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Pan-Tilt Modelling for Face Detection

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Abstract. Object detection is one of the important application in the surveillance system. In system design, a model is needed to be used for the compensator design process. The black-box modeling method is used so that we can get the mathematical model of the plant without using physics laws, while it is used an experimental approach so that it takes input and output data from the open-loop system response. In modeling the system, two datasets are required to estimate the model and validate the data. In the process, Arduino Mega controller commanded to transmit Pulse Width Modulation (PWM) signals on the pan and tilt servo motors. The command sets motion to pan and tilt systems which installed a camera in it, and the dataset retrieval process can be performed. In this case, the PWM signal as input and the center coordinates of the face (pixels) as outputs based on the viola jones method for the image processing of the open-loop system. The results of the mathematical model of the system show that the data obtained is quite accurate, it is proved from the estimation and data validation that has been done.

1. Introduction

Rapid technology advancement leads to the systems that can simplify human works in their daily activities [1, 2]. On the existing science and technology, one of them namely expert system. It is a system attempting to adopt human knowledge to computers designed to solve certain problems [3-6]. Tracking objects are one of the expert system features conducted through image analysis [7], which is developing lately. One of its applications is in security system such as surveillance where humans are the objects [8].

One part of object tracking is facial detection. There are some methods developed in face detection applications, one of them is Viola-Jones. It is considered one of the most frequently-used applications since it is easy to implement [9].

To be able to detect faces well, the performance of the system should be outstanding, it has to be able to cope with various obstacles which will affect the system. One of the possible solutions to this problem is modeling of pan and tilt using a camera to design compensator system [10].

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2. Methodology

To obtain modeling of the face detection, this paper use black-box method so that an approach using physics laws is not necessary for having the mathematical model of the system [11]. It is believed that designing is a series of processes based on basic theories in sharing ideas [12]. In this context, the planning of face detection modeling using Viola-Jones model starts from making a diagram of the system performance, flowchart, data collection, data analysis, input, and output system using the identification tools in Matlab.

3. System design

3.1. Diagram of the system performance

On pan and tilt system, to detect faces, there are two sub-systems working independently to control the movement of the pan and tilt as well as process the algorithm of face detection. To control the movement of the pan and tilt, Arduino Mega with a microcontroller AVR type ATMega2560 with a control board is used. Meanwhile, for the face detection, a software namely Python IDLE run on a PC is used. The data series communication interface is used to connect the PC and main controller. Figure 1 describes the whole processes of the data communication among the hardware used.

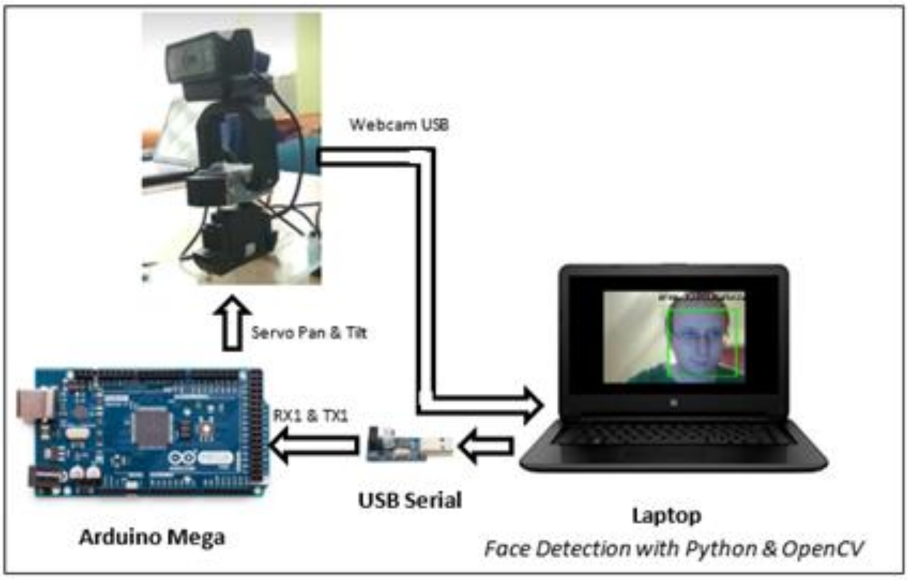

Figure 1. System performance diagram.

3.2. Flowchart

Modeling of the system in this study employs an experimental approach. The response results of the open loop system in the process are obtained from the data input and output of the system. To estimate and validate the model, two datasets are needed in the process of the modeling [13]. The objects (human faces) are placed around 10 cm from the camera and should be in the window frame (320x240). Ardunio is used as a controller which gives Pulse Width Modulation (PWM) signal on motor servo of the pan-tilt in two conditions: high and low. The movement speed of the servo should be controlled accordingly so that the reading process of the system can be effectively done. The input of the system is PMW signal, and the output is facial center coordinate (pixels) for the open loop system. The steps of the modeling system are described in Figure 2.

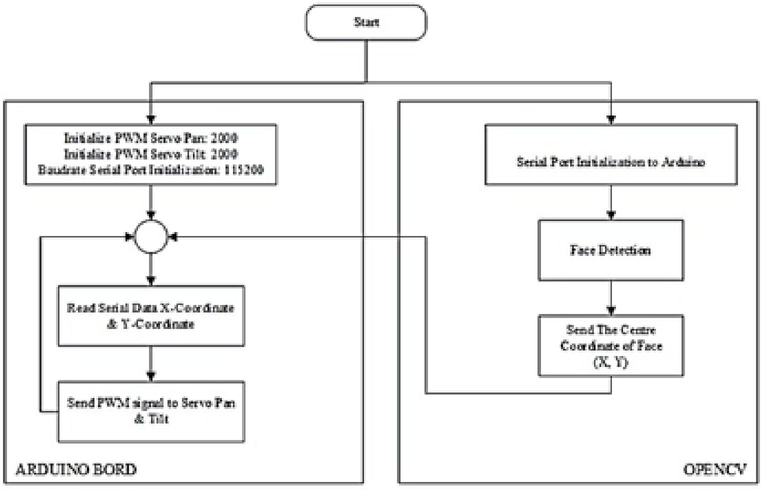

Figure 2. System flowchart.

3.3. System data collection

System data collection on pan and tilt using a camera is done using the 10-cm distance between the objects and the camera. The data are PWM signal to be input to the system and a facial coordinate (pixels) as the output of the system which will be later processed in Matlab. The data collection of the real facial construction for the system modeling is shown in Figure 3.

Figure 3. Data collection construction of pan and tilt with a camera.

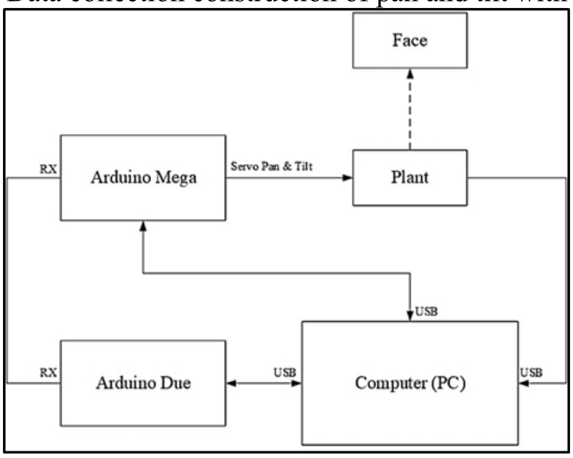

Figure 4. A series of data collection processes of pan and tilt with a camera.

Two pieces of Arduino are used as alternatives if there is no USB data series. Arduino Mega functions to give PWM input signal on servo motor on pan and tilt, while Arduino Due is used to send the data of facial coordinates (pixels) as the output through Universal Serial Bus (USB) of the PC to Arduino Mega. The Pin used to connect the Arduino boards is RX pin [14]. Figure 4 presents the steps used in the calculation process.

The program used in Arduino Mega board is tracking RTOS for image processing by reading two datasets in the part of pan and tilt [15]. From the Arduino monitor projected on the PC monitor, the data time sampling and the facial coordinates detected as pixels as the results of the camera capture will be analyzed in Matlab.

3.4. System identification process

The process of identification in the system is carried out using an identification tool in Matlab. The input is in the form of PWM signal, and the output is pixel data as a result of face detection coordinates by the camera.

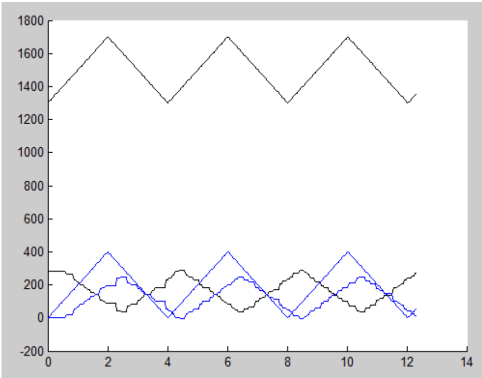

Figure 5. Plot result of pan data.

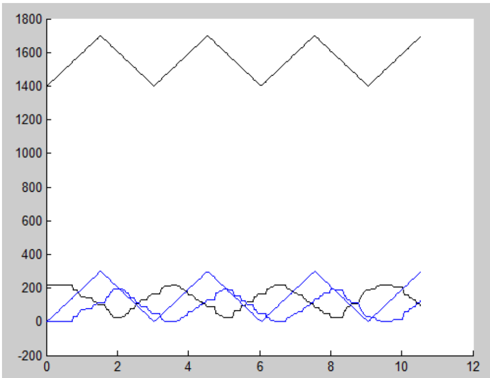

Figure 6. Plot result of tilt data.

The plotted result of pan data in Figure 5 and that of tilt data in Figure 6 show that the blue plot is PWM data and the position in the pixel (1400) for the vertical axis of the Matlab coding. Thus, the results of the plot are at point zero, while the black plot is the original data. There is a delay for around a half second on the plot results of the pixel position. This is due to the delay of the camera when detecting faces.

4. Results and discussion

Modeling on the system has two functions on the pan and tilt. From the results of the modeling, there will be data estimation and validation and further analysis to make sure whether the results of the mathematical model measurement are as expected [16].

4.1. System mathematical model

From the results of system identification using one of the tools in Matlab, a mathematical system model is obtained. The model is a transfer function continuously for pan and tilt as follows.

a. Pan transfer function with camera

$$TF = \frac{6.602}{s^2 + 3.969\,s + 10.63} \tag{1}$$

b. Tilt transfer function with camera

$$TF = \frac{4.838}{s^2 + 2.606\,s + 8.107} \tag{2}$$

4.2. Data estimation

To estimate the data on the system model of pan and tilt, an identification toolbox in Matlab is used. For optimizing the iteration process, the method used is Non-linear Least Square (NLS) with the default control.

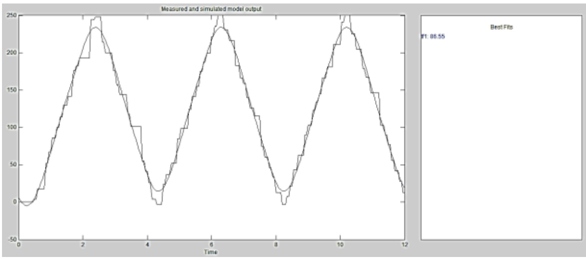

Figure 7. Results of pan data estimation with camera.

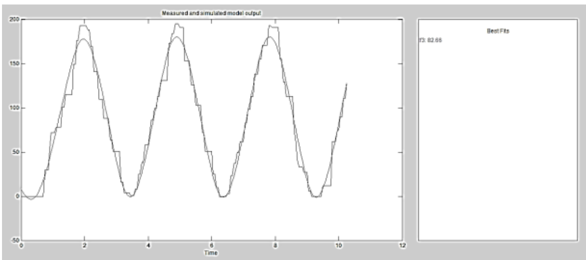

Figure 8. Results of tilt data estimation with camera.

Figure 7 and Figure 8 present the data estimation results using an identification toolbox in Matlab. Both figures show that the dynamic system can be followed by the results of the data estimation. The estimation process is proven to have more percentage on the pan system (86.55%) rather than the tilt system (82.66%). In the next phase, the validation process will take place to verify the results of the modeling with quite accurate results of the estimation in comparison with the other datasets.

4.3. Data validation

Data validation is conducted using coding in Matlab to compare the transfer function acquired with the original data [17]. As the results of the data estimation, Figure 9 shows that pan system performs better best fit validation in comparison with the tilt system.

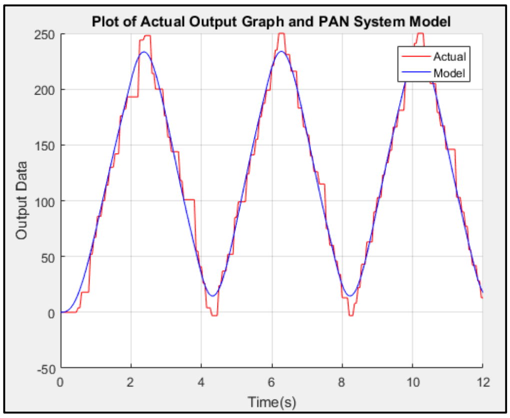

Figure 9. Results of pan data validation with camera.

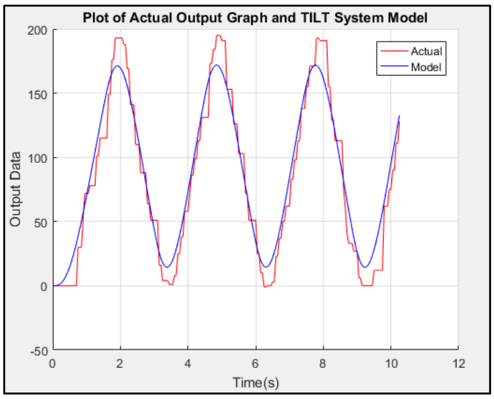

Figure 10. Results of tilt data validation with camera.

5. Conclusions and recommendation

From the results of the modeling, it can be concluded that in the process of data collection, a series of data are needed to connect the control system with the PC. From the data estimation and validation system, it can be said that the system has a good best fit even though it is less than 90%. This is due to the less-fitting mechanic of the system and the low specification of the hardware used. In the meantime, it is recommended that there is no delay in the data collection to have more accurate data so that the system modeling can be better.

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