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Body Motion Auto Tracking Camera System for Online Class Education Supporting Device Using OpenCV and Microcontroller

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Abstract

In the online teaching process, a teacher is necessary to describe the material clearly and have a broad perspective so that the material can be delivered completely. The problem occurs because the camera has different viewing angles, which results in limited movement of people who are teachers whenever explain material on a broad chalkboard. For this reason, a motion tracking camera is designed like a common camera that can move to follow the teacher's upper body. The camera will be connected to servo motors such as MG996R to move the camera on the X-Axis and Y-Axis. Then with OpenCV technology, the camera will track the teacher as an object and follow the direction of his/her movement. The results from this research, it is concluded that by integrating Python into a video conference application and without it, the system can detect the upper body at 2-6 meters. For the X-Axis servo motor angle for conditions using video conference and without video conference application, the servo can rotate by detecting the upper body at angles of 30deg, 60deg, 90deg, 120deg, and 150deg. Then on the Y-Axis movement, it can rotate by detecting the upper body at 90deg, 100deg, 110deg, 120deg and 130deg angles. The test was carried out in a room with an area of 9.1 m x 7.4 m, the light condition of the room was 116 lux the object height was 1.5 m, and the camera height was 0.8 m above the floor.

Keywords

Motion tracking camera, OpenCV, Upper body.

Introduction

Indonesia confirmed the presence of positive coronavirus (Covid-19) cases, leading to a rapid surge in numbers and prompting WHO to declare a global pandemic on March 11, 2020. In response, Indonesia implemented Large-Scale Social Restrictions (PSBB) and closed schools, enforcing an online learning system nationwide starting March 16, 2020.

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The online education system is a learning method where students and teachers do not meet face-to-face, but rather through the internet and digital media to deliver material. Teachers must ensure that the teaching and learning process continues even though students stay at home. Therefore, teachers are required to design innovative learning media using online platforms. This is in accordance with the circular letter from the Minister of Education and Culture of the Republic of Indonesia No. 4 of 2020 regarding the implementation of learning policies during the emergency period of the coronavirus disease (Covid-19) spread.

Previous research on MOTChallenge highlights the importance of standard benchmarks for improving computer vision algorithms, focusing on multi-person tracking with applications in robotics and autonomous (Dendorfer et al., 2021). Another study on OpenCV-based face detection in low-light conditions tested the Viola-Jones algorithm, finding 50 Lux provided the best results with 99.2% accuracy. Face detection effectiveness was influenced by the camera and face rotation, crucial for highlight environments (Julham et al., 2023).

Based on the explanation above, to assist in the online presentation of materials, an instructor needs to present the material clearly and have a broad perspective to fully deliver the content. The issue arises because the camera has a limited field of view, restricting the instructor's movement and explanation on a wide whiteboard. Therefore, a camera with a movable mount designed to follow the instructor's upper body has been developed. This camera will be connected to components such as two MG996R servos to move the camera in the X-Axis and Y-Axis. Utilizing OpenCV technology, the camera will detect the instructor as an object and automatically follow the direction of the upper body's movement.

Methodology

On the camera mount, a U-shaped bracket servo component is used as a connector between the MG996R servos and the USB camera. The MG996R servos act as the camera mount, which will move to follow the instructor's upper body. Here, 2 servos are used for rotation from left to right (X-Axis) and rotation from top to bottom (Y-Axis). The microcontroller used is an Arduino Uno. Input to detect the upper body is done using OpenCV.

Figure 1. System Block Diagram

Arduino will receive messages via USB to control the hardware. The camera is internally connected to the system, and the system processes each frame to track the upper body. The computer will run upper body detection (OpenCV) from the camera and send commands to the microcontroller to follow it. Furthermore, it is integrated into video conferencing via the SplitCam software. The equipment design stage begins with searching for training data in the form of samples used for the datasheet in the training process in the Cascade Trainer GUI application, with the output training file in XML format so that Python can identify the coordinates after tracking the upper body and then send them to Arduino, which will subsequently be received by the servo.

The desired outcome is for the servo to move according to these coordinates. Then, configuring the video capture to SplitCam to integrate it into the video conference.

Cascade Classifier is a classification method that uses multiple stages. Each stage performs selection using the AdaBoost algorithm, which is trained using Haar-like features. The Cascad Classifier process is shown in Figure 2. The purpose of the selection is to separate sub-windows that contain positive objects (images detected to have the desired object) from negative objects, where the selection results are used as input for the next stage of selection.

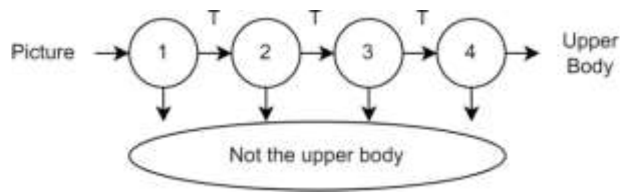

Figure 2. Cascade Classifier Method

The Cascade Classifier will classify by discarding sub-windows that contain a black background. At the second stage, the sub-windows that were discarded in the initial stage are re-detected to obtain more specific criteria. In the subsequent stages, classification is carried out for objects in the shape of the upper body. The training mode is conducted using the Cascade Trainer GUI software. The object to be detected in this design is the upper body. The upper body part refers to the upper body such as the arms, chest, shoulders, and facial area. In this design, 300 positive samples and 300 negative samples are used. Positive image samples are images of the object to be classified and subsequently detected, while negative samples can be any images that do not contain any positive image parts. Then, manually group the positive image datasheets and negative image datasheets and save them in their respective folders, with each sample sequentially numbered. Creating datasheets is necessary to obtain the upper body data to be recognized.

After training the model, the next step is to detect the upper body using the XML training output recognized by OpenCV. When detected, the frame marks the object area and sends the coordinates to Arduino. The tracking system, implemented in Visual Studio Code with Python, outputs coordinates that appear on the monitor and are sent to Arduino to move the servo motor.

The Motion Tracking Camera design uses servos as camera mounts to move the camera based on coordinate points from upper body detection. There are two servos: servo-x for the X-Axis and servo-y for the Y-Axis. Arduino receives coordinates from Python and commands the servos to move accordingly. Initially, the servo library is inputted, and servo coordinates and positions are configured. Each servo adjusts its position based on the given coordinates. The MG996R servos connect to Arduino Uno using male-to-male jumper wires, with data pins connected to pins 9 and 10, and power supply connections to GND and 5V.

The mechanical system design includes two MG996R servos, a multi-servo bracket, and a U-shaped servo bracket. An aluminum board is shaped to securely hold the servos. The first servo controls vertical (Y-Axis) movement, while the second controls horizontal (X-Axis) movement. The webcam communicates via USB, and both servos are controlled by the Arduino Uno microcontroller.

Results and Discussion

Figure 3. shows the result of the motion tracking camera tool design. The analysis simulation results for testing the tool have been carried out using this device. At the bottom mount, there is a microcontroller and servo as the USB camera holder.

Figure 3. Motion Tracking Camera

The object detection range test was conducted to determine how far the camera can detect the upper body without video conferencing. All tests were carried out in room G10 of the Communication Systems Laboratory at the Faculty of Applied Sciences, with a room size of 9.1 m x 7.4 m and light intensity condition of 116 lux. The test involved positioning a human-sized object with a height of 150 cm in front of the camera, with the camera height set at 0.8 m. Subsequently, the object stood at predetermined distance points directly in front of the camera. The results of the object detection range test without using video conferencing in an indoor environment with a light intensity condition of 116 lux can be concluded that the system cannot detect the upper body at 1 meter because the object on the monitor is not an upper body, and the system can detect the upper body at distances of 2-6 meters. In Figure 4. a sample of video with and without tracking is shown.

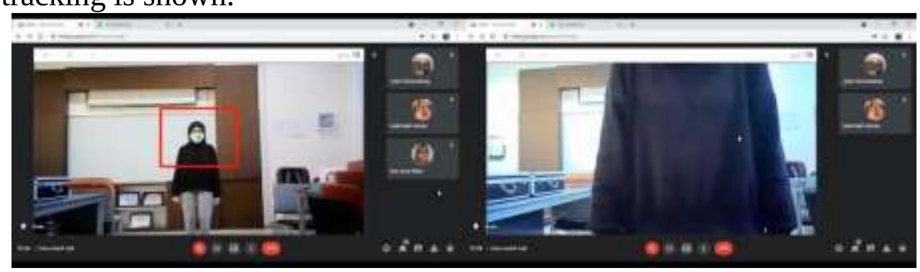

Figure 4. Sample of video with and without tracking

Object detection range testing was conducted to determine how far the camera can detect the upper body using video conferencing. The video communication service used was Google Meet. The test involved positioning a human-sized object with a height of 150 cm in front of the camera, with the camera height set at 0.8 m. Subsequently, the object stood at predetermined distance points directly in front of the camera. The results of the object detection range test using video conferencing in an indoor environment with a light intensity condition of 116 lux can be concluded that the system cannot detect the upper body at 1 meter because the object on the monitor is not an upper body, and the system can detect the upper body at distances of 2-6 meters.

The motor tracking angle testing aims to determine the accuracy of servo motor rotation without using video conferencing and with the use of video conferencing. The testing was based on the distance from the camera to the object by measuring the servo motor rotation angles along the X-Axis and Y-Axis, where the servo rotation is based on the detected object. The distance data was obtained from the object detection range testing, with the camera positioned at a height of 0.8 m and the object having a height of 150 cm. In the column where the object is detected and the servo rotates according to its angle, a checkmark (v) will be given, and in the column where the object is not detected and the servo does not rotate according to its angle, a cross (x) will be given. The results of the servo motor angle testing along the X-Axis can be seen in Table 1.

Table 1. Results of the X-Axis servo motor angle testing

Distance between the camera and the object	Degree of Angle									
	Without video conferencing					Video conference				
	30^o	60^o	90^o	120^o	150^o	30^o	60^o	90^o	120^o	150^o
1	x	x	x	x	x	x	x	x	x	x
2	v	v	v	v	v	v	v	v	v	v
3	v	v	v	v	v	v	v	v	v	v
4	v	v	v	v	v	v	v	v	v	v
5	v	v	v	v	v	v	v	v	v	v
6	v	v	v	v	v	v	v	v	v	v

The motor tracking angle testing aims to determine the accuracy of servo motor rotation without using video conferencing and with the use of video conferencing. The testing was based on the distance from the camera to the object by measuring the servo motor rotation angles along the X-Axis and Y-Axis, where the servo rotation is based on the detected object. The distance data was obtained from the object detection range testing, with the camera positioned at a height of 0.8 m and the object having a height of 150 cm. The results of the servo motor angle testing along the X-Axis can be seen in Table 2.

Table 2. Results of the Y-Axis servo motor angle testing

Distance between the camera and the object	Degree of Angle									
	Without video conferencing					Video conference				
	90^o	100^o	110^o	120^o	130^o	90^o	100^o	110^o	120^o	130^o
1	x	x	x	x	x	x	x	x	x	x
2	v	v	v	v	v	v	v	v	v	v
3	v	v	v	v	v	v	v	v	v	v
4	v	v	v	v	v	v	v	v	v	v
5	v	v	v	v	v	v	v	v	v	v
6	v	v	v	v	v	v	v	v	v	v

The results of the testing are in Table 2. can be concluded that the servo can rotate along the Y-Axis following the direction of the detected object, both without using video conferencing and using video conferencing, according to the angle.

Conclusion

Based on the results of the design made, the following conclusions in this project, a motion tracking camera system has been designed that can detect the upper body and then move along the X-Axis and Y-Axis according to the movement of the upper body. The motion tracking camera uses a USB camera, 2 MG996R servos as camera mounts, and an Arduino Uno to control the hardware. Based on the testing and analysis conducted, it is concluded that in the object detection range testing using video conferencing and without using video conferencing, the system can detect the upper body at distances of 2-6 meters. In the servo motor angle testing along the X-Axis for both conditions using video conferencing and without video conferencing, it is concluded that the servo can rotate while detecting the upper body at angles of 30^o, 60^o, 90^o, 120^o, and 150^o. Then, for the Y-Axis, under both conditions using video conferencing and without video conferencing, it is concluded that the servo can rotate while detecting the upper body at angles of 90^o, 100^o, 110^o, 120^o, and 130^o.

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