DESIGN AND DEVELOPMENT OF AN AUTOMATED VIDEO CAMERA SYSTEM FOR PRESENTING AND ONLINE TEACHING

K.K.B. Kariyawasam[1], K.A.V. Perera[2], M.P.H. Nuwan[3], D.D.D. Suraweera[4]
Department of Electrical and Electronics Technology
University of Vocational Technology
Ratmalana, Sri Lanka.
kkbkariyawasam@gmail.com kkbkariyawasam@yahoo.com

***Abstract*— The Covid-19 pandemic had a greater impact on the day-to-day life of people around the world. Due to the pandemic, most countries have started to change their education system into an 'online teaching method' and have tried to carry out the educational system unstopped. As a result of this pandemic, most of the higher education sector and secondary education sector in the world has started to offer courses in an online manner. In Sri Lanka, most of the teachers use online meeting software applications to communicate with children via the in-built camera in the instrument they are using. Sometimes teachers shared their screens with students and use slides or lecture notes while teaching. Usually, teachers or lecturers used several blackboards or whiteboards to explain the subjects in the face-to-face classroom session. In an online delivery system,some teachers teach using a board and film the lecture using a separate camera and a person to operate the camera. This method has several issues, cannot capture several boards at one time clearly, and so on. If the lecturer uses another board for teaching purposes without regular ones, the camera cannotmove directly in the board's direction without an operator. Because the camera frame is focused on a single normal teachingboard and if the camera changes its capturing position manually, it causes unclear video capturing. Therefore, this research paper is presented to overcome those problems using an automated camera system.**

Keywords- Online Teaching, Computer Vision, Pan-tilt Mechanism.

I. INTRODUCTION

The Covid-19 pandemic was done a greater effect on the world's education system and most countries adopted technologies for their teaching system to deliver education to students continuously. In Sri Lanka, most institutes and schools were trending to online systems to deliver education. A survey was conducted among the teachers and lecturers who currently working in government institutions and the private sector to get an understanding of the practical issues of online education delivery in Sri Lanka. According to the survey results, the need for this type of automated camera was identified.

This paper covers the design and development of a low-cost, user-friendly automated camera system that can be used for the online delivery of lessons. The proposed system will help teachers and presenters work online while preserving the audience's or students' undivided attention on the presenter or lecturer. Basically, this proposed system works on a pan-tilt mechanism with the gears system and computer vision technology. Face identification and colour-tracking methods are used in this system and the Raspberry Pi 3b+ microprocessor-based system is used to the run main system. For this system, a 5Mp web camera was used. This system has a teacher-tracking capability and if the lecturer wants to use another board, the lecturer can move the camera to that board via remotely. The user can identify the position of the camera which is focused on what board through the remote application. The remote application of this camera system was built in the NodeRed environment. After further development, there is a possibility of using this kind of camera system for security purposes, in the film and television industry.

II. LITERATURE REVIEW

Kumar and Ashish (2019) have conducted a study on detecting objects and motion using Artificial intelligence face detection and motion detection were key technologies of this research and studied different methodologies for object detection using neural network technology [1].

Paulraj et al. (2009) had done their research using a simple colour recognition algorithm using a Neural Network model and applied it to determine the ripeness of a banana. The captured image of the banana is resized and its RGB colour components are extracted they used MATLAB software for programming [2].

Shweta et al. (2018) proposed Autonomous vision-based robots are intelligent robots that take visual data and provide the appropriate output their aim is to develop autonomous color-tracking robots using a raspberry pi and compared the various color-tracking techniques [3].

Ali et.al. (2016) designed a computer Vision system for Object Recognition and Tracking Based on Raspberry Pi. The main task of this project is the recognition and tracking and key component of video surveillance and monitoring systems. They used a Continuously Adaptive Mean Shift algorithm and color detection in darkness for tracking a target with video sequences in real-time [4].

Ivask and Martin (2015) presented the thesis to explore different methods for helping computers interpret the real world visually, investigate solutions to those methods offered by the open-sourced computer vision library, OpenCV, and implement some of these in a Raspberry Pi-based application for detecting & keeping track of objects [5].

Puri and Raghav (2018) designed system to detect the shape, color, and contour using OpenCV and Python. They used the OpenCV vision library and NumPy to detect the shape, colour has given binary images [6].

Navada and Samthosh (2014) implemented a prototype for colour blind people for detecting the colour and edges of a given image that are of similar colors and the LabVIEW platform is used to display the edges and color of the image [7].

Wile and Lucas (2018) Presented a research paper for Computer Vision and Image Processing. This paper provides a survey of recent technologies and theoretical concepts explaining the development of computer vision mainly related to image processing using different areas of their field application [8].

Tr'emeau et al. proposed an automated sorting system that uses Raspberry Pi 2. They used a USB camera for colour detection of objects and OpenCV (Open-Source Computer Vision) to implement a colour detection algorithm [9].

This project is completed at a low cost and the appropriate technologies to be used for this project were selected as follows. Studied the appropriate technologies to create this system through the research papers mentioned above. Accordingly, it became clear that it is possible to use colour detection and tracking technology and face detection and tracking technology.

METHODOLOGY

This camera system is manufactured for automatic self-video recording. The installed camera will be used for video recording and tracking the presenter's movement. Image Processing and computer vision technologies are used to identify the presenter's position using a coloured band on their hand. Faces identification technology was used to confirm that the person in front of the camera is a human.

A servo motor mechanism is used to move the maincamera system. The whiteboard or blackboard is divided intothree zones, zone 1, zone 2, and, zone 3 as shown in Figure 1. The camera system will focus on any of this zone through a remote-control application as the preference of the presenter.

The raspberry pi board is the main part of this system. The raspberry pi board is receiving the data related to the movement of the presenter detected by the camera. Then the raspberry pi board will release a relevant signal to the servo motor through the motor driver to rotate the camera horizontally and vertically, following the presenter. DC power supply is giving power to the raspberry pi board and servo motor. A buck converter is used to give stable power to the servo motors.

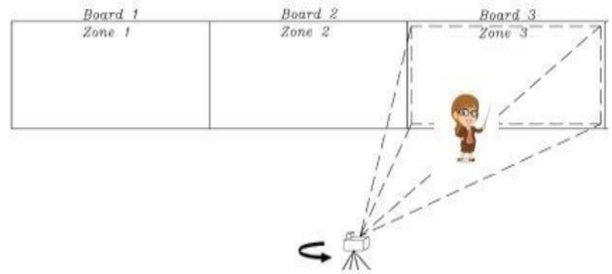

Figure.1 Board selection system

A. Development Board

A raspberry pi 3b+ single computer development board is used for the operation of this system. It has a quad-core 1.4GHz central processing unit (CPU) with 1GB of random access memory (RAM). Python programming language is used for programming purposes. It also contains the 40-pin header and is used to develop a connection with the external electronic device. It also has the ability to communicate through Bluetooth and Wi-Fi technologies.

Figure.2 Raspberry pi development board

B. Camera

Figure 3. USB camera

The most important part of this system is the camera. A web camera was used for this system. The weight, frame rate, and dynamic resolution were taken as the factors when selecting the camera. Also, the camera was selected focusing on the line length and focal length of the camera. Also, the maximum required current to operate this camera is low, which helps to maintain the efficiency of this system at a high value. The specifications of the selected camera for this system are as follows.

Table 1 Camera Specifications

Specification	Details
Image sensor	CMOS
High definition	720P
Dynamic resolution	1080 * 720P
Frame rate	30fps
Line length	150cm
USB interface	USB 2.0
Video format	AVI
Working Voltage	5VDC
Current	1A
Lens	Superior quality glass lens

C. Motors

In choosing the motors required for this system, attention was mainly focused on the torque and power supply. The torque produced by the camera has been calculated as 0.06615 Nm. These calculations are done without paying attention to the weight of the camera retainer and the gear ratio and decided to use servo motors for this system based on the market prices and the scarcity of goods. According to the calculations, selected a servo motor with torque three times greater than the torque produced by the camera. Accordingly, SG 90 servo motors with 2.5 Kgcm torque were used for this system.

Figure 4. SG 90 servo motor

D. Motor Control Board

In this project, the PCA 9698 motor control board is used to control the servo motors of the system. It has the capability to operate 16 servo motors at one time. This control system is used Inter-Integrated Circuit (I2C) communication protocol to communicate with the main processing board. The operational voltage is 5 VDC and 50Hz.

Figure 5. PCA 9698 servo motor control board

E. Manufacturing Material

Polylactic Acid (PLA) and Acrylic materials were used to design and assemble the system. These two materials have good safety factors according to the design.

1) Acrylic

Acrylic is an obvious plastic fabric with extremely good strength, stiffness, and optical clarity. Acrylic sheet is simple to fabricate, bond nicely with adhesives and solvents, and is simple to thermoform. It has advanced weathering residences as compared to many different obvious plastics. The mechanical properties of Acrylic are shown in the below table.

Table 2 Mechanical Properties of Acrylic

Property	Value	Unit
Density	1200	$kg{\cdot}m^{-3}$
Tensile strength	73	MPa
Elastic modulus	3	GPa
Yield Strength	45	MPa
Poisson's ratio	0.35	-
Shear modulus	890	MPa
Thermal expansion coefficient	5.2e-05	K^{-1}

2) Polylactic acid (PLA)

PLA is the second one maximum produced bioplastic after thermoplastic starch and has comparable traits to polypropylene, polyethylene, or polystyrene, in addition to being biodegradable. The cloth residences of PLA make it appropriate for the manufacture of plastic film, bottles, biodegradable scientific gadgets, etc. PLA may be used as a shrink-wrap cloth because it constricts beneath Neath heat. This ease of melting additionally makes polylactic acid appropriate for three-dimensional (3D) printing applications. PLA may be degraded through hydrolysis, thermal degradation, or picture graph degradation. The mechanical properties of PLA are shown in the below table.

Table 3 Mechanical Properties of PLA

Property	Value	Unit
Density	1.210–1.430	$g{\cdot}cm^{-3}$
Melting Point	150 - 160	°C
Young's Modules	3.5	GPa
Yield Tensile Strength	25	MPa
Ultimate Tensile Strength	35	MPa
Elongation at Break	6.0	%
Coefficient of Thermal Expansion	68	ɥm/m/°C

F. Structure Development

Structures contained in this system were created using SolidWorks 2018. Designed 3D structures are converted to standard triangle Language (STL) files. Those STL files are converted to geometric code (G-code) files. For geometric code (G-code) converting purposes use Ultimate Cura software. 80% infill is used for all structures and creates some supporters to help with printing purposes. For this project, PLA material is used as printing material. The below figure shows the G-code converted structures.

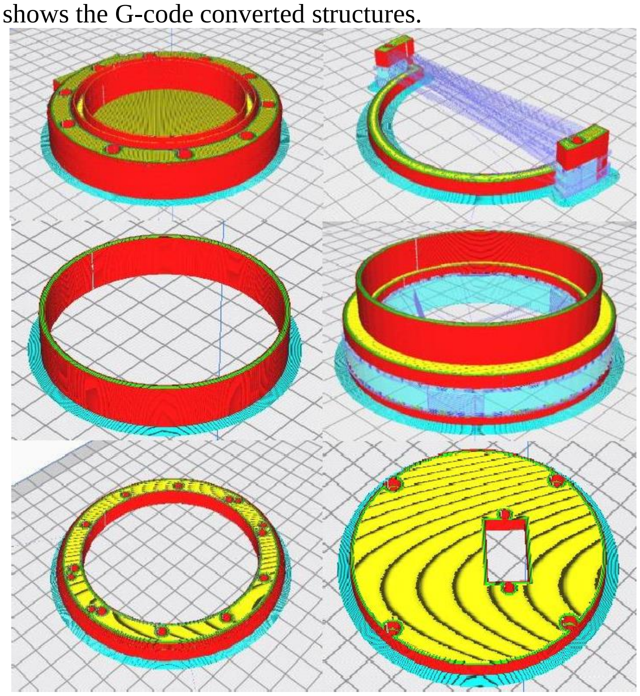

Figure 6. G-code files of designed structures

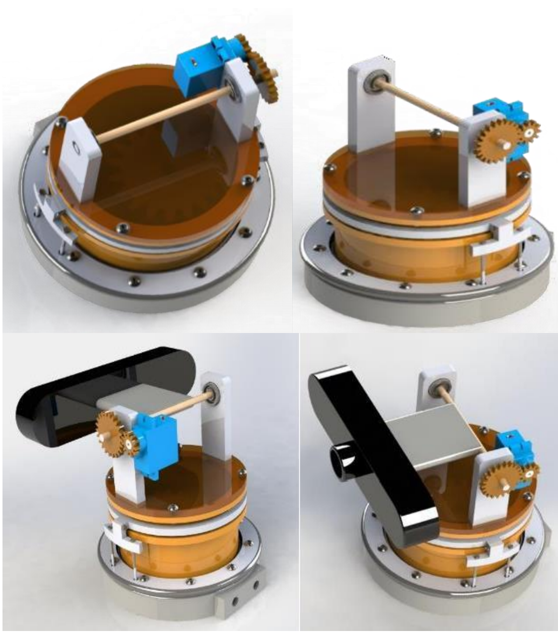

Figure 7. Designed structures using SolidWork

G. Power Arrangement

There are two power supplies which are 12VDC and 5VDC. The 12VDC power supply is used to supply power to the servo motor via a buck converter. This buck converter is used to create a sharp, constant power supply to the Servo Motor Driver without any fluctuations in voltage. The 5VDC power supply is used to supply power to the Raspberry Pi Development Board, which then supplies power to the camera using its USB cable.

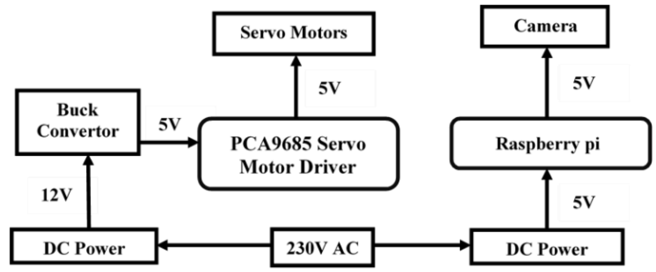

Figure 8. Block diagram of power arrangement of the system

H. Communication Arrangement

This project used three communication protocols, those are I2C, USB, and the Internet. I2C communication protocol has been used to communicate between raspberry pi development boards and with the Servo motor drivers. This I2C communication protocol has also been used to communicate between the servo motor driver and the servo motor. As shown in the diagram USB communication protocol has been used to communicate between theraspberry pi development board and camera. To communicate between the raspberry pi development board and remote-control application has used HTTP communication protocol.

1) Inter-Integrated Circuit (I2C) communication Protocol

I2C communication protocol recently becomes a popular protocol for short-distance communication. This protocol is a serial communication protocol that is used to connect low-speed devices. It has the capability to connect and control multiple slave devices from a single master. SDA and SCL are two bidirectional open-drain lines used for data transfer of this protocol. The communication protocol is synchronous. This protocol uses two cables for communication purposes in which one wire is used for the data (SDA), and another wire is used for the clock (SCL). pull up resistors are used for both lines and it also has the capability to link two I2C buses with different voltages.

2) Universal Serial Bus (USB) Communication Protocol

Universal Serial Bus (USB) is a common interface that allows devices to communicate with a host controller such as a PC or a smartphone. It Connects peripherals such as cameras, keyboards, and printers. Universal Serial Bus has a specific data transmission protocol that uses various specific types of data packets for its operation. USB or Universal

Serial Bus is an easy-to-use, reliable, and efficient data transfer protocol. To this end, the system has defined the USB data transmission protocol, data packet format, and other parameters that allow for predictable encoding and transmission of data. The bus also functions uniquely, recognizing multiple attached devices regardless of the physical configuration of the system.

3) Hypertext Transfer Protocol (HTTP) Communication Protocol

It is the main protocol for accessing the World Wide Web (WWW). HTTP is a request-response protocol. Typical use of HTTP is between a web browser and a web server. HTTP makes it easier to access hypertext from the World Wide Web by defining how information should be formatted and transmitted, and how web servers and browsers should respond to various commands.

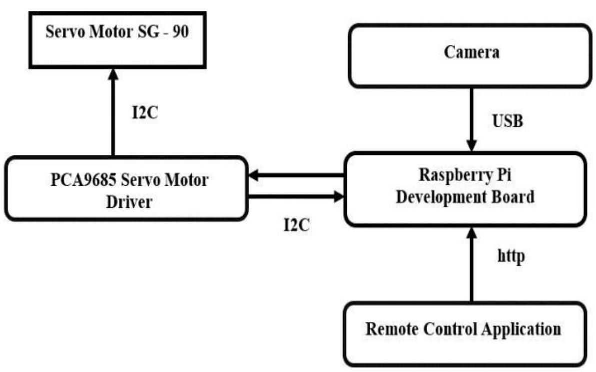

Figure 9. Block diagram of the communication arrangement

I. *Programme Development*

Image processing and computer vision technologies were mainly used to design this system. The key here is to identify the face and move the camera system in the direction that the colour band is moving, capturing the recording video by making the teacher or presenter frame it for the picture frame. Python programming language was also used to write this program. Also, OpenCV and NumPy libraries are used for this programming.

1) Open-source computer vision and machine learning software system library

OpenCV is an open-source computer vision and machine learning software system library. It is an open-source library that can be used to perform tasks like face recognition, objection tracking, landmark recognition, color recognition, and more. This library supports multiple languages inclusive of Python, Java, C++, etc.

2) NumPy

NumPy is a library for the Python programming language, including assistance for massive, multi-dimensional arrays and matrices, in conjunction with a massive series of high-degree mathematical capabilities to perform on those arrays. It additionally has capabilities for operating in the area of linear algebra, Fourier transforms, and matrices.

J. *Remote Control Application Development*

An application was created to control this camera system remotely according to the user's wishes. The NoteRed environment was used to develop this application. Through this application. Mainly, it is possible to develop the required application using the function block in the NoteRed application. Furthermore, it is possible to use the function block programmed by JavaScript programming language in the NoteRed application.

This application can be accessed using an Internet Protocol (IP) address. When using this application for the first time for calibration purposes, need to focus the camera on the whiteboard areas and save the relevant data to providethe necessary data for the angles at which the servo motorsshould operate. Here, a window will open to provide the datarequired to display the whiteboards through the setting button in the application. Whiteboards 1 to 3 are lined up as smart boards in the dropped-down menu here. By using the arrow keys, the view angles belonging to the whiteboards in each zone are given to the program by the save button.

The three smart boards and the auto-tracking feature appear in the main window of this application. By touching the smart board icon shown in the main window, the camera can be directed to the required whiteboard and the live comment shows which whiteboard the camera is currently targeting. When the auto-tracking feature is turned on, the camera will track the presenter without the whiteboards. When this feature is turned off, the user can redirect the camera to a whiteboard that needs it.

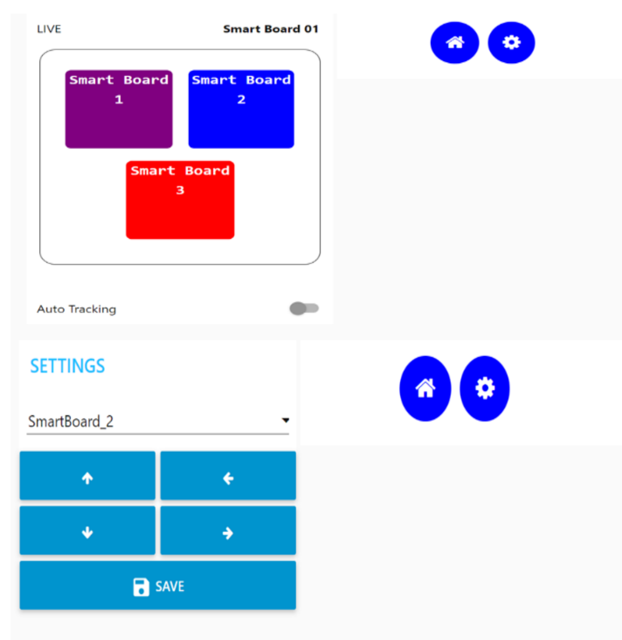

Figure 6. Remote control application environment

K. External Gear Calculations and Design

The module of the gear is chosen as 1.0 and the pressure angle is 20^0. For External Gear arrangement, selected over gear arrangement to capture the quick movement of the human. This arrangement has been used to help vertical (Y direction) movement. Therefore, the gear ratio is 2:1 is chosen. Therefore, the selected number of teeth for the drive gear is 11, and the number of teeth for the driven gear is 22. According to the calculation, an external gear arrangement was designed using SolidWork. Acrylic was used to manufacture the external gear system. Other calculations of the external gear system are tabulated below table.

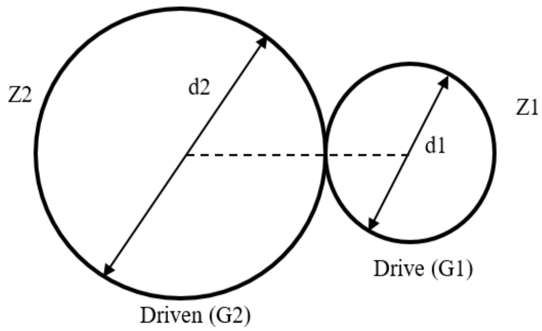

Figure 7. Basic structure of external spur gear arrangement

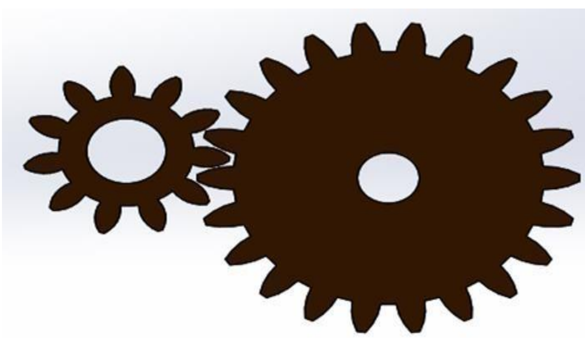

Figure 8. Designed spar gear arrangement using SolidWork

Table 4 Summarized calculation of External Gears

Calculation items	Symbol	Calculated result	
		Small gear	***Large gear***
Center distance	a	16.5 mm	
Pitch circle diameter	d1, d2	11.0 mm	22.0 mm
Addendum length	ha1,ha2	1.0 mm	1.0 mm
Tooth length	h1,h2	2.25 mm	2.25 mm
Tip diameter	da1, da2	13.0 mm	24.0 mm
Root diameter	df1, df2	8.5 mm	19.5 mm

L. Internal Gear Calculations and Design

The module of the gear is chosen as 2.5 and the pressure angle is 20^0. The required Gear Ratio is 3:4 is chosen. Therefore, the selected number of teeth for the drive Gear is 18, and the number of teeth for the driven gear is 24. The summarized calculation of the internal gear system is shown in the below table. Basically, an internal gear system has been used to help with horizontal (X-direction) movement and the manufacturing material is acrylic for this gear system.

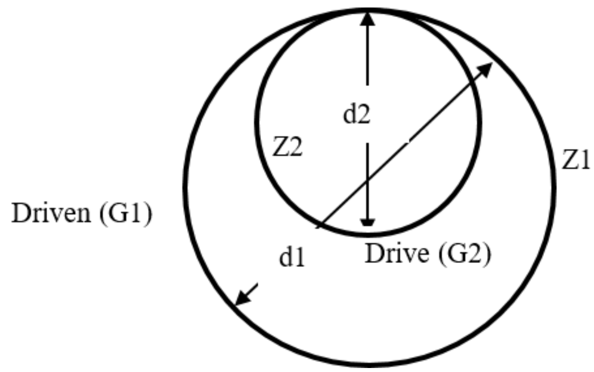

Figure 9. Basic internal gear structure

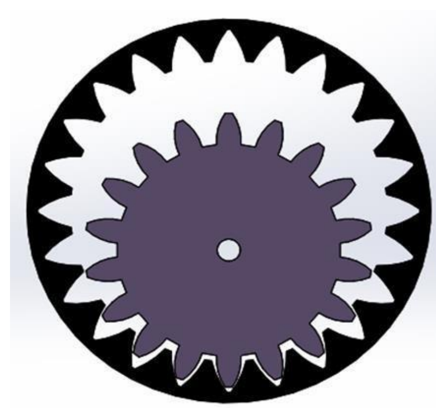

Figure 10. Designed internal gear arrangement using SolidWork

Table 5 Summarized calculation of External Gears

Calculation items	Symbol	Calculated result	
		External gear	***Internal gear***
Center distance	a	7.5 mm	
Pitch circle diameter	d1, d2	45.0 mm	60.0 mm
Addendum length	ha1,ha2	2.5 mm	2.5 mm
Tooth length	h1,h2	5.63 mm	5.63 mm
Tip diameter	da1, da2	50.0 mm	55.0 mm
Root diameter	df1, df2	38.75 mm	66.25 mm

M. Circuit Arrangement

The wiring diagram of the hardware belonging to the camera system. The PCA9685 servo motor driver is powered through a buck converter. The reason for doing so is that the current that can be obtained by the GPIO pin of the Raspberry Pi development board is limited, so if a high current flows, the Raspberry Pi will be damaged. And the reason for powering the Raspberry Pi development board with a 5V/2Astandard power supply is to prevent damage to the board in the event of a short circuit. The manufacturer has specified touse of a separate power supply.

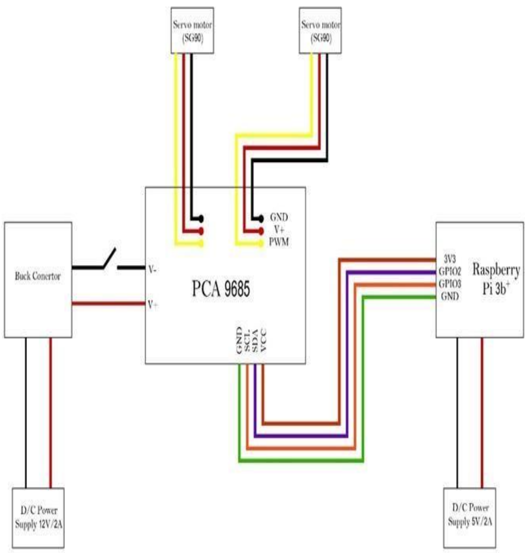

Figure 11. Wiring diagram of hardware architecture

N. Camera Test Method

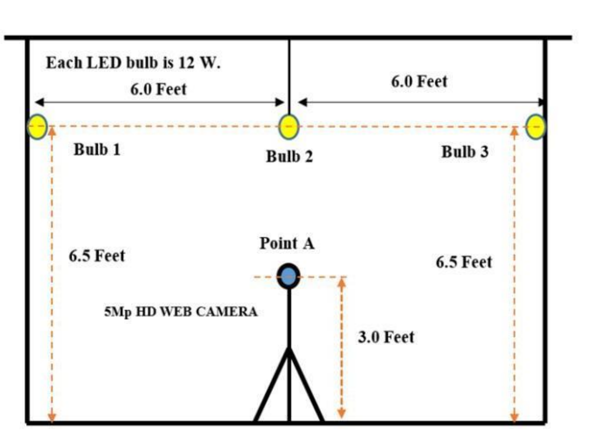

Figure 12. Testing setup of the camera system

The camera system was tested in a test area shown in the figure above to determine the response of the camera system when operated under room lighting conditions. This camera was tested under three different light levels (Lux levels) and three dynamic resolutions.

III. RESULT AND ANALYSIS

A. Parts Analysis

Basically, the most important parts of this system are the external gear wheel system, internal gear wheel system, and camera-mounted shaft. Therefore, a static analysis and factor of safety analysis of those parts were carried out using solid work simulation. The above analysis was done for the raw materials of acrylic, PLA, and nylon for gear wheel systems.

1) Factor of Safety

A safety factor is a number used to determine workload. It is based on experimental work on the material. It accounts for all uncertainties such as material defects, unforeseen loads, manufacturing defects, unskilled labor, temperature effects, etc. A safety factor is a dimensionless number. When the value of the Factor of safety (FOS) is greater than 1, it is possible to operate the system safely. The below table shows the FOS value of each part of this system.

Table 6 Factor of Safety Values of each part

Part	**The Factor of Safety for Manufacturing Materials**			
	PLA	**Acrylic**	**Nylon**	**Aluminum**
External Gear System	0.55	0.53	1.3	-
Internal Gear System	11	8.3	26	-
Shaft	4.2	-	-	28

B. External Gear Arrangement Analysis

Although there is a high Factor of Safety value for nylon, nylon is not used for the external gear wheel system due to the relatively high price of nylon in the market and the high machining cost. Therefore, the external gear system was assembled using acrylic, an easily Machinable material. Compared to nylon, the FOS value obtained for acrylic is lower. But for the prototype, an external gear system made of acrylic was used without any problems. Basically, for the external gear system, the static analysis was carried out assuming that the maximum torque of the servo motor acts on the gear wheels, there is no friction between the gear wheels, and the efficiency between the gears is 100%. 2mm thick acrylic parts were used to assemble the external gear system after analyzing the different thicknesses. According to the results, stress occurs between the teeth of the external gear system. It ranges between (1.75*10^-7 - 3.50*10^-7) N/m ^2. But a maximum displacement of 0.108mm can be seen on the teeth of the small gear belonging to the external gear wheel system according to the analysis. Here, the torque produced by the camera also affects the external gear wheel system. Hence displacement is gradually increasing among the gear tooth of the drive gear.

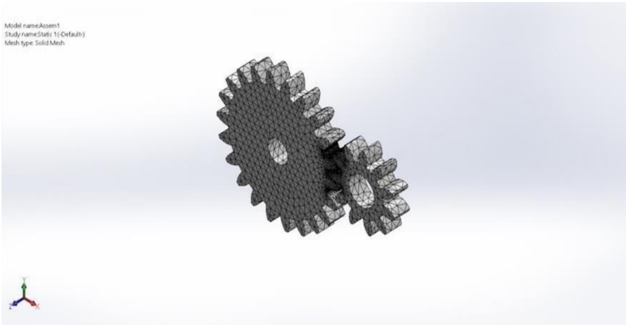

Figure 17. Mesh arrangement of external gears

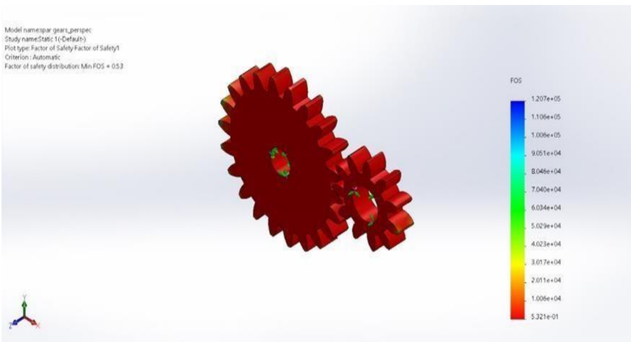

Figure 18. Factor of safety simulation of external gears

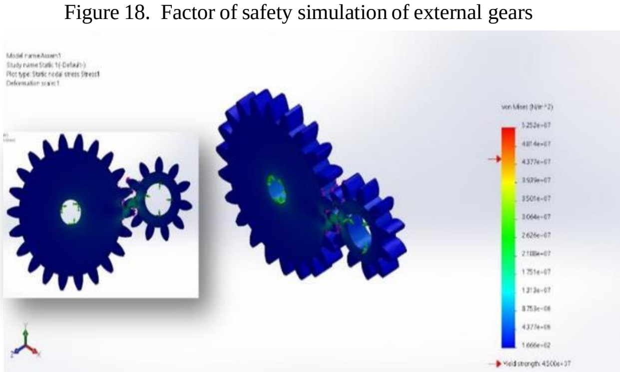

Figure 19. Stress analysis of external gears

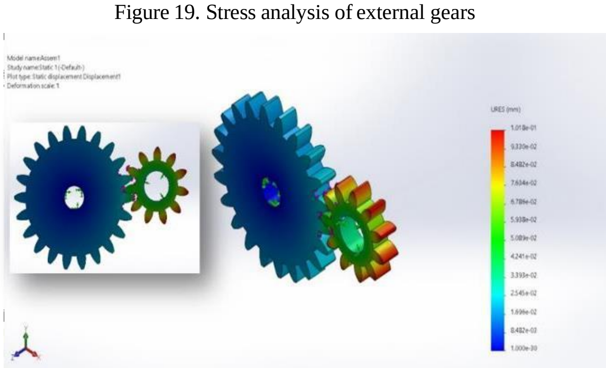

Figure 20. Displacement analysis of external gears

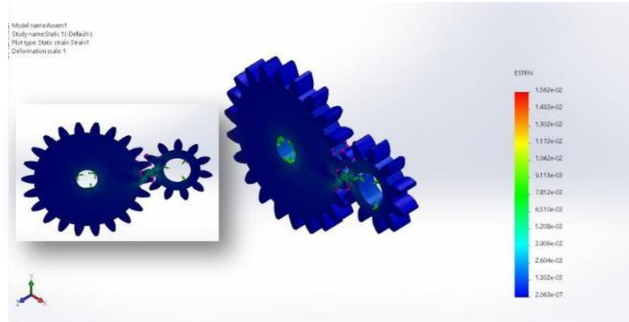

Figure 21. Strain analysis of external gears

C. Internal Gear Arrangement Analysis

In the factor of safety analysis, a value of 8.3 was obtained for acrylic. Considering the ease of assembly and other considerations, the internal gear system was assembled using 2mm thick acrylic parts. Here the large cog of the internal gear system is connected to the main body of the structure. For the internal gear system, the static analysis was carried out assuming that the maximum torque of the servo motor acts on the gear wheels, there is no friction between the gear wheels, and the efficiency between the gears is 100%. The displacement analysis was performed for the internal gear system where a displacement of 0.009618 mm is observed on the teeth of the pinion.

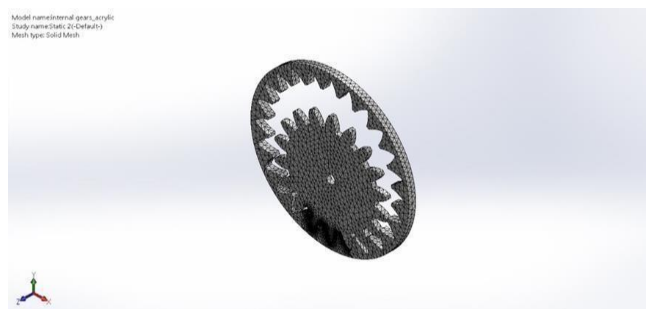

Figure 22. Mesh analysis of internal gears

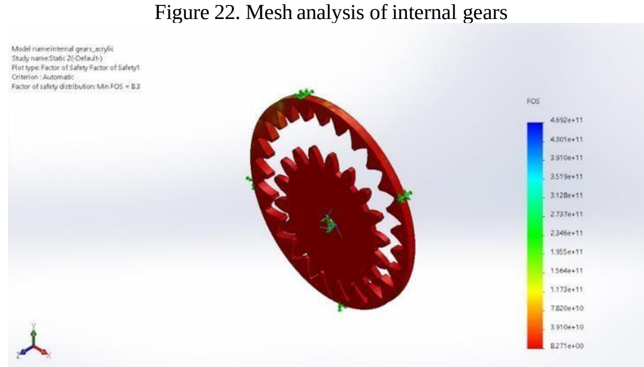

Figure 23. Factor of safety analysis of internal gears

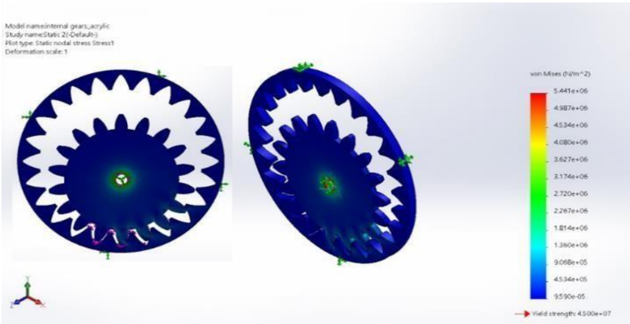

Figure 24. Stress analysis of internal gears

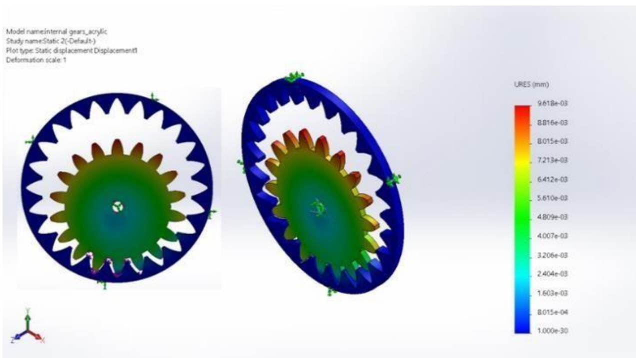

Figure 25. Displacement analysis of internal gears

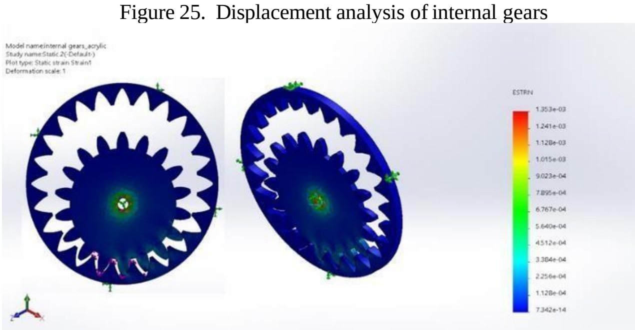

Figure 26. Strain analysis of external gears

D. Shaft analysis

The FOS value for aluminum is 28. Therefore, a 3mm aluminum rod was added to this system to hold the camera. Camera weight was used as a factor in the analyses. Here, there is no friction between the bearing and the rod, and the transmission efficiency is assumed to be 100%. the stress in the range of (4.082e+00 N/m^2-1.085e+07 N/m^2) is applied to the shaft. Also, a maximum displacement of 1.183e-02 mm can be seen. The following figures show the FOS analysis, displacement analysis, and strain analysis of the shaft. Here, the maximum torque provided by the servo motor is taken as the torque acting on the shaft and the force caused by gravity has also been used as an indicator for the analysis. After doing all Simulations, the camera system began to be assembled.

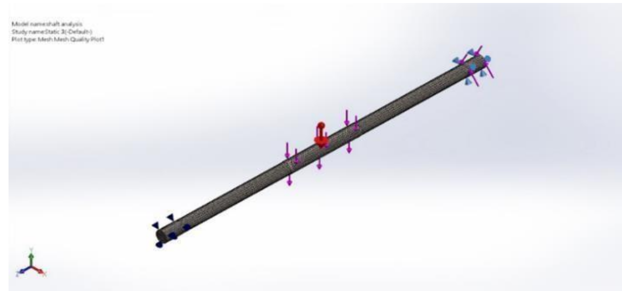

Figure 27. Mesh analysis of camera mounted shaft

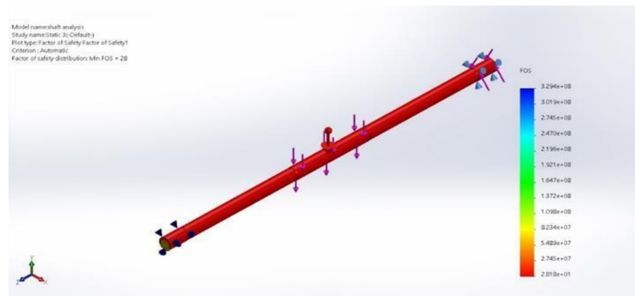

Figure 28. FOS analysis of camera mounted shaft

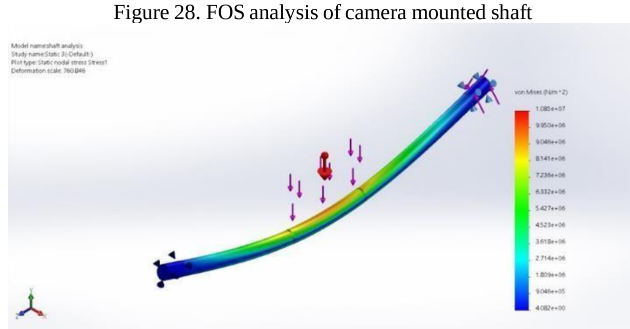

Figure 29. Stress analysis of camera mounted shaft

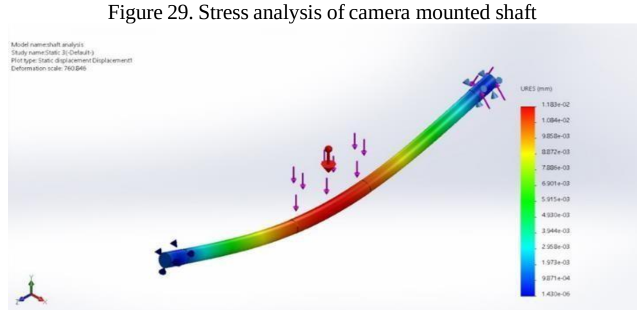

Figure 30. Displacement of camera mounted shaft

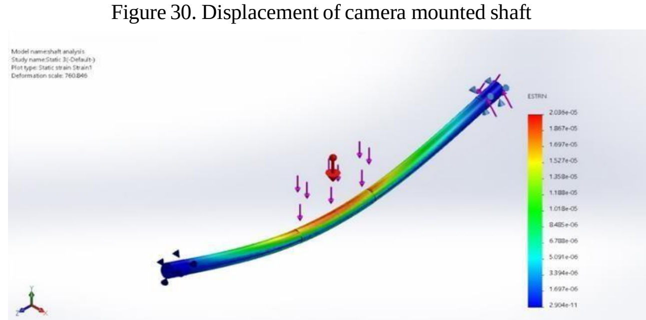

Figure 31. Strain analysis of camera mounted shaft

E. Product Analysis

Figure 32. Final prototype of the camera

Figure 33. Teachers tracking feature

Once, the auto-tracking feature is turned on, the camera moves and captures the video according to the presenter's movements. the camera focused according to the movements of the user in vertical and horizontal directions. Also, through the remote control app, the user can automatically direct the camera to the desired board. the figures above show the complete Camera system.

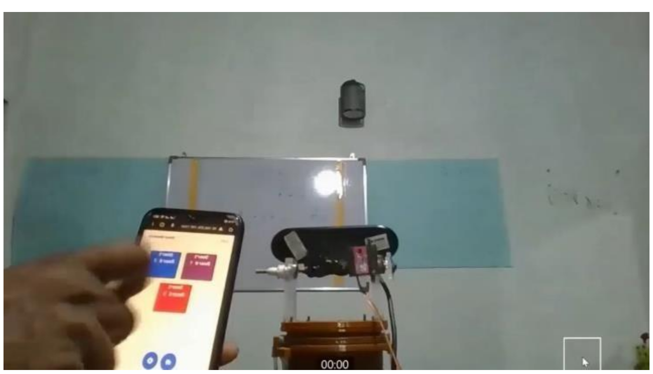

Figure 34. Remote application with camera system

F. Test Results of Detection Capability of the Camera

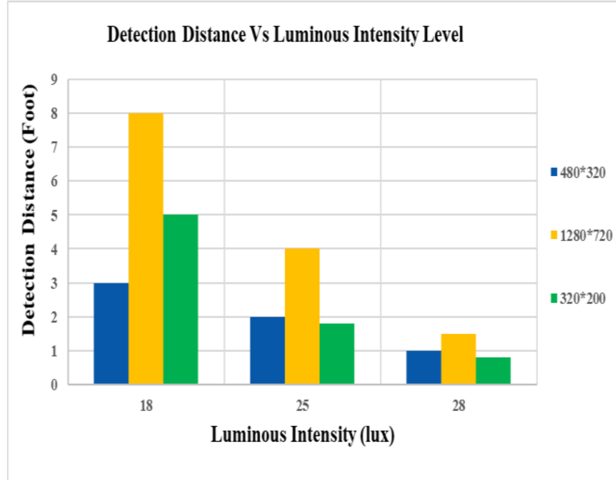

Figure 35. Detection distance Vs luminous intensity level graph

The detection distance Vs Luminous intensity level graph is shown in above figure 35. According to the test results, As the light intensity increases, the detection distance gradually decreases. As the dynamic resolution decreases, the detection distance also decreases. Furthermore, even if the light condition is increased, the detection ability gradually decreases in a frame with a higher dynamic resolution. Also, the lower the dynamic resolution, the lower the detection ability. The best detection results are given by the High-Definition (HD) frame.

IV. CONCLUSION AND FUTURE WORKS

There should be good lighting to get clear frames and good lighting conditions to easily identify the colour of the band worn on the hand. As the lighting conditions change gradually, the accuracy of colour detection also changes. Here, the intensity of light can be mentioned as a factor that contributes to colour recognition. As the tracking action is related to the colour band, as the distance between the presenter and the camera increases, the ability to detect colour gradually decreases. Then, it affects the tracking action of the camera. As the distance increases, the area allocated to the color region of the image decreases and so does the number of pixels belonging to that color region, so the detection accuracy gradually decreases. The distance between the presenter and the camera can also be a factor in colour recognition. If this system is developed further, there is the possibility of using it for security purposes, the film industry, and the television industry. In the future, it is hopedto create a lighting system that changes depending on the ambient light intensity to obtain clear video frames and improve the programming to understand the user's hand movements (improve gesture features) and develop the feature to remove the distortion that occurs in the scenes when taking the image frames in the corner zone.

REFERENCES

[1] Kumar, Ashish, "Artificial Intelligence in Object Detection," National Taipei University of Technology, p. 4, 2019. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Paulraj M P, Hema C.R, R.Pranesh Krishnan, Siti Sofiah Mohd Radzi, "Color Recognition Algorithm using a Neural Network Model in Determining the Ripeness of a Banana," Proceedings of the International Conference on Man-Machine Systems (ICoMMS), p. 4, 13 October 2009.

[3] Shweta M. Shinde, Prof.Jagadale, "Autonomous Color Tracking Robot Using Raspberry Pi," International Journal of Creative Research Thoughts (IJCRT), pp. 274-277, 2 April 2018.

[4] Ali A. Abed, Sara A. Rahmanb, "Computer Vision for Object Recognition and Tracking Based on Raspberry Pi," International Conference on Change, Innovation, Informatics, and Disruptive Technology, pp. 177-189, October 11, 2016.

[5] Ivask, Carl-Martin, "Raspberry Pi-based System for Visual Object Detection and Tracking," Tallinn University of Technology, Tallinn, 2015.

[6] Puri, Raghav, "Contour, Shape, and Color Detection using Open Cv – Python," International Journal of Advances in Electronics and Computer Science, pp. 26-27, March-2018.

[7] Bhagya R Navada, Santhosh K V, "An Image Processing Technique for Color Detection and Distinguish Patterns with Similar Color: An aid for Color Blind People," International Conference on Circuits, Communication, Control, and Computing, pp. 333 - 336, 2014.

[8] Victor Wile, Thomas Lucas, "Computer Vision and Image Processing: A Paper Review," International Journal of Artificial Intelligence Research, pp. 28-36, June 2018.

[9] Alain Tr´emeau, Shoji Tominaga, Konstantinos N. Plataniotis, "Color in Image and Video Processing: Most Recent Trendsand Future Research Directions," EURASIP Journal on Image and Video Processin, p. 26, 17 April 2008.

[10] S. Skogestad and I. Postlethwaite, Multivariable Feedback Control, John Wiley & Sons, 2001.