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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

OBJECT DETECTING GIMBAL USING CAMERA AND SERVOS

TECHNICAL SEMINAR REPORT

Submitted by

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Under the guidance of
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RV College of Engineering®

In partial fulfilment for the award of degree
Of
Bachelor of Engineering
In
Electrical and Electronics Engineering
2019-2020

RV COLLEGE OF ENGINEERING®, BENGALURU-59

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CERTIFICATE

Certified that the Technical Seminar work titled ***'Object detecting gimbal using camera and servos',*** carried out by **Yashas B K (1RV17EE412),** the bonafide student of RV College of Engineering®, submitted in partial fulfilment for the award of degree of **Bachelor of Engineering in Electrical and Electronics Engineering** of the Visvesvaraya Technological University, Belagavi, during the year 2019-2020. It is certified that all corrections/suggestions indicated for the Internal Assessment have been incorporated in the technical seminar report deposited in the departmental library. The technical report has been approved as it satisfies the academic requirements in respect of technical seminar work prescribed by the institution for the said degree.

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Dr. Sridevi A	**Dr. Rudranna Nandihalli**

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DECLARATION

I, Yashas B K student of eighth semester B.E., Department of Electrical and Electronics Engineering, RV College of Engineering®, Bengaluru-59, bearing **USN: 1RV17EE412** hereby declare that the technical seminar titled ***'Object detecting gimbal using camera and servos'*** has been carried out by me and submitted in partial fulfilment for the award of degree of **Bachelor of Engineering** in **Electrical and Electronics Engineering** during the year 2019-20.

Further, we declare that the content of the dissertation has not been submitted previously by anybody for the award of any degree or diploma to any other university.

Place: Bengaluru

Date:

Name	**Signature**
1. Yashas B K (1RV17EE412)	

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Abstract

Gimbals are typically used in aerial vehicles to attenuate vibrations and stabilize the camera in the presence of angular motion of the vehicle and other disturbances. Autonomous target tracking using a camera/gimbal combination is an extremely important functionality for vision enabled robotic systems, e.g., in autonomous cinematography/intelligent shooting applications. Gimbals effectively hit the Field of View (FOV) of the camera through angular motion. FOV constraints are more complex and difficult when the stabilization and tracking is involved.

An extensive literature survey has been conducted to design and develop a servo mechanism for gimbal control. The conventional mechanism has bottle neck like limited angle, weight and instability. This makes the mechanism more slaggy and slow. The axis control in servo mechanism makes them feathery compared to conventional methods and also improve object stabilization with more precise control. The traditional gimbal control action during angular movement affects the optics leading poor tracking and identification of objects. The design of gimbal control mechanism races ahead in improving in control as well as stability.

The extensive study of gimbal control mechanism and object tracking is done with help of computer aided simulations like Solid works for designing housing of servo motor with enhanced stability. The other hand to hand software is MATLAB to develop algorithm for object tracking and detection. The computer aided simulation showed that the design is better for Gimbal operation. A hardware model has been developed with servo motor along with controller for tracking and detection. The object based stabilization is used, thanks to servo motors for its accurate stabilization and enhanced operation. The object tracking and detection is done with Viola-Jones based object tracking algorithm. The algorithm mainly works on time constraints for better and quick response of mechanism. The developed model has been tested from various points of view for good results. The module showed better performance in terms of accuracy and reliability.

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ACRONYMS:

Field Of View	-	FOV
Unmanned Air Vehicles	-	UAV
Miniature Aerial Vehicle	-	MAV
Intelligent Surveillance Reconnaissance	-	ISR
Region Of Interest	-	ROI
Computer Aided Design	-	CAD
Computer Aided Engineering	-	CAE
Integrated Development Environment	-	IDE
Pulse Width Modulation	-	PWM

CHAPTER 1
INTRODUCTION

CHAPTER 1

INTRODUCTION

Gimbals are normally utilized in aerial vehicles to stabilize the camera and attenuate the vibrations occurred due to angular movement and motor rotation. In addition, gimbals effectively covers the Field of View of the camera through angular motion, that is combined with translational motion to capture the required shooting position. This ability to reduce the FOV problems becomes more complex if tracking of moving object is included.

In fact, autonomous target tracking adopting a gimbal/camera combination is an extremely important function for vision based robotic systems, e.g., in self governing cinematography/ advanced photography applications. Achieving the goal of pointing the camera towards a target can be divided into two tasks. The first concerns visual object detection and tracking. This stage provides the image measurements that are used as input to the second module for controlling the gimbal so that the camera optical axis points in the desired direction.

Fig. 1.1: 3 axis drone gimbal

The past decade has exceptional growth in the application of remote controlled air vehicles. The fig. 1.1 shows the 3 axis drone gimbal used in modern drones for stabilizing the camera. Even though large UAV's are capable of performing complex mission, its availability is costly and limited. Thus development of low cost, small UAV (i.e. Miniature Aerial Vehicle) is increased. MAV are used for military and civil application. One of the major problems to small Unmanned Aerial Vehicle Intelligent Surveillance Reconnaissance systems is they are not capable of carrying a stabilized gimbal, that can deliver the stabilization performance required for high target resolution while the platform stays outside of its detection footprint.

In order to have stable gimbal, the target has to be locked to the camera. Target locking is the act of maintaining the target in the sensor's center field of view, under target motion. In order to achieve it, target is tracked continuously and to have the object in centre of image, the camera is moved in Pan and tilt direction according to target position in image.

1.1 Literature review

This paper addresses the problem of controlling the orientation of a 3-axis gimbal that is carrying a cinematography camera, using image measurements for feedback. The control objective is to keep a moving target of interest at the center of the image plane. A ROI that encloses the target's image is generated through the combination of a visual object detector and a visual object tracker based on Convolutional Neural Networks. These are specially tailored to allow for high frame rate performance with restricted computational power. Given the target's ROI an attitude error in the form of a rotation matrix is computed and a attitude controller designed guarantees convergence of the target's image to the center of the image plane. Experimental results with a human face as the target of interest are presented to illustrate the performance of the proposed scheme[1].

The development of an object tracking controller for a quadcopter using an on-board vision system is presented. Using low-cost components, a novel system is introduced that operates entirely on board the quadcopter, without external localization sensors or GPS. A low-frequency monocular computer vision algorithm is applied in closed-loop control to track an object of known color. Parallel PID controllers for aircraft bearing, relative height and range are implemented with feedback from object offset and size in the image frame. The noise exaggerated by measuring range from object pixel area is mitigated with a Kalman filter. Stable closed-loop tracking is demonstrated experimentally for all three control axes when tested individually and coupled together. Individual settling times were under 10 seconds and coupled control settling times under 25 seconds[2].

Detailed design of tracking system that enable a Micro Aerial Vehicle, equipped with a pan-tilt gimbaled camera to be stabilized and to track the target, with target asin center of image. The algorithm performs automatic tracking of target while camera gimbal is moved according to the target position in image. 2- Axis gimbal camera set up is made with servo motors and

FPV 10x zoom camera. Gimbal camera set up is integrated with APM and XBee to replicate real set up of MAV in laboratory. And it is controlled with GCS set up made of joystick, XBee, Matlab and Mission Planner software. Thus, closed loop for control of gimbal camera designed. Image processing algorithm is used to track the target and to compute the position of target in image. Accordingly, control algorithm will generate control PWM signal for control of camera gimbal[3].

1.2 Problem statement

The problem to be solved in this paper is the design of servo mechanism for gimbal action and include object detection for tracking the object.

1.3 Objectives

The objective of this work is to design and implement a mechanism to move the camera and to detect the object

- Development of an algorithm for detecting moving object from a video feed
- Design and development of pwm signals for the actuation of servos.
- To design and implement 2 axis servo mounts.

1.4 Methodology

The block diagram of the methodology of the effort is shown in fig. 1.1.

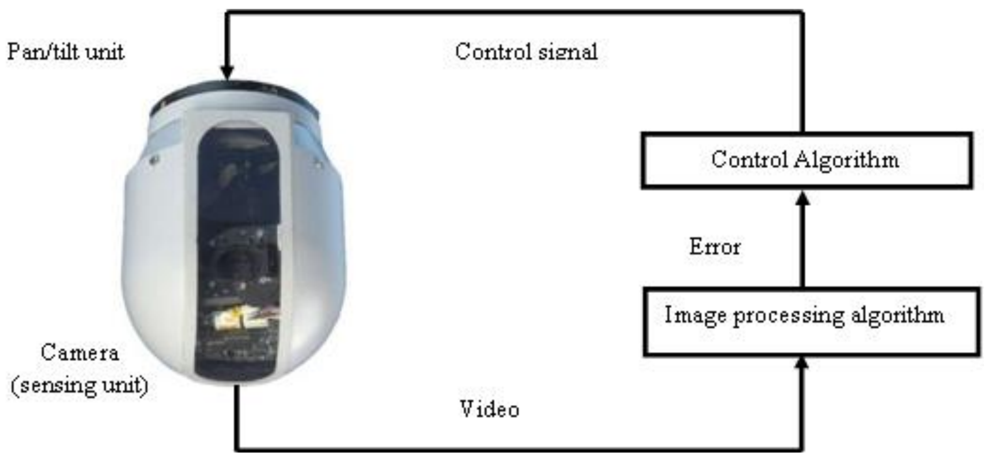

Fig. 1.1: Block diagram of methodology

Camera is used as a feedback unit for sending the image to the control algorithm. Video Frames captured from the camera are stored in the computer and further processed using matlab. In Image detection algorithm the object within the frame is detected i.e. whether the object is in the middle of the frame or not. If the object is not in the middle of the frame then the algorithm produces the corresponding error signal. The error signal is sent to the Arduino uno to produce corresponding pwm signals to drive servos that are holding the camera and the correction is applied. The error signal can be amplified using the constant multipliers, if specific response time is required.

1.5 Organization of the Report

Chapter 1: Consists of introduction, literature survey, objectives of the project, layout of the project and methodology.

Chapter 2: Explains the theory of gimbal and viola jones algorithm used for the detection of object in a frame.

Chapter 3: Explains the design of hardware and software required to successfully build a gimbal.

Chapter 4: Results are displayed; thus, validating the implementation of the proposed objectives in this chapter.

Chapter 5: Presents a brief conclusion about the project and insight into the future scope of the project.

CHAPTER 2

THEORY OF GIMBAL AND VIOLA JONES ALGORITHM

Chapter 2

THEORY OF GIMBAL AND VIOLA JONES ALGORITHM

A gimbal is a turned help that permits the pivot of an item about a solitary hub. A lot of three gimbals, one mounted on the other with symmetrical turn tomahawks, might be utilized to permit an item mounted on the deepest gimbal to stay autonomous of the revolution of its help. For instance, on a boat, the whirligigs, shipboard compasses, ovens, and even beverage holders regularly use gimbals to keep them upstanding regarding the skyline notwithstanding the boat's pitching and rolling. The fig. 2.1 shows the essential idea of Gimbal utilized in Ships.

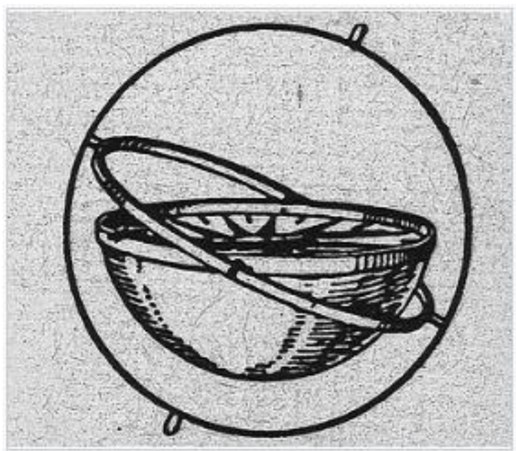

Fig. 2.1: Basic concept of Gimbal

Nowadays the gimbal mechanism is used in almost every modern devices. Even the mobile phone has a gimbal named gyroscope is electronic one having the same principle as the basic gimbal. The rockets use the same mechanism to maintain itself in certain angle while throttling. Our region of interest is regarding the use of gimbal mechanism in frame capturing technology.

2.1 Gimbal for the drone

A camera stabilizer, or camera–balancing out mount (Gimbal), is a gadget intended to hold a camera in a way that forestalls or makes up for undesirable camera development, for example, "camera shake”. For little hand-held cameras, a bridle or moulded edge steadies the camera against the picture taker's body. In certain models, the camera mount is on an arm that distends before the picture taker; underneath the camera is a handle hold. Another variety positions the camera on a support propped against the picture taker's chest or mid-region.

Fig. 2.2: Drone with Gimbal

The extent of this course focuses to the utilization of gimbal for the camera utilized in drones as appeared in fig. 2.2. Automatons being high force devouring vehicles need to utilize least weight and stuffed components to get all the more working occasions. An automation with a fixed camera flops in catching wide edge see or in any case catches foggy pictures as the automaton must turn to catch the wide zone. If there should arise an occurrence of security drones pointing on to a moving item is the primary enthusiasm for this case gimbal is a need. Naturally following an item will help the automaton administrator to follow the moving article effectively without missing it on account of human blunder. Up and coming parts shows the plan and execution of article distinguishing gimbal.

2.2 Viola Jones algorithm

Developed in 2001 by Paul Viola and Michael Jones, the Viola-Jones algorithm is an object-recognition framework that allows the detection of image features in real-time. Viola-Jones is quite powerful and its application has proven to be exceptionally notable in real-time face detection.

There are 2 stages in the Viola-Jones Algorithm:

1) Training
2) Detection

2.2.1 Training

The calculation recoils the picture to 24 x 24 and searches for the prepared highlights inside the picture. It needs a ton of facial picture information to have the option to see highlights in the extraordinary and fluctuating structures. Viola and Jones took care of the calculation 4,960 pictures (each physically named). For certain pictures, you can take care of the identical representation of a specific picture, that would be fresh out of the plastic new data for a PC.

Viola and Jones provided the calculation 9,544 non-facial pictures. Inside these, a few pictures may seem to be like highlights in a face, yet the calculation will comprehend that highlights are bound to be on a face and those highlights would clearly not be on a face.

2.2.2 Detection

Viola-Jones was intended for frontal countenances, so it can recognize frontal the best instead of faces looking sideways, upwards or downwards. Prior to identifying a face, the picture is changed over into grayscale, since it is simpler to work with and there's lesser information to process. The Viola-Jones calculation initially distinguishes the face on the grayscale picture and afterward finds the area on the hued picture.

Viola-Jones diagrams a container and looks for a face inside the case. It is basically looking for these haar-like highlights. The case moves a stage to one side in the wake of experiencing each tile in the image. With smaller steps, a number of boxes detect face-like features and the data of all of those boxes put together, helps the algorithm determine where the face is.

2.2.3 Haar-like Features

Haar-like features are named after Alfred Haar, a Hungarian mathematician in the 19th century who developed the concept of Haar wavelets The features below show a box with a light side and a dark side, that is how the machine determines what the feature is. Oftentimes one side will be lighter than the other, as in an edge of an eyebrow. In images the middle portion may be shinier than the surrounding boxes, that can be interpreted as a nose. The fig. 2.3 shows the Haar-like features used in viola jones algorithm.

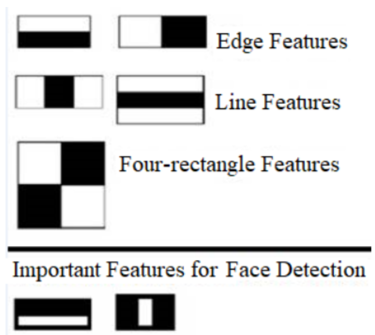

Fig. 2.3: Haar-like features

There are 3 types of Haar-like features that Viola and Jones identified in the research:

- Edge features
- Line-features
- Four-sided features

These highlights help the machine understand what the picture is. One side will be lighter than the other, making that edge like highly contrasting component. In the two significant highlights for Face Detection, the level and the vertical highlights portray what eyebrows and the nose, separately, look like to the machine.

CHAPTER 3

DESIGN OF HARDWARE AND SOFTWARE

CHAPTER 3

DESIGN OF HARDWARE AND DEVELOPMENT OF ALGORITHM

This chapter deals with the selection of hardware components required to make a gimbal, design of the pan-tilt mounts and development of the algorithm for detecting and producing error signals based on the object position inside the video frame. The software that are used for implementing the algorithm , testing the servos and generating the pwm signals are also discussed in this chapter.

3.1 Hardware components required

Table 2.1 Hardware components

S.no	Name	Quantity
1	Arduino UNO	1
2	USB camera	1
3	Servo 9g	2
4	Jumper wires	1

3.1.1 Arduino UNO

The 14 computerized input/output pins can be utilized as info or yield pins by utilizing pinMode(), digitalRead() and digitalWrite() works in arduino programming. Each pin work at 5V and can give or get a limit of 40mA current, and has an inside draw up resistor of 20-50 K Ohms . Out of these 14 pins, a few pins have explicit capacities as recorded underneath.

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.

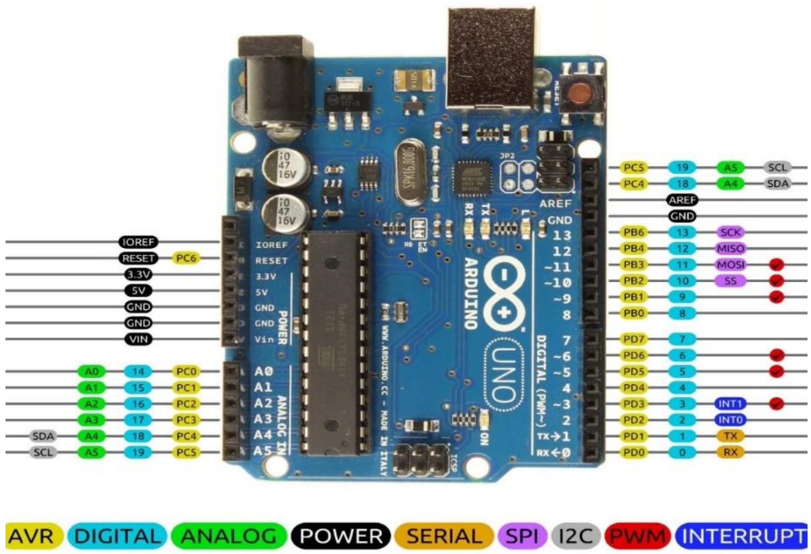

Fig. 3.1: Arduino uno

- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off.

Along with 14 Digital pins, there are 6 analog input pins, each of them provide 10 bits of resolution, i.e. 1024 different values. They measure from 0 to 5 volts but this limit can be increased by using AREF pin with analog Reference() function. The fig. 3.1 shows the Arduino with its multipurpose pins.

3.1.2 Servo 9g

The reason behind using this 9g model shown in fig. 3.5 is that, it is light in weight and requires less power to operate thereby saving the energy for extra flight time.

Fig. 3.5: 9g servo motor

- Model: SG90
- Weight: 9 gm
- Operating voltage: 3.0V~ 7.2V
- Servo Plug: JR
- Stall torque @4.8V : 1.2kg-cm
- Stall torque @6.6V : 1.6kg-cm

3.1.3 USB Camera

USB camera shown in fig. 3.6 is chosen to make sure that the camera itself should not become a major load for the servo mechanism for tilt and pan movement. Other wireless camera's are costly and wireless transmission is not really necessary for this application as the processing is achieved on board.

Fig. 3.6: USB Camera

Specification

- 720p
- 30fps
- 5MP

3.2 Design of Servo camera mounts:

The servos used in this project are responsible for pan and tilt movement of the camera. The design is done by considering the weight factor as the whole structure weight is carried by the drone. **Solidworks 2018** is used to design the mounts required to hold the camera and servos. SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program. SolidWorks is published by Dassault Systèmes.

Building a model in SolidWorks ordinarily begins with a 2D sketch. The sketch comprises of geometry, for example, focuses, lines, bends, conics (with the exception of the hyperbola), and splines. Measurements are added to the sketch to characterize the size and area of the geometry. Relations are utilized to characterize characteristics, for example, juncture, parallelism, oppositeness and concentricity. The parametric idea of SolidWorks implies that the measurements and relations drive the geometry, not the reverse way around. The measurements in the sketch can be controlled autonomously, or by connections to different boundaries inside or outside the sketch.

In a get together, the simple to portray relations are mates. Similarly as sketch relations characterize conditions, for example, intersection, parallelism, and concentricity regarding sketch geometry, gathering mates characterize equal relations as for the individual parts or segments, permitting the simple development of congregations. At last, drawings can be made either from parts or gatherings. Perspectives are naturally produced from the strong model, and notes, measurements and resiliences would then be able to be effectively added to the drawing varying. The drawing module incorporates most paper sizes and measures.

3.2.1 Design considerations:

The design of structure is made in such a way that it should acquire less amount of space with least weight. The material chosen is ABS because of its high vibration withstanding capability. The dimension of the structure is taken according to the servo size.

The design is 3D printer friendly i.e. it does not have any complicated overhang that requires lot of supports causing wastage of ABS filament. The fig. 3.7 shows the servo mount 1 that holds one servo. Fig. 3.8 shows the servo mount 2 connected to the servo mount 1 holds the camera device. The fig. 3.9 shows the base that holds every other structure required for gimbal mechanism.

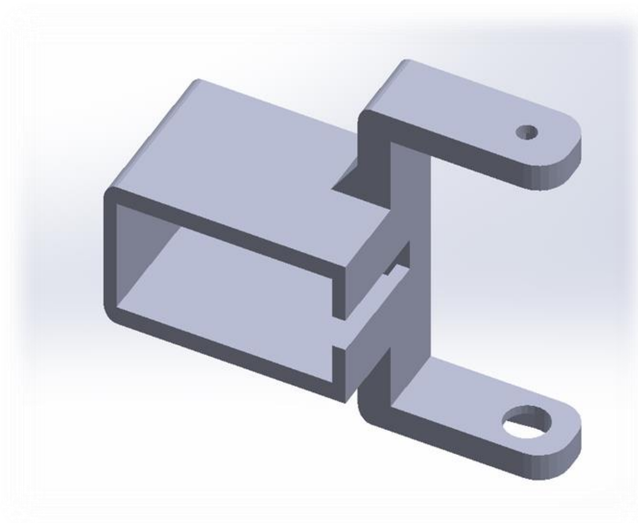

Fig. 3.7: Servo mount 1

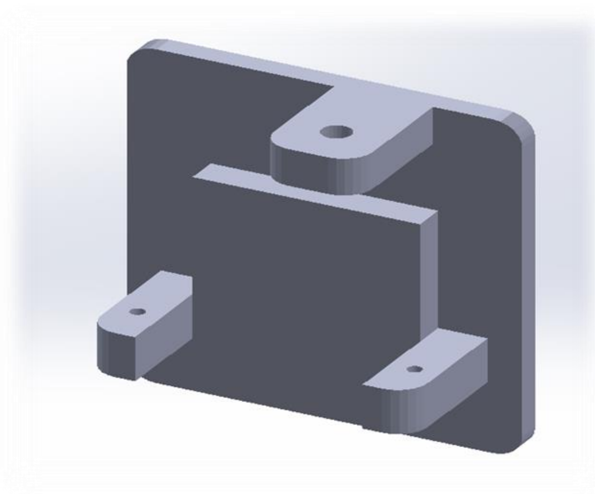

Fig. 3.8: Servo mount 2

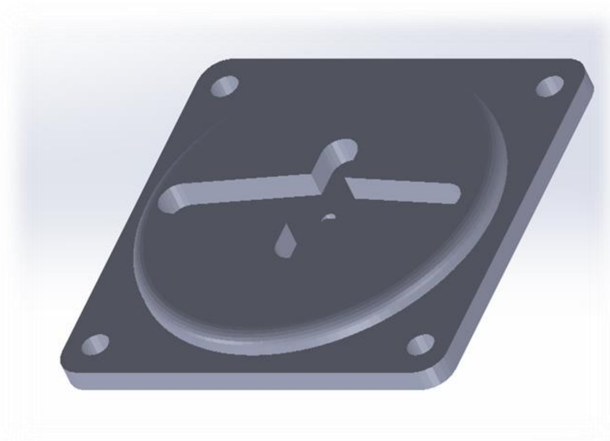

Fig. 3.9: Servo base

3.3 Implementation of Algorithm and Softwares used

3.3.1 Implementation of Algorithm in Matlab

Algorithm:

1) Set the port of arduio Eg: COM5
2) Define the arduino pins for sending error signal i.e. D3 and D5
3) Define variables as pan,tilt and error.
4) Initialize the video input device using imaqhwinfo function.
5) Put the video frame into the CascadeObjectDetector() module.
6) CascadeObjectDetector()module detects the object and it's position in the frame.
7) Show the detected object in a separate window using vision.VideoPlayer.
8) Amplify the error signal Ex: error*2
9) Write the amplified error signal to the Arduino pins
10) Repeat the steps from step 4.

3.3.2 MATLAB

MATLAB (matrix laboratory) is a multi-worldview numerical figuring condition and restrictive programming language created by MathWorks. MATLAB permits framework controls, plotting of capacities and information, execution of calculations, production of UIs, and interfacing with programs written in different dialects.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

3.3.3 ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a cross-stage application (for Windows, macOS, Linux) that is written in capacities from C and C++. It is utilized to compose and transfer projects to Arduino perfect sheets, yet in addition, with the assistance of outsider centres, other seller development boards.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, that provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution.

3.3.4 PROCESSING IDE

Processing is an open-source graphical library and IDE built for the electronic arts, new media art, and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context.

Processing utilizes the Java language, with extra disentanglements, for example, extra classes and associated scientific capacities and tasks. It additionally gives a graphical UI to disentangling the assemblage and execution stage.

CHAPTER 4

RESULTS

CHAPTER 4

RESULTS

4.1 Testing

Testing the servo mechanism is achieved by using the processing IDE. The fig. 4.1 shows the interface for the software and the small window shows the vertical and horizontal movement of the mouse. The pan and tilt movement corresponds to the mouse cursor movement.

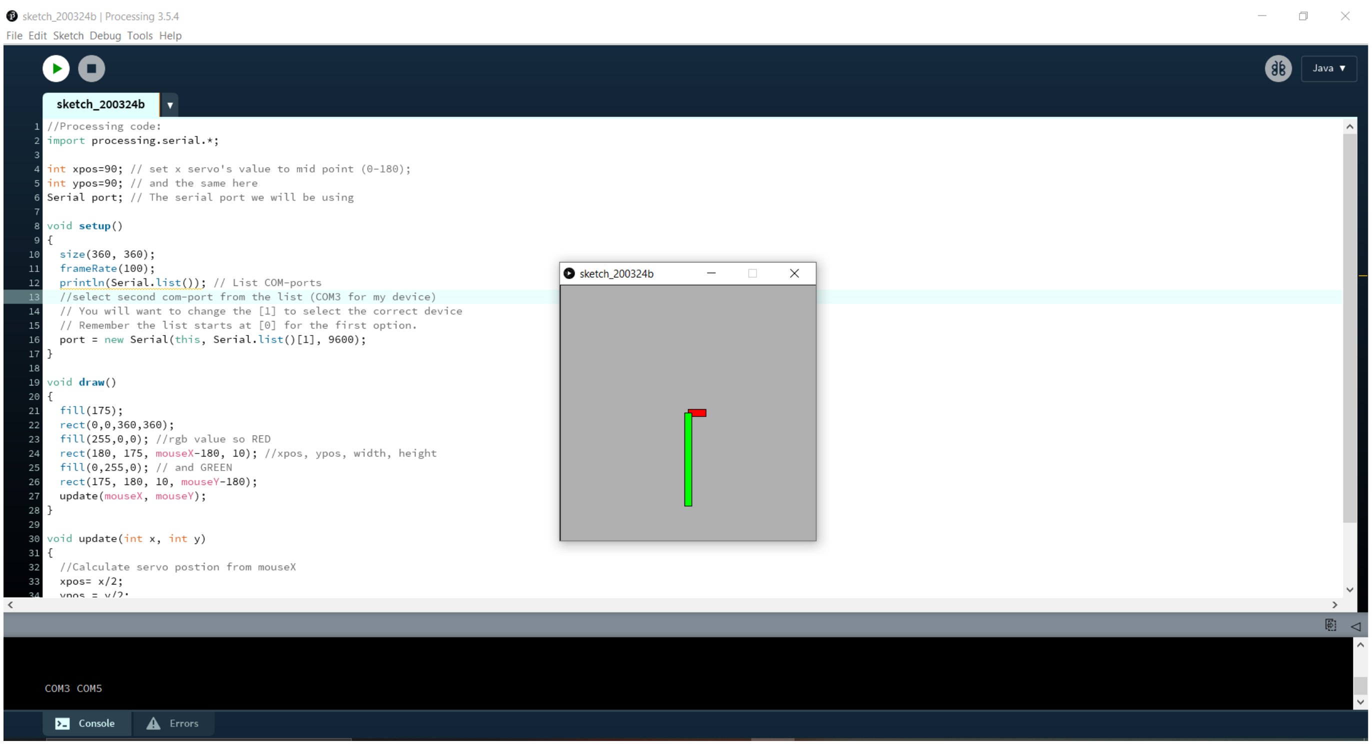

Fig. 4.1: Processing IDE

Fig. 4.2 shows the connection of Arduino with servos and computer. Arduino is connected to computer using serial connection. Servos are connected to Digital pin 3 and Digital pin 5 of Arduino. Power is given to servos using 5V pin in Arduino and Ground pins of servos is connected to the Ground pins of Arduino. Fig. 4.3 and Fig. 4.4 shows the mechanical connection of servos and camera mount.

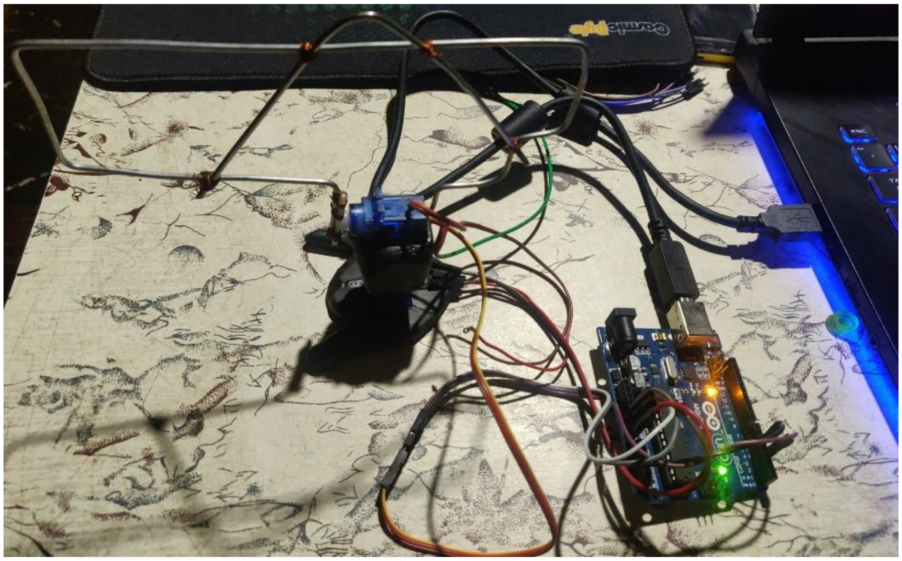

Fig. 4.2: Arduino connected to servo motors and Computer

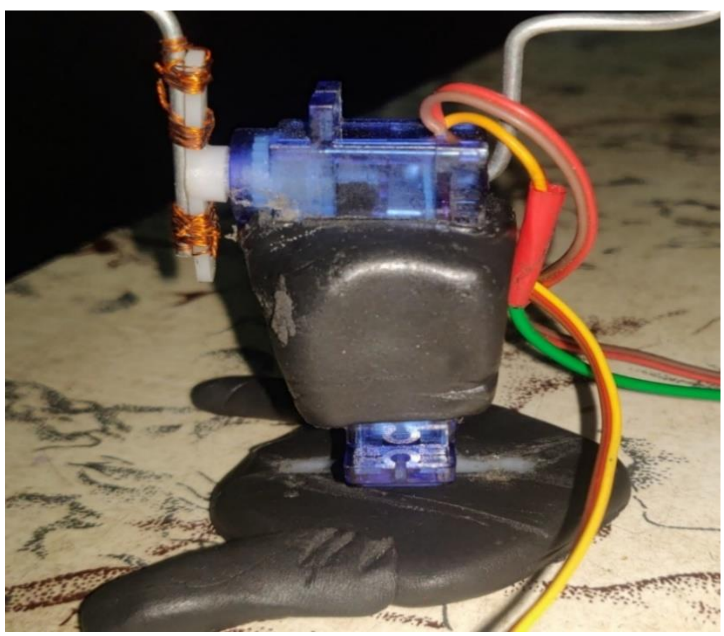

Fig. 4.3: Servo motor attached on servo mounts

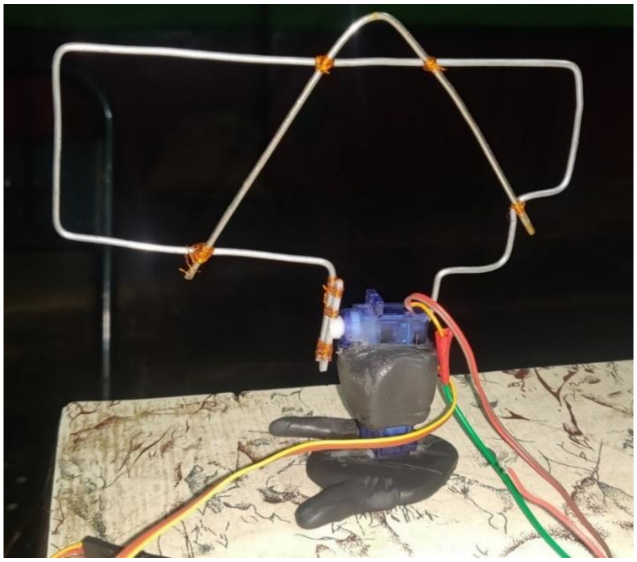

Fig. 4.4: Servo’s mounted with a camera holder

The fig. 4.5 shows the Matlab software that runs the code required for the gimbal action.The small window inside the Matlab window shows the video frames captured by the capturing device.

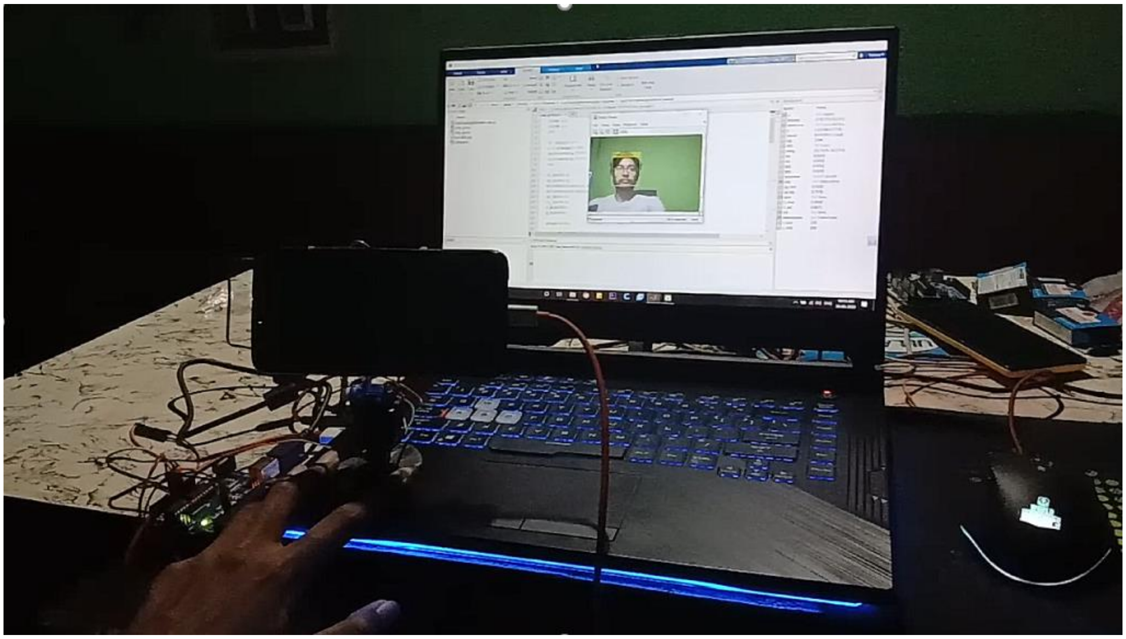

Fig. 4.5: Matlab executing the object detection algorithm

4.2 Test cases:

Case 1: Testing the pan mechanism holding the camera (Mobile phone)

- The weight of the camera (Mobile phone) is more than the servo's lifting capacity so the pan action is restricted to 20 degree from the vertical plane.
- Without the camera the pan action is able to reach 180 degree rotation.

Case 2: Testing the tilt mechanism with camera (Mobile phone) fixed on it

- The tilt servo reached total of 180 degrees rotation with and without holding the Camera (Mobile phone).
- The base of the tilt servo is not sufficient to hold the camera in a stable position.

Case 3: Response of the servos based on the gain multiplied with error signal

- The gain of 12 percent yielded smooth response.
- The gain of 30 and above made the system oscillate.
- The gain <3 percent is not able to move the servos.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

Conclusion:

The vibrations and disturbances during the angular movement of camera are wiped off by gimbal. These are widely employed in aerial devices such as drones. Gimbals effectively augment the Field of View (FOV) of the camera through angular motion, that can either compensate for or be combined with translational motion to achieve the desired shooting objective. The ability to mitigate the FOV constraint becomes even more critical when tracking of moving targets is involved. In fact, physical, autonomous target tracking using a camera/gimbal combination is an extremely important functionality for vision enabled robotic systems, e.g., in autonomous cinematography/intelligent shooting application. Gimbal control is extensively studied in the recent times, as an integral part of the so-called Inertial Stabilized Platforms used to stabilize the line of sight of a sensor mounted on a platform, that is possibly moving and rotating, relative to a target or an inertial reference frame.

The study of control mechanism and object tracking is done extensively for the improved stabilization in optics performance. The gimbal control mechanism is designed with computer aided simulation called Solid Works 2018. The designed and built servo mechanism supports the camera in angular motion as well as during tracking. The object tracking is done in MATLAB 2019b version. The algorithm developed to detect the image /object is better in terms of speed of stimuli and response. The gimbals stabilization along with object tracking is integrated for better results. The FOV constraint of camera had improved with the integration. The integrated module is fast and reliable for object tracking and detection.

The problem of controlling the orientation a gimbal-mounted camera to point at a target of interest is addressed. The aim of this project was to develop object tracking mechanism. A matlab code that includes Viola-Jones algorithm is written in Matlab. Matlab will process each frame from a video, try to keep the interested object into the middle of the frame. If any deviation occurs, then the corresponding error signals are generated and sent to a Arduino serially. Arduino generates the pwm signal according to the error signal and is sent to the servo will make a rotatory motion to correct the error. The servo mechanism improved the response as well as stability to optics and object detection was reliable with good response. The effort showed it is better in terms of size, response, stability and weight.

Future Scope:

- It will be utilized for home security cameras to increase the security.
- Android application will be built to point out the object to track.
- A newer approach for the fixtures to drone for keeping track of a interested object.

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