sign language at all, one of the examples is recognizing traditional script. In the end, a total of 20 literature were collected with 7 of them in Indonesian and 13 in English.

The collected literature is different between one another. Starting from the method used, the issues raised, solutions provided, the dataset used, sign language, and accuracy. Therefore, literature grouped into the following categories.

Focus of the Research. In this focus, references will be classified based on their research focus. It was noticed that there were two main research focuses in the collected literature. The first is focused on disability. The focus of this research is drawn to the accessibility of persons with disabilities, deaf and mute. There are literatures focused on disability. The second is focused on the interaction between humans and computers. This research is focused on the ability of computers to interact with humans in different ways or using different media. There are literatures focused on human interaction with computers. Computers that are meant here are not only personal computers but also can be smart phones, game consoles, and so on. Among the 20 literature that have been collected, there are two literatures that contain each research focuses at once, they are disabilities and human-computer interaction. However, there is still a focus of research that is used as the primary objective.

Problems and Their Solution. Every literature has problems raised and also the solutions provided. In this category, the main points of the problems and the solutions will be drawn so that they can be categorized easily. For the problems, it is broken down into 3, they are, (a) the ability to interact with computers, (b) heavy computing, and (c) lack of communication. Meanwhile, the solution is divided into 4, they are, (a) Hand gestures as a medium of interaction, (b) Easing computation, (c) Educating hand gestures, and (d) Trying other methods.

Dataset Used. Data is very important for doing research. Data can be obtained from various sources from the Internet or collecting the data by yourself manually. Collecting data can also be tough because the data acquired is not necessarily as easy as imagined, plus the amount of data acquired is sometimes insufficient. Corrupted or incomplete data also commonly encountered during the process of collecting data. There are several datasets that cannot be accessed by the public but can be purchased legally. It can be an alternative solution to get data quickly, although it doesn't guarantee that the raw data is in good or bad condition.

Method Used. From all the literature collected, it was found that Convolutional Neural Network are the most used methods, found in 13 literatures. Next one is Support Vector Machine with the most used classifier, found in 5 literatures. Some literature also includes more than one method used in one paper, so the methods will be separated and each method will be counted as one. The choice of method also affects the performance of the model.

III. Prepare Your Paper Before Styling

The findings written in the Material and Method section will be discussed in more detail in this section. In the Material and Method section, there are four important categories that will be used as a guide in studying the papers that have been collected.

The four categories are the focus of the research, the methods used, the problems and their solutions, and the last is the dataset used. In this section, each category will be discussed one by one based on the findings obtained from the collected literature.

A. Based on the Research Focus

Based on a review of each collected literature, there are two topics that became the main focus of this research. They are disabilities and computer interaction. Based on Table 1, computer interaction is the most discussed topic. In addition, there are also some other topics as well, but not discussed in depth.

Table 1. Research topics in each literature

Literature	Disability	Computer Interaction
Li [8]		✓
Elsayed [9]	✓	
Mufarroha [10]	✓	✓
Oyedotun [11]		✓
Kumar [12]	✓	
Mantecón [13]		✓
Yuliana [14]		✓
Gafar [15]	✓	
Rozani [16]	✓	
Parlindungan [17]	✓	
Bagus [18]	✓	
Fadillah [19]		✓
Yolanda [20]		✓
Adithya [21]	✓	
Pratama [22]		✓
Cui [23]		✓
Cayamcela [24]		✓
Islam [25]		✓
Raj [26]	✓	
Zhan [27]		✓

Based on **Kesalahan! Sumber referensi tidak ditemukan.**, literature Mufarroha [10] discuss the topic of disability and computer interaction in one paper. However, after exploring it, it turns out that the literature is likely to discuss the topic of computer interaction. Therefore, computer interaction is the most discussed topic.

Since we are discussing the technology in this paper, then the development of hand gesture and sign language recognition technology is important here. For the deaf and mute, they rely on sign

language to communicate. Therefore, they need an application or program that can translate sign language so that normal people can understand what deaf and mute people say. Meanwhile the hand gesture recognition technology in Human-Computer Interaction leads to giving commands to computers.

B. Based on the Problems and Solutions

Since we are discussing the technology in this paper, then the development of hand gesture and sign language recognition technology is important here. For the deaf and mute, they rely on sign language to communicate. Therefore, they need an application or program that can translate sign language so that normal people can understand what deaf and mute people say. Meanwhile the hand gesture recognition technology in Human-Computer Interaction leads to giving commands to computers.

Table 2. The problem raised

No.	Problem	Literature
1	Heavy computing	Literature [8]–[10], [20], [24], [27]
2	Lack of communication	Literature [12], [15]–[18], [21], [26]
3	Ability to interact with computer	Literature [11], [13], [14], [19], [22], [23], [25]

Let's discuss one by one, the literature that has problem in point number 1 complains about the heavy computation in the meaning that it takes a long time to recognize hand gestures image or even when training the datasets. In the Yolanda [20] literature says it took 164 seconds to train 1 second video at 30 frames per second. There are also those who complained about the complexity of the feature extraction process, for example the literature Li [8].

For point number 2, these literatures are concerned about deaf and mute people because they have difficulty communicating with other people. Plus, not many people learned sign language. Therefore, it is expected that there will be technology that at least can make it easier for deaf and mute people to communicate.

Next is interaction with computers. Most literature that discusses it expects another easy way to interact with the computer, not only using the keyboard or mouse but also by hand gestures as well. This hand gesture feature actually already exists on some today's smartphones. For example, there are smartphone features that help us to take pictures by using hand gestures. That is just one example and from there it can be developed more by leveraging the latest technology.

Table 3. The solution given

No.	Solution	literature
1	Easing computation	Literature [8]–[10], [20], [27]
2	Hand gesture as the medium for interaction	Literature [11], [12], [14], [19], [21]–[23], [25], [26]
3	Trying other method	Literature [13], [24]
4	Education for using sign language	Literature [15]–[18]

The solutions offered are quite varied, but the main point remains the same. In point number 1 there is literature that wants to lighten computation by simplifying the model built. There are also those who add pre-processing steps such as removing background and convert it to black and white images in the dataset, for example in literature Mantecón [13].

Next one in point number 2, it is hand gestures as a medium of interaction. All literature that offers this solution basically makes a model that can recognize hand gestures as the input. The only difference is the datasets and the methods that they use. Unfortunately, there is no further development such as developing applications or programs, they only create Machine Learning models from training to testing processes. Even so, it is still needed to be appreciated, the Machine Learning model they built has good accuracy and the most important thing is that the main goal is successfully realized, that the model has succeeded in recognizing hand gestures or sign language images.

Specifically, in point number 3, these literature claims to use a new way to detect hand gestures. Precisely in literature Yuliana [14], they detect only the location or shape of the finger skeletons.

For point number 4, the goal is very good which is to educate the people to learn sign language. Especially in literature Gafar [15] and Rozani [16]. Even though they only make Machine Learning models, they hope that the Machine Learning models they built can be developed more further such as make into applications or so on.

If we look at it in general, it turns out that there is a possibility that one paper provides the same solution as the other literature, but they raised different problems. For example, in literature Oyedotun [11] and Kumar [12], the two literature discuss different problems. Literature written by Sharath Kumar have problems with communication limitations while the literature written by Oyedotun have problems in interacting with the computer. From two different problems, found a similar solution is to use hand gestures as a medium to communicate. From there, they initiated to build Machine Learning models that could recognize hand gestures to realize the solution.

C. Based on the Research Focus

Using image datasets has been done quite often, it can be seen in the literature that has been collected. Almost all literature collected uses an image dataset in their research. There are only two literature that use video, they are literature Kumar [12] and literature Raj [26]. In this paper found three types of image datasets, and two of them are languages. They can be seen in **Kesalahan! Sumber referensi tidak ditemukan.**

Table 4. Types of datasets used

No.	Datasets	Total
1	American Sign Language (ASL)	12
2	Hand Gesture	7
3	Indonesian Sign Language (BISINDO and SIBI)	4

Most of the literature uses the American Sign Language (ASL) datasets in their research. Data from ASL is divided into several sections. Not every literature uses all sign language in ASL. Some of them only use 24 or even just 10 letters of the total 26 alphabet available. This is due to two letters which cannot be identified through images but through video. They are letters J and Z.

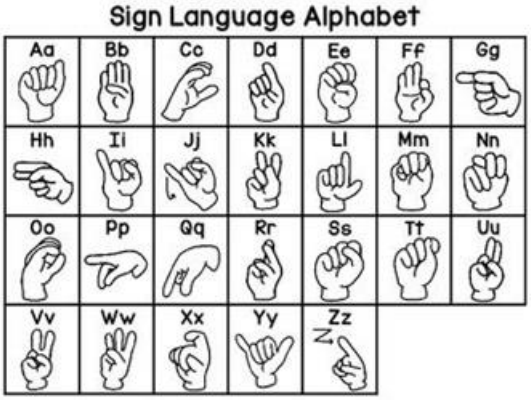

Fig. 1. American Sign Language alphabets

There are 5 literature that use 26 letters while still detecting the letters J and Z by capturing the first frame of hands motion. There are 2 literature that uses 24 letters with note that the letters J and Z are not included. There is one literature that uses 13 letters the various alphabets they choose. There are 3 literature that use 10 letters with the various alphabets they choose in each literature. Last, there is one literature that uses only 3 letters and uses video as the input.

The hand gesture datasets also have various variations and there is no specific reference. Basically, hand gesture datasets include hands motion that are made in such a way whatever the

shape is depending on the purpose of each study. There is literature that uses hand gesture datasets because its shape is easy to imitate, there is also literature that uses hand gestures as commands for computers such as to open a program. Some examples of hand gestures include fists, straight hands, combining things, and so on.

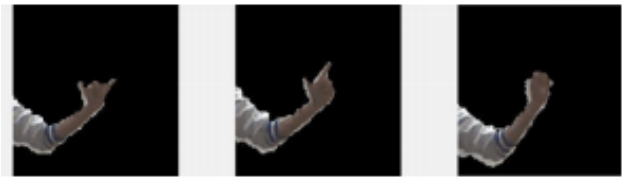

Fig. 2. Example for hand gestures

The literature uses hand gesture datasets because the gestures are basically hand movements that are commonly performed by humans and also easy for people with special needs or disabilities to imitate. Hand gestures meant here are used as an input to the computer as a command.

Indonesian Sign Language is found in four literatures. Indonesian Sign Language is divided into two versions, they are formal and informal. BISINDO is an informal Indonesian sign language that has 26 letters just like a normal alphabet.

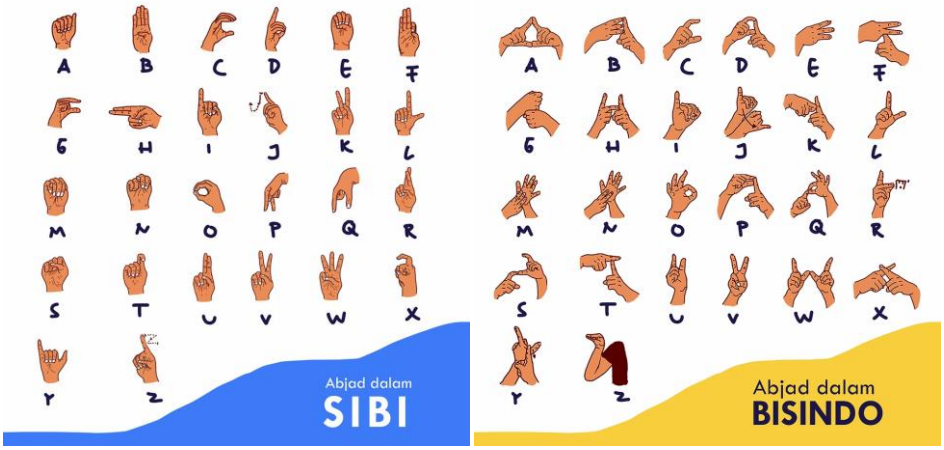

Fig. 3. Indonesian Sign Language alphabets (SIBI and BISINDO)

Formal Indonesian Sign Language is called SIBI and was adopted from American Sign Language (ASL). It is similar to American Sign Language (ASL); the difference is only in 2 letters, namely letter G and letter P.

D. Based on the Method Used

When solving a problem, there are methods that can be used to help in resolving the problem. In this case, the problem faced is image recognition of hand gestures. Using the right method, it might help to get optimum results as well. Therefore, choosing the right method is important in resolving a problem. The methods used in the collected literature are shown in **Kesalahan! Sumber referensi tidak ditemukan.**

Table 5. Types of methods and the number of uses

Feature Extraction and Classifier	Type	Literature	Total
Convolutional Neural Network	Feature Extraction and Classifier	Literature [8], [11], [25]–[27], [17]–[24]	13
Support Vector Machine	Classifier	Literature [8], [12], [17], [25], [26]	5
K-Nearest Neighbor	Feature Extraction	Literature [9], [10], [12], [15]	4

Feature Extraction and Classifier	Type	Literature	Total
Multi-Layer Perceptron	Feature Extraction	Literature [16], [20]	2
Multiclass Support Vector Machine	Classifier	Literature [9], [13]	2
Fuzzy Inference System	Classifier	Literature [10], [15]	2
Convex Hull	Feature Extraction	Literature [14]	1
Convexity Defects	Feature Extraction	Literature [14]	1
Long Short-Term Memory	Feature Extraction	Literature [20]	1

The combination of some methods can be used to get optimum results, such as in literature Li [8], Parlindungan [17], Yolanda [20]. Some literature also uses more than one method in a study but then compares one method to another to determine which method is the best. Examples can be found in the literature Elsayed [9].

IV. Results and Discussion

According to data from the Management Information System of Persons with Disabilities of the Ministry of Social Affairs, among people with disability in Indonesia, as many as 13.026 people are deaf, and 5.020 people are muted. With a ratio of 57 percent for men and 43 percent for women [28].

Looking at the facts above, it proves that quite a lot of people are deaf and dumb. Therefore, sign language is one of the media that people with disabilities can use to communicate with people. Education on sign language can also be given to normal people so that they can communicate with the deaf and dumb people. Meanwhile, sign language recognition technology could be further developed, such as developing a sign language translation application so that deaf and mute could communicate with normal people anytime and anywhere in real time since quite a few people are fluent in sign language.

This paper is made with expectation that it will be able to open up researchers' insights in developing new technologies, especially in making it easier for persons with disabilities to communicate with people. Maybe in the future, sign language recognition technology can be built as light as possible so that sign language recognition technology can be used on smartphones. Not only that, hand gestures can be an option for communicating with computers. Hand gesture as the input can be used to control or give commands to computers, for example to open a file.

There are some interesting facts during the writing of this paper. Quite a lot of research has been found regarding hand gesture recognition written in English with various methods and performance. Unfortunately, research in Indonesian is still quite difficult to find. Actually, there are Indonesians who do research on hand gesture recognition, but the dataset they studied was not informal Indonesian Sign Language like BISINDO, they use American Sign Language.

BISINDO is more common among sign language users than SIBI. BISINDO also appears naturally among sign language users which makes the language feel more flexible. SIBI was officially released by the government, but so far it has only been used for learning purposes in schools for people with special needs. SIBI is considered more difficult because it contains standard and complicated vocabulary, and has a prefix and a suffix. Unlike BISINDO, SIBI only uses one hand [29].

Quite a lot of literature that discusses the hand gesture and its objectives also vary. Some of the literature that has been collected can be used as a good reference for exploring further about the development of hand gesture recognition technology. For example, the literature written by Gongfa Li [8]. The performance of their model managed to touch 98.52% or the highest among the 20 literatures collected. Once analyzed, there are several possibilities so that they can produce such good performance. The first thing is combining several methods. It was written that they used Convolutional Neural Network as an image extraction method, then used the Support Vector Machine classifier as a classification of the image input. The second is they do denoise processing because there is a lot of noise in the image which leads to low quality of the datasets, so they need to filter the image. They use a mean filter algorithm, but it can only reduce noise and cannot remove

noise. Moving on to the method, they said that the Long Short-Term Memory architecture can actually be used because it has better performance than the Convolutional Neural Network in the long dependencies. But Convolutional Neural Network has the advantage that it can be configured to use different feature maps to capture objects each time and the object is captured multiple times. So, they prefer to use Convolutional Neural Network instead of Long Short-Term Memory.

There are also several reasons that are believed to make performance better. Looking at some literature Elsayed [9] and Mufarroha [10] where they use the K-Nearest Neighbor method, the process of removing the background is a way to make the detection process faster than the image with the background. There are literature Elsayed [9] and Oyedotun [11] converting RGB or colored images to binary or black and white images. In addition, it was also stated that light intensity is also very influential in the training process because light intensity can manipulate or change skin color. This is the thing that can affect performance. Therefore, several methods are used to manipulate these skin color changes, one of which has been mentioned above, which is changing a colored image into a binary image.

Talking about time, only Oyedotun [11] wrote down the computation time. In the Oyedotun study, only one method was used but it was manipulated in multiple different configurations. The method is Convolutional Neural Network. With the same number of samples and learning rate, Oyedotun changes the number of iterations and the number of hidden layers. Although the changes are only slight, the resulting effect is quite noticeable. In configuration 1, it takes 523 seconds of training with 14,400 iterations and 2 hidden layers. In configuration 2, it takes 620 seconds of training with 14,400 iterations and 3 hidden layers. In configuration 3, it takes 745 seconds of training with 20,000 iterations and 4 hidden layers. From here, we can see that the configuration can also affect performance. To get optimal results, the tuning process or some people might say hyperparameter optimization, can be done in this case. With the suitable configuration, the model could be trained in a less time and with good results.

Tuning in Machine Learning is an optimization problem. All that needs to do is to set the hyperparameters and to find the right combination of their values which can achieve either the minimum loss or the maximum accuracy. This is important to find the best Machine Learning model for a dataset [30].

V. Conclusions

Based on the analysis of all the literature collected, there is no definite formula for how a model can achieve the best results. There are many factors that affect performance, one of them is the method used. Using the right method can be the key that makes the model attain high performance. Trying to combine feature extraction and classifiers can be the right choice to get better performance. The choice of method also depends on what kind of dataset is used. Dare to try can be the key to get optimum configuration.

Hand gestures can be used as a medium of communication for persons with disabilities and hand gestures can also be used as input on a computer. Personal computers, smart phones, game consoles, and home devices like smart televisions are some examples of a computer that can be set to use hand gestures as input. In this paper, it is repeatedly mentioned that deaf and mute people have difficulty communicating with other people. This statement is enough to indicate that with today's technology it should be able to overcome this kind of problem. Hand gesture recognition can also be developed to other topics as well, apart from the two examples discussed in this paper.

From all the literature collected, all the models that are built have successfully recognized the image dataset very well. In addition, there is quite a lot of literature that discusses hand gesture recognition/sign language especially using image datasets even though most of them only use the alphabet. It shows that the power of today's machines is strong enough to handle it. Unfortunately, not many researches that uses video as dataset.

Since most of the literature in this paper uses the image dataset for training and testing, the future may be directed to use the video as a testing data. It would be even better if further research could detect hand gestures in real time. This makes sense because some literature that uses the American Sign Language dataset has difficulty detecting moving hand gestures such as the letters J and Z.

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