The Prototype of Hand Gesture Recognition for Elderly People to Control Connected Home Devices

Shalahudin Al Ayubi 1, Dodi Wisaksono Sudiharto 2, Erwid Musthofa Jadied 3 and Endro Aryanto 4

1234 School of Computing, Telkom University, Bandung 40257, Indonesia

Abstract. Nowadays, the technology development makes a human can create a tool which is used to recognize an object and it becomes a popular technology device. It happens because this tool has an important role for interaction between a human and a computer. One example of this technology usage is to recognize a hand gesture for controlling a home automation system. The existing of this technology creates the change related to how the human controls any tools in a house and it also reduces the complexity including an effort when it is used for controlling. This feature is very useful, especially for elderly people who stay in independent living. This study is going to develop a controller prototype by using FAST (Features from Accelerated Segment Test) algorithm to detect hand gesture for operating the connected home devices. This controller uses an embedded system to translate a command which is created by using the hand gesture of senior captured by the cam for controlling the lamps. The lamps itself are represented as several tools in the house. The observation gives a result that the hand gesture is potential to be implemented as a command for controlling the proposed system prototype in the range which is not far than 1 meter with the percentage average recognition accuracy is almost 80%.

1. Introduction

Object detection is one of the technologies which is related to a computer vision. This certain technology can be used to process an image, so it can be applied for detecting the object such as human, face, building, car, etc. That technology can be applied in any necessities such as for surveillance, image capturing, or home automation [1].

For elderly people who stay in independent living, an effort to do any daily activities such as starting entertainment equipment and room lighting can be done by using hand gestures [2]. This kind system is called as home automation system which is a technology that can automate the operation of any tools in the house. Frequently, that automation system covers any tool which are related to the daily human life, including the automation of home security devices [3] [4].

Based on related studies such as in [3] [5] [6] [7] [8], they have implemented a hand gesture detection. However, the studies do not use it for the home automation system as an implementation or as a system prototype. It can be said that the study related to the connected home device controlling by using hand gesture is still can be explored widely. So that, this study is going to make a home automation prototype which controls devices in the house and the senior user just uses the hand gesture to control it. The FAST algorithm as a feature extractor is selected because it has a good performance to detect a feature and is also suitable to implement in real time [6].
2. Related Works
There are several studies related to how to detect the hand gesture. The methods presented can be seen in the followed table:

| Reference | Method |
|-----------|--------|
| [9]       | Comparing several corner detection algorithms for finding the best one |
| [7]       | Using Haar-like features and also Canny Edges detector for hand tracking and gesture recognition which are used for Human-Computer Interaction |
| [5]       | Finding Convex Hull and Convexity Defects to recognize the hand gesture |
| [3]       | Using a stereo camera and processing the image step by step to detect the hand which is used for Human-Computer Interaction |
| [6]       | Matlab simulator is applied for hand gesture recognition processing by using a laptop |
| [8]       | Comparing SIFT and SURF algorithms by using bag of visual words |

In [9], several corner detection methods are compared to determine which one is the best for gesture detection. The corner detection methods compared are SUSAN (Smallest Univalue Segment Assimilating Nucleus) detector, IPAN (Image and Pattern Analysis group) detector and FAST (Features from Accelerated Segment Test) detector. The methods of IPAN, SUSAN, and FAST have good performance to detect the gesture. However, according to the processing time, the FAST is the fastest and it is suitable to be used for real-time application.

The next study, in [7], hand gesture detection and tracking are used for the interaction between a human and a computer such as for substituting the function of a mouse. The hand gesture in this study is divided into two steps which are Background Subtraction and Face Removal by using Haar-like features method. After that, edge segmentation is done by using Canny Edges detector, and then followed by skin color extraction. A palm center is detected after that, followed by fingertips determining, including recognizing a simple hand gesture. The assessment of this study is implemented by using several scenarios such as mouse cursor controlling, google earth navigation, fruit game, 3D viewer. All scenarios are measured by using 5 parameters which are fun, intuitive, accuracy, usability, and comfort. The result of the first trial gives the mean value of 61.33% and it is improved when the second trial is presented with the mean correctness of 86.66%.

In the next study which is [5], detection of simple hand gesture to move a robot is applied. Detection is carried out by using several stages such as taking pictures, after that blurring the frame by using the Gaussian blur technique, frame segmentation, contour drawing, and the last is looking for convex points to find the fingertips. The assessment which is implemented in this study is by actuating a robot with 5 commands. Then the robot is going to move such as going forward, backward, right, left, and stopping from a movement. The measurement of the experiment accuracy is 98%.

In [3], the interactive system design to detect hand gesture in three dimensions has been done by using 2 cameras. The detection technique used is divided into 6 steps. The first step is pre-processing.
It is done by converting the image color into grayscale. The second step is generating map depth. After that, the third step is skin processing. The fourth step is detecting and tracking the hand by using Haar-like and CAMshift algorithms. Then, the fifth step is hand contouring by using freeman chain. The last is finger detection. In this study, several assessment scenarios are implemented. Firstly, by navigating the cursor in 8 directions. The result is 93%. Secondly, is applying a zoom mechanism which gives a value of 93.75%. Lastly, the assessment result is 90% for mouse clicking. This study focus is how to develop an interactive navigation system and not to build a home automation system.

The next study, in [6], the hand gesture system for home automation is executed by using MATLAB. However, this study only presents that the proposed method which is more accurate than glove-based method without implementing it in the home automation system.

In [8], the performance study of SURF and SIFT algorithms is done. In this study, bag of visual words is used to form a feature and a descriptor which have been extracted into vector formation and support vector machine (SVM). Then they are used to recognize the hand gesture. The observation result shows that SURF algorithm reaches the accuracy of 88% by using international sign language alphabet data set. On the other hand, SIFT only has the accuracy of 19% with the same data set.

Then in [2], the Gesture Pendant is allowing older users to control home automation systems via hand gestures. Based on this study, it can be said that there is a potential issue related to the hand gesture for controlling connected home devices.

Based on the literature above, there are many methods which can be used to detect the gesture. However, there is only a little study which applies those methods by using Raspberry Pi as an image processor machine for home automation system studies, especially in independent living. The studies mentioned shows that Raspberry Pi is suitable for a home automation system. Furthermore, FAST algorithm can detect hand gesture and is also suitable to be used in the system for home automation. This reason because the fast and lightweight process for recognizing is needed

2.1. Feature Detection
Feature detection is a method which is used for making local decisions to every image points. It is used to determine whether the image has a feature which is needed to be processed or not. The feature detector including its classified feature which is applied can be seen in the followed table [10]:

| Reference             | Edge | Corner | Blob |
|-----------------------|------|--------|------|
| Canny                 | v    |        |      |
| Sobel                 | v    |        |      |
| Kayyali               | v    |        |      |
| Harris & Stephens / Plessey / Shi – Tomasi | v | v |      |
| SUSAN                 | v    | v      |      |
| Shi & Tomasi          | v    |        |      |
| Level curve curvature | v    |        |      |
| FAST                  | v    | v      |      |
| Laplacian of Gaussian | v    | v      |      |
| Difference of Gaussian| v    | v      |      |
| Determinant of Hessian| v    | v      |      |
| MSER                  | v    |        |      |
| PCBR                  | v    |        |      |
| Grey-level blob       | v    |        |      |
2.2. FAST Detector

FAST (Features from Accelerated Segment Test) detector can be said as a new algorithm which used to
detect the feature fast by using machine learning. It is proposed firstly by Edward Rosten and Tom
Drummond in 2006. Then it is revised by themselves in 2010 [11]. FAST detector has an ability to
execute its algorithm fast because it only needs a moderate level in the computation, so that it is suitable
to be implemented for real-time application.

As an example, for special pixels such as boundary, each pixel around the captured pixel is going to
be checked. If each continued pixel has a higher value or less value than the captured pixel then the pixel
is classified as corner [11]. It can be seen in the followed figure:

![Corner detection on the image](image)

**Figure 1.** Corner detection on the image

The box highlighted is the pixels used in the feature detection. Pixels at C is the center of the detected
angle and there is a dashed line which passes 12 adjacent pixels, and which is brighter than C, and which
exceeds the threshold. It means the FAST parameter value needs to be brighter or less than the query
pixels.

FAST detector result can be enhanced by creating repetition and making fit corner comparative.
This way can be said that machine learning can create a fast and a reliable detector.

2.3. OpenCV

OpenCV contains libraries which can be used for the certain functional program. It is developed
according to real-time computer vision application. In the first time, it is developed by Intel. After that,
it is continuously developed by Willow Garage which is a robotic research lab. Until now, it has been
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After that, it is continuous developed by Willow Garage which is a robotic research lab. Until now,
it has been maintained by Itseez. The libraries of OpenCV can be implemented in the cross-platform
system and is also a free source to be developed based on the BSD license [12].

2.4. Raspberry Pi

Raspberry Pi is a small single board computer which is developed in England by Raspberry Pi
Foundation to promote basic computer science study in United Kingdom and also in developed
countries. Nowadays, there are many models of Raspberry Pi such as Raspberry Pi I Model A and B,
Raspberry Pi 1 Model A+ and B+, Raspberry Pi 2, Raspberry Pi Zero, and the newest is Raspberry Pi 3
Model B and Raspberry Zero W.
The usage of Raspberry Pi becomes wider such as for education, home automation, industrial automation, including for commercial purposes.

3. Problem Definition
The study related to the hand gesture for controlling connected home devices is potential to elaborate widely because there are still a little number of studies which explore it. The existence of the hand gesture for controlling also has an advantage for elderly people because this certain controller can reduce the human effort, so the user can manage the devices touchless.

This study is going to observe the usage of the hand gesture for home automation. The specific users which are seniors are requested to know the performance of the proposed system which is going to be used, a distance metric and response time as parameters required are also going to be analyzed. Including, the ability of the system to prevent the detection of anomaly hand gesture which is not needed is also developed so that the system built is going to have a good performance.

4. Proposed System
The developed system uses a USB camera which is connected to Raspberry Pi 3 Model B as an embedded computer for capturing gestures. The embedded computer is equipped by OpenCV libraries which are used to recognize gestures and to convert it to be as commands to control lamps which are connected to a relay. The architecture of the proposed system can be seen in the followed figure:

![Diagram of Proposed System](image)

**Figure 2.** The proposed system prototype

Normally, the proposed system scheme which is described by using a flowchart can be seen in the next figure:
**Figure 3.** The data training of proposed system

**Figure 4.** The hand gesture recognition process
The figure shows that the system operation runs in two steps. Firstly, capturing a hand gesture image for a dataset. Secondly, doing a feature extraction by using FAST algorithm to make it becomes vectors. Thereafter, doing a training by using the dataset based on the data which is captured before. Next, the real-time hand gesture data is recorded for hand gesture recognition with indoor light level in the range 100-300 lux which is light level for normal activities in the indoor places [13].

The process of hand gesture recognition is done by using Raspberry Pi. The comparison between the feature of real-time data and the trained support vector machine data is executed by using FAST algorithm for matching the similarity. When the matched hand gesture data is found then the Raspberry Pi is going to process a translation for running a command to the device related to the specific command which is fit with the recognized hand gesture.

4.1. Hand gesture pattern design
The hand gesture patterns which are utilized for giving commands to any devices from the system can be discovered by following the next table:

| Hand gesture | Name                        | Action                                                                 |
|--------------|-----------------------------|------------------------------------------------------------------------|
| Open hand    | Selecting device 1          |                                                                        |
| Love hand    | Selecting device 2          |                                                                        |
| Pistol hand  | Turning on the selected     | Turning on the selected device and release device selection            |
|              | device and release          |                                                                        |
|              | device selection            |                                                                        |
| Point up hand| Turning off the selected    | Turning off the selected device and release device selection          |
|              | device and release          |                                                                        |
|              | device selection            |                                                                        |

The four lamps represent two devices. The lamp of 1a and 2a are used as device selection for handling Parkinson [14]. The other ones act as the device which is going to be turned on or off by the user.

4.2. The assessment scenarios
The assessment is performed to explore the proposed system performance. The parameters which are applied for the observation can be read on the followed explanation.
4.2.1. Discovering a command accuracy by applying hand gesture recognition.
The experiment is done by 30 old people. Each person is requested for making a specific hand gesture pose. Afterward, the system is going to recognize that gesture. It is executed to know whether the hand gesture can be recognized or not without any presented obstacles at all.

4.2.2. Discovering a command accuracy by using hand gesture recognition in a certain range.
Each hand gesture pose is shown by using 30 seniors. The variation ranges between the pose and the camera are presented such as 0.5 meters, 1 meter, and 2 meters. This study is executed to explore whether the hand gesture can be recognized or not by the existing of obstacles in different range values.

5. Analysis and discussion
For discovering a command accuracy, there are captured data which can be shown by the followed table:

| User | G-1 | G-2 | G-3 | G-4 | User | G-1 | G-2 | G-3 | G-4 |
|------|-----|-----|-----|-----|------|-----|-----|-----|-----|
| 1    | √   | ×   | √   | ×   | 16   | √   | √   | √   | √   |
| 2    | √   | √   | √   | ×   | 17   | √   | √   | √   | √   |
| 3    | √   | √   | ×   | √   | 18   | √   | √   | √   | √   |
| 4    | √   | √   | √   | √   | 19   | √   | √   | √   | √   |
| 5    | √   | √   | √   | √   | 20   | √   | √   | √   | ×   |
| 6    | √   | √   | √   | √   | 21   | √   | √   | √   | √   |
| 7    | √   | √   | √   | √   | 22   | √   | √   | √   | √   |
| 8    | √   | √   | √   | √   | 23   | √   | √   | √   | ×   |
| 9    | √   | √   | √   | √   | 24   | √   | ×   | √   | √   |
| 10   | √   | ×   | √   | ×   | 25   | √   | ×   | √   | √   |
| 11   | √   | √   | √   | √   | 26   | √   | √   | √   | √   |
| 12   | √   | √   | √   | √   | 27   | √   | √   | √   | √   |
| 13   | √   | √   | √   | √   | 28   | √   | √   | √   | ×   |
| 14   | √   | ×   | √   | ×   | 29   | √   | √   | √   | ×   |
| 15   | √   | √   | √   | √   | 30   | √   | √   | √   | √   |

The headers shown can be represented as:

- G1 = open hand (gesture 1)
- G2 = love hand (gesture 2)
- G3 = pistol hand (gesture 3)
- G4 = point up hand (gesture 4)

Based on the captured data above, the proposed system accuracy for open hand gesture recognition (G1) gives a value of 100%. Next, for love hand gesture recognition (G2) shows a value of 83.3%. Then followed by pistol hand gesture recognition (G3) presents a value of 100%. Lastly, the point up hand gesture has a value of 66.6%.

It can be said that the average recognition accuracy of all hand gestures is 87.5% which means that those gestures are potential for being implemented as commands to control the system and the system works properly.

For determining a command accuracy by using a variety of ranges as obstacles, there are captured data which can be seen in the next table:
Table 5. Hand gesture recognition in 0.5 meters of range

| User | G-1 | G-2 | G-3 | G-4 | User | G-1 | G-2 | G-3 | G-4 |
|------|-----|-----|-----|-----|------|-----|-----|-----|-----|
| 1    | ✓   | ×   | ✓   | ×   | 16   | ✓   | ✓   | ✓   | ✓   |
| 2    | ✓   | ✓   | ✓   | ×   | 17   | ✓   | ✓   | ✓   | ×   |
| 3    | ✓   | ✓   | ✓   | ✓   | 18   | ✓   | ✓   | ✓   | ✓   |
| 4    | ✓   | ✓   | ✓   | ✓   | 19   | ✓   | ✓   | ✓   | ✓   |
| 5    | ✓   | ✓   | ✓   | ×   | 20   | ✓   | ✓   | ✓   | ×   |
| 6    | ✓   | ✓   | ✓   | ✓   | 21   | ✓   | ✓   | ✓   | ✓   |
| 7    | ✓   | ✓   | ✓   | ✓   | 22   | ✓   | ✓   | ✓   | ✓   |
| 8    | ✓   | ✓   | ✓   | ✓   | 23   | ✓   | ✓   | ✓   | ×   |
| 9    | ✓   | ✓   | ✓   | ✓   | 24   | ✓   | ×   | ✓   | ✓   |
| 10   | ✓   | ×   | ✓   | ✓   | 25   | ✓   | ×   | ✓   | ×   |
| 11   | ✓   | ✓   | ✓   | ✓   | 26   | ✓   | ✓   | ✓   | ✓   |
| 12   | ✓   | ✓   | ✓   | ✓   | 27   | ✓   | ✓   | ✓   | ✓   |
| 13   | ✓   | ✓   | ✓   | ✓   | 28   | ✓   | ✓   | ✓   | ×   |
| 14   | ✓   | ×   | ✓   | ✓   | 29   | ✓   | ✓   | ✓   | ✓   |
| 15   | ✓   | ✓   | ✓   | ✓   | 30   | ✓   | ✓   | ✓   | ✓   |

Based on the captured data above, the proposed system accuracy in 0.5 meters of range for open hand gesture recognition (G1) displays a value of 100%. Next, for love hand gesture recognition (G2) presents a value of 83.3%. Then followed by pistol hand gesture recognition (G3) shows a value of 100%. Finally, the point up hand gesture has a value of 66.6%.

It can be said that the average recognition accuracy of all hand gestures is 87.5% in 0.5 meters which means that those gestures are still potential for being implemented as commands to control the system and the system works properly if the range between the pose and the camera is 0.5 meters.

Table 6. Hand gesture recognition in 1 meters of range

| User | G-1 | G-2 | G-3 | G-4 | User | G-1 | G-2 | G-3 | G-4 |
|------|-----|-----|-----|-----|------|-----|-----|-----|-----|
| 1    | ✓   | ✓   | ✓   | ×   | 16   | ✓   | ✓   | ✓   | ×   |
| 2    | ✓   | ✓   | ✓   | ×   | 17   | ✓   | ×   | ✓   | ×   |
| 3    | ✓   | ✓   | ✓   | ✓   | 18   | ✓   | ✓   | ✓   | ✓   |
| 4    | ✓   | ×   | ×   | ✓   | 19   | ✓   | ✓   | ✓   | ✓   |
| 5    | ✓   | ×   | ✓   | ✓   | 20   | ✓   | ✓   | ✓   | ×   |
| 6    | ✓   | ✓   | ✓   | ✓   | 21   | ✓   | ✓   | ✓   | ×   |
| 7    | ✓   | ✓   | ✓   | ✓   | 22   | ✓   | ✓   | ✓   | ✓   |
| 8    | ✓   | ✓   | ✓   | ✓   | 23   | ✓   | ×   | ✓   | ✓   |
| 9    | ✓   | ✓   | ✓   | ✓   | 24   | ✓   | ×   | ✓   | ✓   |
| 10   | ✓   | ×   | ✓   | ✓   | 25   | ✓   | ×   | ✓   | ×   |
| 11   | ✓   | ✓   | ✓   | ✓   | 26   | ✓   | ×   | ✓   | ✓   |
| 12   | ✓   | ✓   | ✓   | ✓   | 27   | ✓   | ×   | ✓   | ✓   |
| 13   | ✓   | ✓   | ✓   | ✓   | 28   | ✓   | ×   | ✓   | ×   |
| 14   | ✓   | ×   | ✓   | ✓   | 29   | ✓   | ✓   | ✓   | ×   |
| 15   | ✓   | ✓   | ✓   | ✓   | 30   | ✓   | ✓   | ✓   | ✓   |

The proposed system accuracy in 1 meter of range for open hand gesture recognition (G1) presents a value of 100%. Next, for love hand gesture recognition (G2) displays a value of 70%. Then followed by pistol hand gesture recognition (G3) exposes a value of 90%. In the end, the point up hand gesture has a value of 56.7%.
So that the average recognition accuracy of all hand gestures is 79.1% in 1 meter which means that those gestures are also potential for being implemented.

The result is different when the range used as the obstacle is more than 1 meter such as 2 meters. All hand gestures cannot be detected. So that it can be said that this range is impossible to be implemented for the proposed system to recognize all hand gestures.

6. Conclusion
In this study, a hand recognition system prototype has been presented with a locking mechanism. This mechanism is important for a senior who has Parkinson or a little of it to execute commands related to turn on or off the device properly. The proposed system is potential for being implemented based on an average accuracy of 87.5% in 0.5 meters and 79.1% in 1 meter. However, in the range of more than 1 meter, it cannot detect any hand gestures at all. It happens because the feature of real-time data cannot be captured and recognized accurately by the camera as a feature which can be compared with trained SVM data.

For future work, a better camera which can differentiate between the dark-side and the light-side of the image can be used to enhance the observation result. A larger dataset also can be used to improve the results since this study only used 30 pictures for each gesture.

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