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TARGET FOLLOWER

Group Number: D12

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1. Abstract

The project explores the various aspects of a simplified autonomous target tracking system. The primary aim of the project is cost-effectiveness and simplicity. We have deliberately not gone for commercially available webcams because then we would not be able to explore the inner workings of an image sensor and it's interfacing. Also, we decided to not to opt for programmable camera modules like CMUCAM, because they were expensive and with them, the problem merely reduces to just coding. This project aims to provide an image-based target tracking tool for low-end users; who do not require the system to have the ability to track fast moving targets or multiple targets. An Image sensor is interfaced with a micro-controller and the assembly is mounted on a platform which provides two degrees of freedom – vertical and horizontal; controlled by the micro-controller. Based upon the image given by the image sensor, the micro-controller detects the motion of the target and gives appropriate signals to the motors in order to bring the target into the frame of the image sensor. For demonstration purposes, we have a black object on a white background and we track the motion of the black object.

2. Introduction

Surveillance is the process of collecting information and monitoring the behavior of people, objects or processes within systems for conformity to expected or desired norms in systems for security, data accumulation or social control.

Surveillance methods are varied, in terms of variety of equipment used and form of data collection and storage. Surveillance can be carried out through a number of ways such as CCTV cameras, electronic bugs, etc.

Since the past ten years the popularity of CCTV camera as a surveillance device for commercial as well as personal use has soared. This is primarily due to suitable cameras being available over the counter at reasonable rates. This is evident from the large number of organizations using security cameras (mostly CCTV cameras) for surveillance.

The state and security services still have the most powerful surveillance systems, because they have the requisite finances and legal authority. Today levels of surveillance have increased, and we are now able to draw together many different information sources to produce profiles of persons or groups in society.

While CCTV security systems seem to be cheap and easier to operate and maintain, it should not be overlooked that behind every 3-4 cameras we need to have at least one security guard. Thus we are actually wasting manpower. Also such a system is not error proof. In fact it is highly error prone. The security guard cannot concentrate on all the cameras at once. He/She may have to leave the cameras unmonitored for some time. And if the guard is disposed off, then the system is of no use. The answer to this would be automated surveillance systems, which can operate with only a few men behind the helm of the system. Such systems automatically detect motion in the frame of the camera and follow/flag it. However, it must be kept in mind that automated surveillance camera systems still cost a small fortune to install and maintain and the sophistication required for operating and maintaining them makes them an unattractive option for most organizations and security agencies. Hence most security agencies and organizations use a bank of cameras which are either stationary or keep rotating with a pre-specified pattern with guards appointed to look over the cameras.

2.2. TARGET FOLLOWER

TARGET FOLLOWER is a system which, on being given a specific object, keeps the object in its field of vision. This ensures that there is no need for extensive manning of the surveillance system, which is the case until now.

The input to the TARGET FOLLOWER is through an image sensor which gives a digital image. The system can then recognize the patterns as needed and as and when the target pattern moves in the vision of the input device, the system starts turning the sensor with two degrees of freedom so as to keep the object at the center of its field of vision. In our project we have implemented the TARGET FOLLOWER, with the basic objectives being cost-effectiveness and functionality. TARGET FOLLOWER provides a relatively cheaper and user friendly alternative to the highly expensive and sophisticated automatic surveillance systems which have been the norm till now.

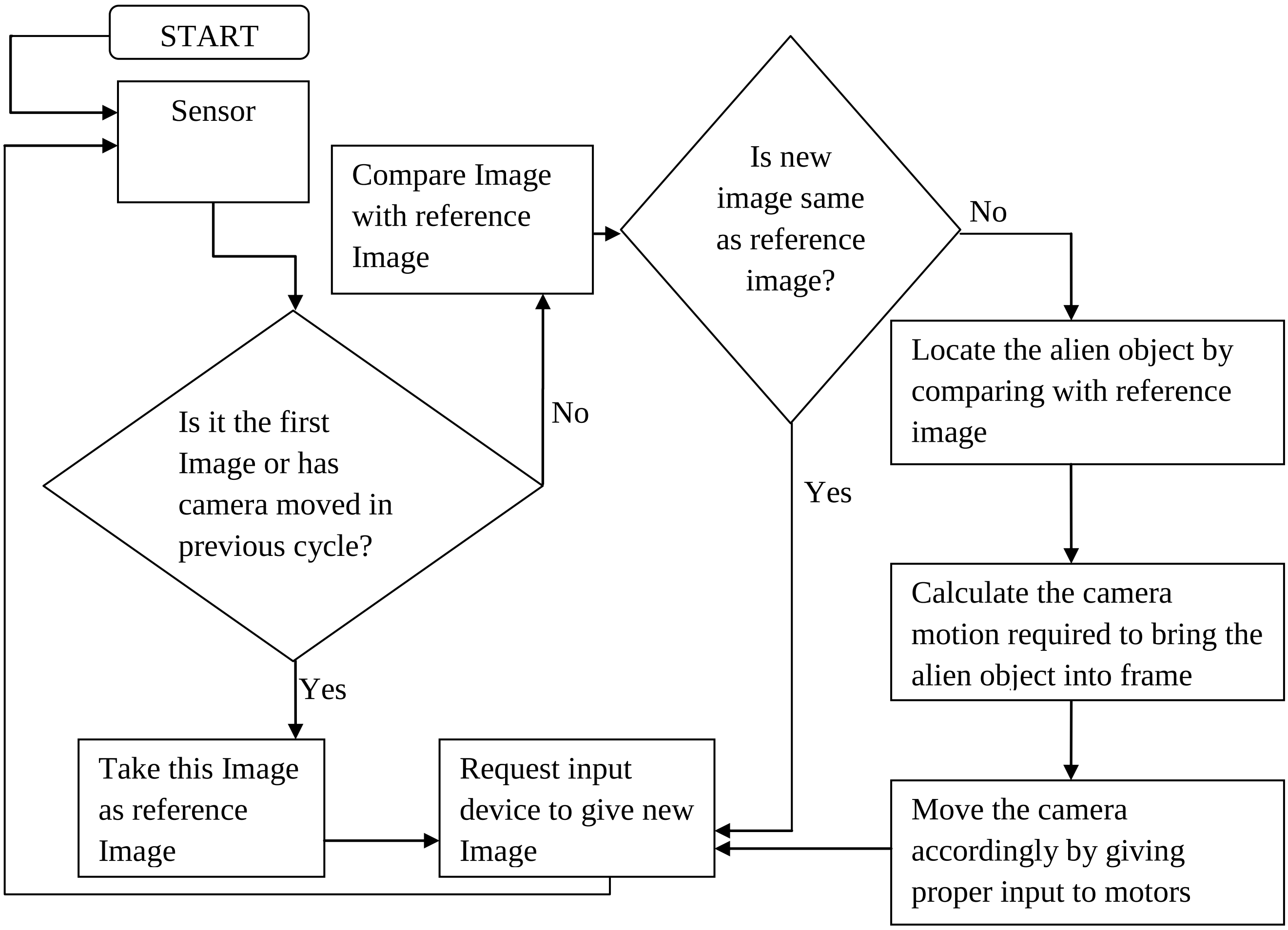

FIG 2.1: Flow Chart of Functioning of TARGET FOLLOWER

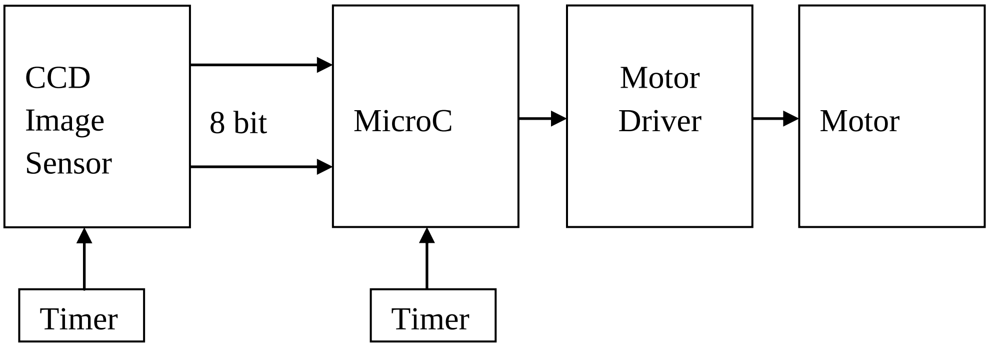

FIG 2.2: Block Diagram of TARGET FOLLOWER

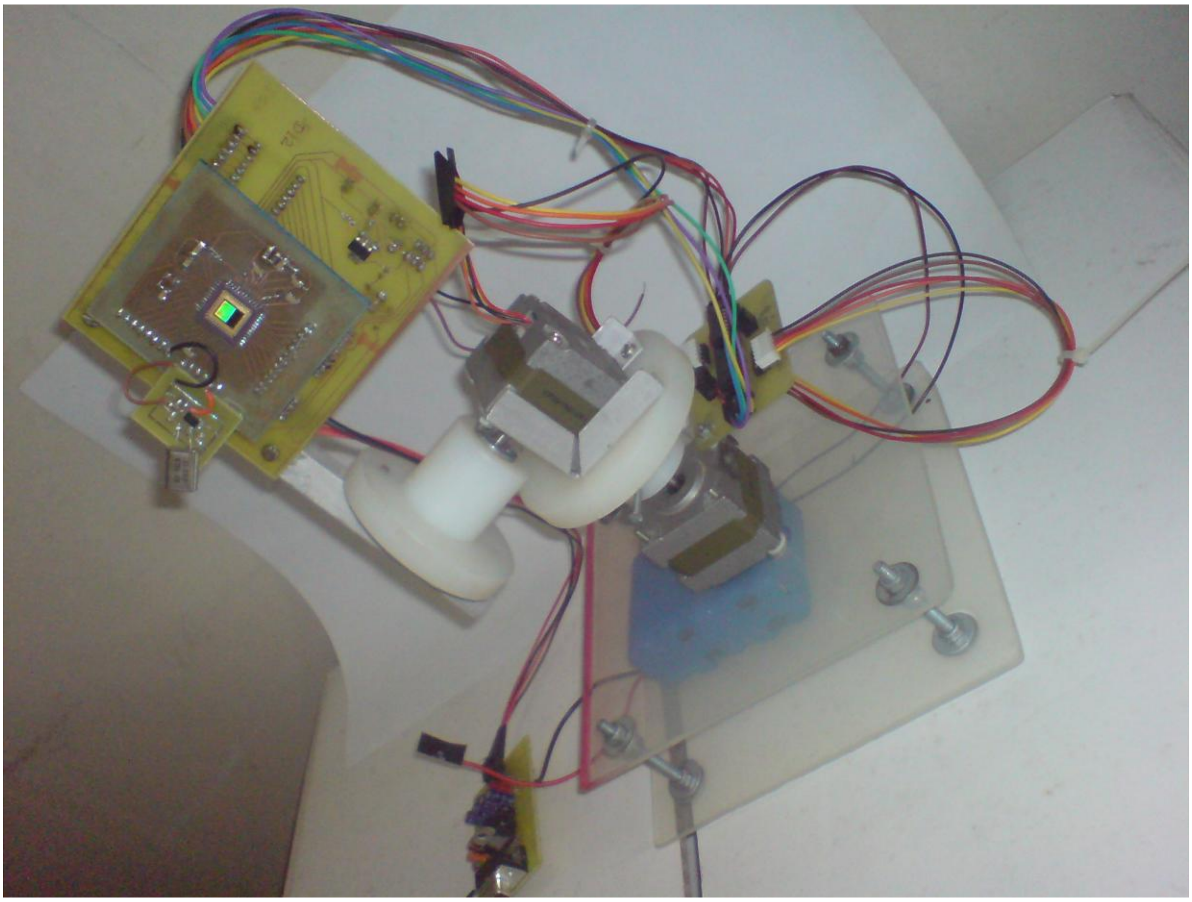

FIG 2.3: TARGET FOLLOWER

The following were the main sub-objectives of the project:

1. Getting an Image Sensor that should give data at a reasonably low fps, so that the product does not become computation-intensive. We preferred grayscale image as compared to colour image, because for colour image (RGB, YUV) we would need three times more data rate as compared to grayscale image.
2. Next step was to take the digital output of the image sensor and transmit the same to a computer. The data transmission was done after each row had been received by the micro-controller. UART was used for this and data was transmitted through serial port. The data is sent into MATLAB. We selected ATMega 32 for this.
3. Once the data has been transferred, an algorithm was to be designed and implemented in MATLAB to find the location of the alien object (target).
4. Next we had to design a motor assembly which could move the sensor in Φ and Θ coordinates accurately.
5. Next step was to send the coordinates of the alien object from the computer to the microcontroller and use it to drive the motor assembly.

Hardware portion of the product:

1. Motor Assembly
2. Image Sensor to give Image
3. Image Sensor – Microcontroller interface for input data (1 port) and control (TWI)
4. Microcontroller – computer serial data transfer using UART. (for testing)
5. Microcontroller – Motor Assembly interface through motor drivers

Software portion of the product:

1. Microcontroller Code for control of Image Sensor using TWI
2. Microcontroller code for receiving data from Image Sensor and sending the same to the computer through RS232 using UART
3. MATLAB code for finding coordinates of target and sending the same back to the microcontroller through RS232 using UART
4. Microcontroller Code for receiving target coordinates from computer and for turning the stepper motors of motor assembly through the required angles

3. CONSTRUCTION AND PART SELECTION

3.1 Mechanical Construction

3.1.1 Requirements

Our requirements were of a mount which could support two stepper motors and remain stable on a flat surface. The mechanical mount must also provide a suitable base for keeping the power supply and must be robust. The stepper motors must be mounted on top of one another, so as to give two degrees of freedom - - one for the horizontal sweep and one for the vertical sweep. Also, one motor had to support the assembly of image sensor and the related circuitry

3.1.2 Material Choice and Fabrication

Special attention was paid to the proper choice of **platform** as it would decide the ergonomics of the final system. Instead of having a solid wooden board, the group opted for acrylic sheets. The advantages for their usage were manifold. Firstly, the sheets could be attached in such a manner that a hollow space could be left in between them which could then be utilized for placement of other paraphernalia such as batteries, circuit boards, etc. Secondly, by choosing appropriate area taking into consideration the stability of the entire mounted structure, the weight could be kept well within its solid wooden counterpart.

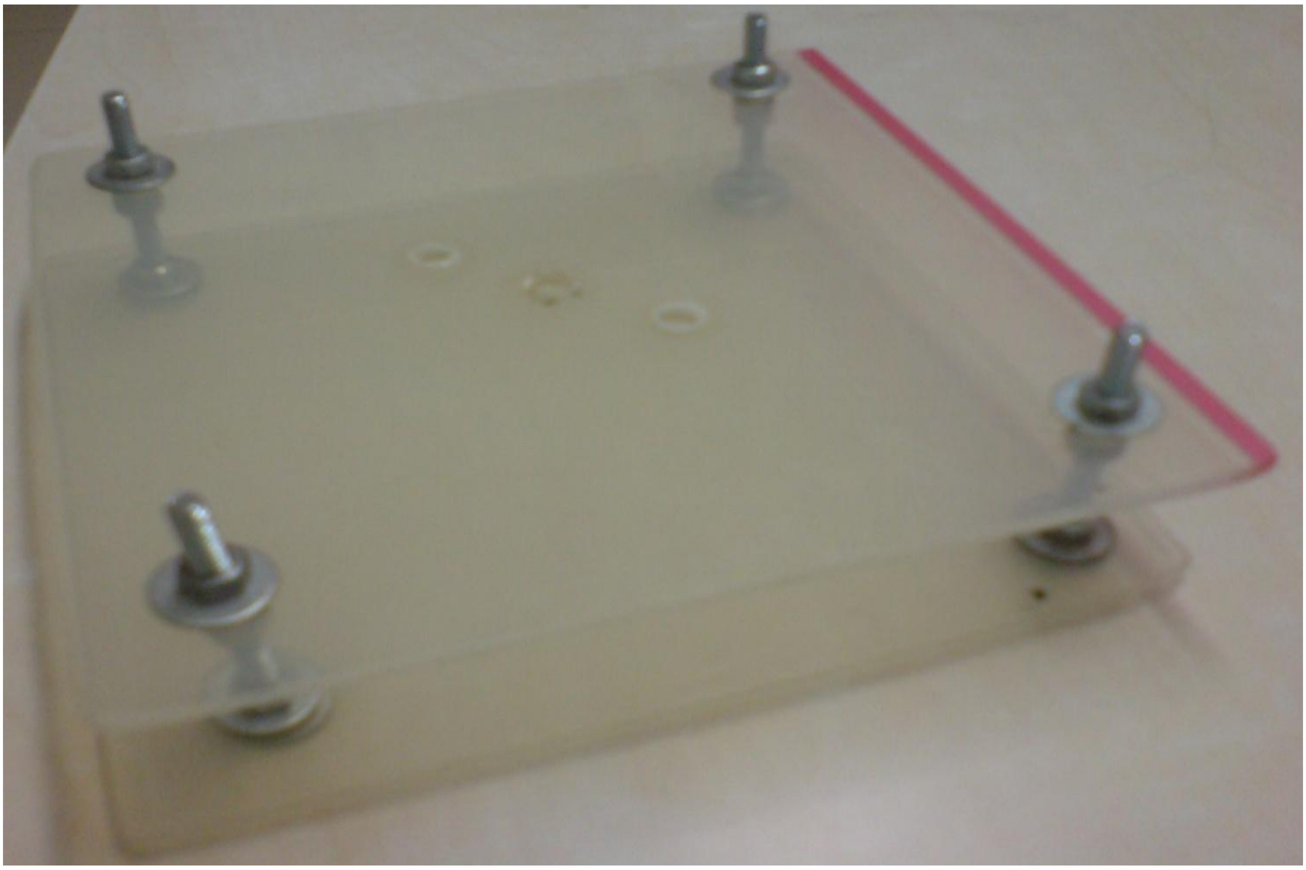

FIG 3.2 – The Platform made with acrylic sheets

Uni-polar stepper motors were used. The motors were available with a coupling on its shaft which provided the basis for further attachment to them. Instead of using already available parts and modifying them to our requirements (like LEGO, MEHCANIX, etc) we opted for manufacturing of our own bases. An advantage of manufacturing the bases was that the base so fabricated would meet our specifications perfectly and there would not be any unnecessary degree of freedom in the coupling of the base and the shaft. The material chosen was Nylon in cylindrical shape over its Aluminum counterpart due the cost issues. Previous working experience on Lathe machines greatly helped us getting the required bases ready from the Institute's Mechanical Workshop.

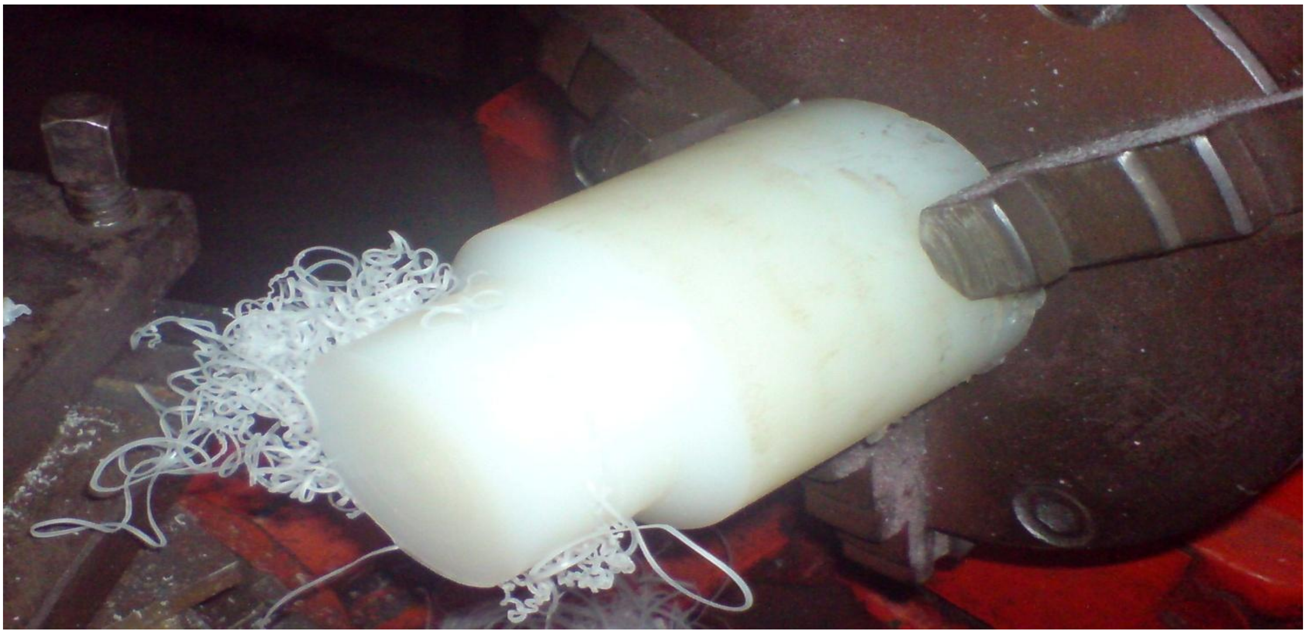

FIG 3.3 – Lathe work on nylon bases

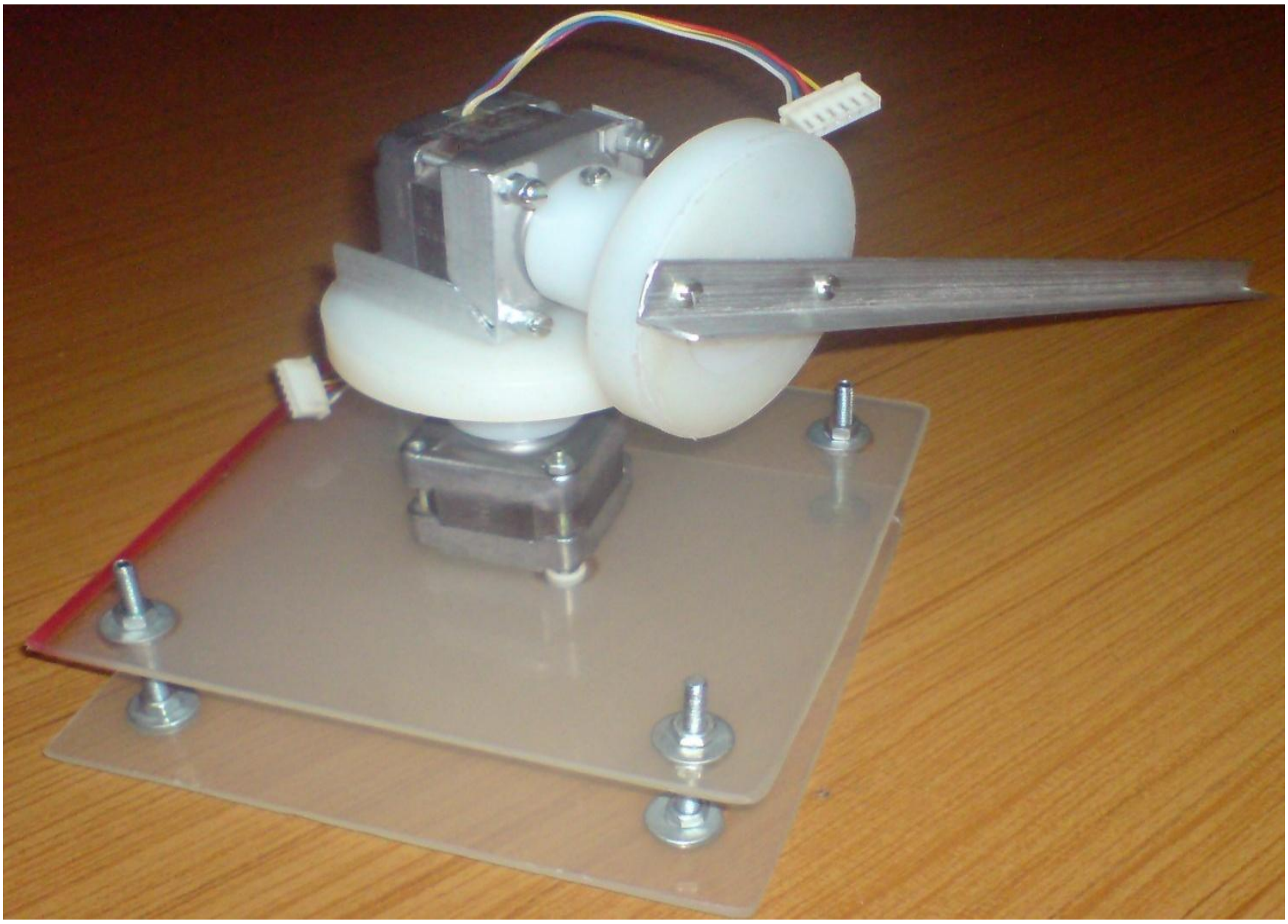

FIG 3.3 – Final Mechanical Assembly

3.2 Electrical Components

A list of the major components required is provided in table 1.

Table 1 – List of Major Electrical Components required

Component	**Actual Package used**
Input Module (image sensor)	Kodak KAC- 9619 CMOS Image Sensor
Microcontroller	ATMega 32L
Motor drivers	L293D
Motors	Uni-polar stepper motors

3.2.1 Image Sensor

Kodak's CMOS KAC-9619 Colour Image sensor (648 X 488 active pixels) was used as an input module. After studying the datasheet for the sensor, many salient features were known. Some of them are listed below:

i) Single supply:3.3V +/-10%

ii) Maximum Frame Rate: 30fps

iii) Video and Snapshot operations

iv) Programmable pixel clock, inter-frame and inter-line delays

v) Windowing Mode

vi) 12-bit digital video data output through on- chip 12- bit A/D convertor, fixed pattern noise elimination circuits and video gain and separate colour gain amplifiers.

The Image sensor requires for its operation various clock signals which are derived internally from a master clock, Mclk. The range for Mclk is 12 to 48 MHz. A 12 MHz Mclk was chosen to minimize the effects of high frequency disturbance. The pin diagram of the image sensor is given in section A.1

A clock generator circuit was designed to give an output clock (12 MHz) to the image sensor. The circuit diagram is given in section A.2.

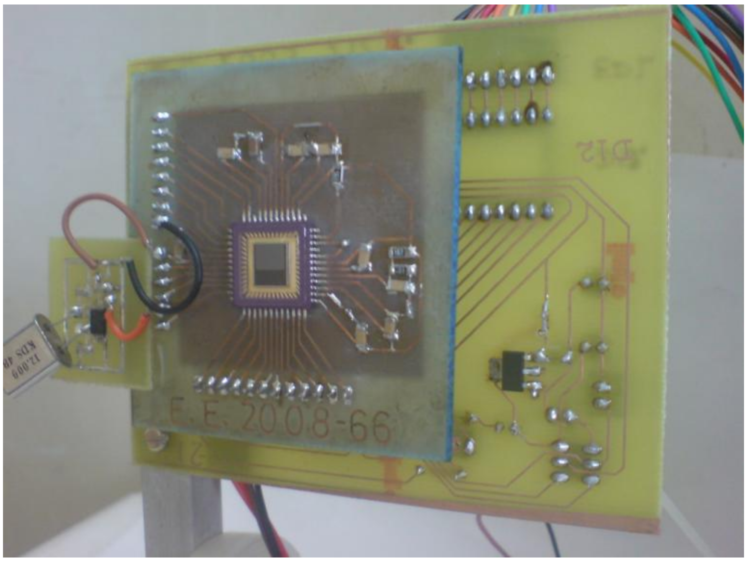

FIG 3.4 – Image Sensor

3.2.2 Micro Controller

ATMega 32L was chosen as the micro-controller for the project. Some of the salient features which governed the decision were:

- More Number of ports
- Appropriate amount of memory for image storage
- Variable supply voltage (2.7 V – 5 V)
- Maximum frequency of 8 MHz at 3.3 V
- Cheap
- Availability of TWI
- Availability of UART

The pin diagram of ATMega 32 is given in section A.3

3.2.3 Motor Driver

The choice for motor drivers was between L293D, ULN2003 and L298N. ULN2003 could source maximum current up to 500 mA while the same for L293D and L298N were 600mA and 2000mA respectively. The coils of the unipolar stepper motors required current of about 200ma (with no load) and about (550 mA). ULN2003 was opted out because of current requirements. Using L298N was also ruled out since it required external 1A diodes to be attached for each motor channel, the total number of diodes going to 8. Hence L293D seemed a better choice. Pin diagram of L293D is given in section A.4

3.3 Coding Unit – Programming-cum-testing board

The Coding Unit consists of a programmer-cum-testing board for the microcontroller to load and test the different codes. After going through much of the different types of programmer board configurations, we ultimately settled with AVR Parallel Port Programmer Board. The number of components required in the parallel port programmer board was less, and the design was easier as compared to other programmers. Availability of a PC with a parallel port and easy availability of components were the main motivating factors that guided the choice. The circuit diagram of the coding unit used is given in section A.5.

4. TESTING AND FUNCTIONING

4.1. Key Features

The image sensor has an active pixel array of 648 (H) x 488 (V) pixels and it supports windowing mode. Hence a window of 100 x 100 pixels was used. This was done in order to decrease the amount of computation required at the cost of decrease in quality of image obtained. Presently the only constraint on the size of the target is that the area which it covers on the screen of image sensor must be comparatively much larger than the noise in the output of image sensor for reasonable accuracy. This places a limit on the radial distance over which the target tracker can work effectively. The computation speed places a constraint on the speed of the target. As per the master clock, line delays and the crystals used, the fps works out to be around 2 fps. Therefore the time for each frame is 0.5 seconds. The constraint on the target speed for effective tracking being that the distance from the center of the sensing area to the edge of the sensing area should not be covered by the target in less than 0.5 seconds. Also, the minimum step angle of the motor in half-stepping mode is 7.5 degrees. This makes the minimum sweep in vertical or horizontal direction to be 7.5 degrees. Wires are used to connect the stepper motors and the turning of the motors causes a twist and strain of the wires. This places a physical constraint on the maximum sweep angle to be 90 degrees. The screen has been placed at a distance of 50 cm from the axis of the motor and is of size 100 cm x 100 cm. The pixel area works out to be 1 cm^2. Hence

Minimum step in terms of pixels
= (7.5 degrees/step)*(100 pixels) / (90 degrees)
= 8.34 pixels/step

Number of steps required for full sweep
= (90 degrees/ full sweep) / (7.5 degrees / step)
= 12 steps / full sweep

4.2. Algorithm Development and Testing

The product has been designed with the following points in mind:

- We consider that the environment in which the product is to be used is well-illuminated and not highly noise prone
- The area is movement-free and any movement of any kind is undesirable. Any moving object is to be regarded as a target.
- At a time, there is only one target in the area. The system is incapable of tracking multiple targets. However, in case of multiple targets, the system would move towards the target with larger size

We take the image as an N x N matrix of pixels. The first image is taken as the reference image. The next image (another N x N matrix) is compared pixel by pixel with the reference image and a new N x N matrix is created. If the same pixel (within some error threshold) is detected, then the corresponding entry of the third matrix is made 0, otherwise 1. Thus, in the new matrix, the 1s' correspond to the target, while 0 corresponds to the background. We find the centroid of this image (represented by the third matrix) with respect to the center of the image and the same is give to the stepper motor code snippet. The stepper motors are moved accordingly.

120	124	89	10	20	30
220	102	134	20	8	34
209	198	145	20	8	5

(A)

120	124	189	110	120	30
220	102	34	120	18	34
209	198	45	120	28	5

(B)

0	0	1	1	1	0
0	0	1	1	1	0
0	0	1	1	1	0

(C)

Fig 4.2: (a) Image 1 (Black = Object) – reference image, (b) input image, (c) third image constructed by XORing (A) and (B) [value in cell is value of colour]

The test condition consists of tracking a slowly-moving black object on a completely white screen. The lighting all over the screen should be uniform. For testing, instead of XORing two images, we can do hard thresholding; as the image is in pure black and white. Thus we would get a 100x100 image with 2-symbol representation: symbol 1 corresponding to black (the target) and symbol 2 corresponding to white (the background screen). We find the centroid of the image so obtained and find the distance of the center of the frame to the centroid. Then the sensor itself is moved in Θ and Φ co-ordinates so that the centroid moves to the center of the frame. Thus, we track the centroid of the image.

5. CONCLUSION

We have implemented a simple and cost effective implementation of an image based target follower. Further improvements can be as follows:

- We can include a password entry block on the six port pins' of the microcontroller which are currently unoccupied.
- We can use an external memory and store images in it for later retrieval and review.
- We can include facilities for sounding alarm and alerting people on detection of a target. This would act as a burglar alarm

6. APPLICATIONS

Applications of Target Follower are varied and numerous in fields of defense, surveillance, air traffic control, motion detection, etc.

- **Border Patrolling:** Cross Border Infiltration is a major issue and large part of the army (BSF) is engaged in patrolling the borders. Cameras on the border need constant surveillance by army men and human errors always occur. If the target follower is placed at sensitive locations then it would help the border patrolmen and also reduce the number of soldiers required.
- **Curfews/Prisons:** If the system is activated during curfew time or in high security locations like jails, banks, asylums then any motion can be detected and hence

breakouts/break-ins can be detected without needing to have many security personnel supervising the cameras.

- **Civilian Surveillance:** If such systems are installed in a mall/plaza after closing hours and if some intruder is seen, then all cameras in the mall/plaza will center on the intruder whenever the intruder is in front of a camera.
- **Curbing Crime:** If the system is set to focus on any close by object then the camera will keep focusing on a random person irrespective of whether there is a human operator at the other end or not. This gives an impression of there being a human operator being present at the other end; thereby making would-be criminals think twice before committing a crime. Also this would induce better social behavior as people would believe that they are being "watched".
- **Power Plants/Factories:** At places in power reactors/factories/control rooms where unwanted human/animal presence is not desired, this system can be used effectively to sense presence of any moving object.
- **High Security and Self Targeting Assault Vehicles/Systems:** In high security regions, this system can be employed to detect any motion of any kind. This can also be used in self targeting assault vehicles/systems in high security zones.
- **Air Traffic Control:** If the system is set to monitor the sky in a no flying zone, then any aerial vehicle would be tracked by the system making it easier to spot.

7. REFERENCES

- **Online References**

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  - http://www.homes.cod.ic.ac.uk/~ih/doc/stepper/control2/sequence.html
  - http://www.homes.cod.ic.ac.uk/~ih/doc/stepper/control2/connect.html
  - http://hubbard.engr.scu.edu/embedded/avr/boards/index.html
  - http://www.8051projects.net/stepper-motor-interfacing/programming-microcontroller.php

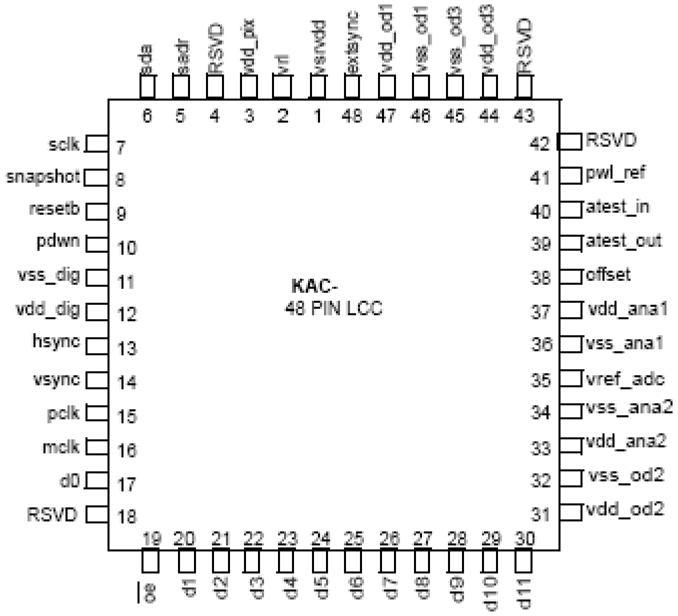
8. APPENDIX

A.

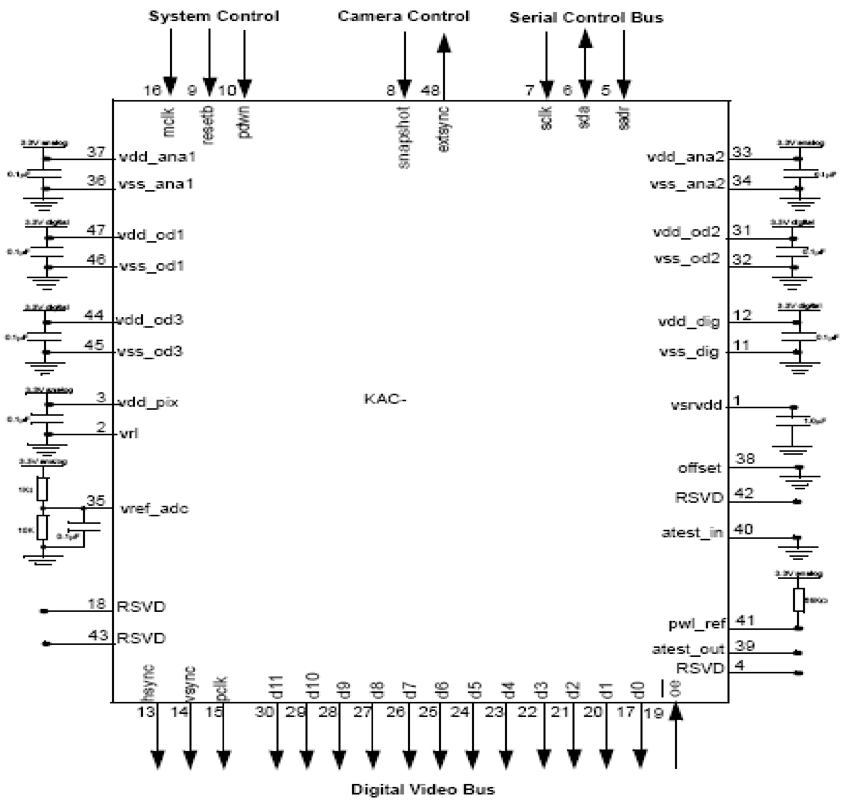
A.1 Image Sensor

(source: Datasheet of Kodak KAC-9619 Image sensor)

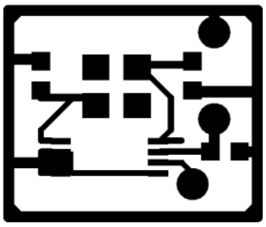
A.1.1 Connection pin diagram



A.1.2 Application pin diagram

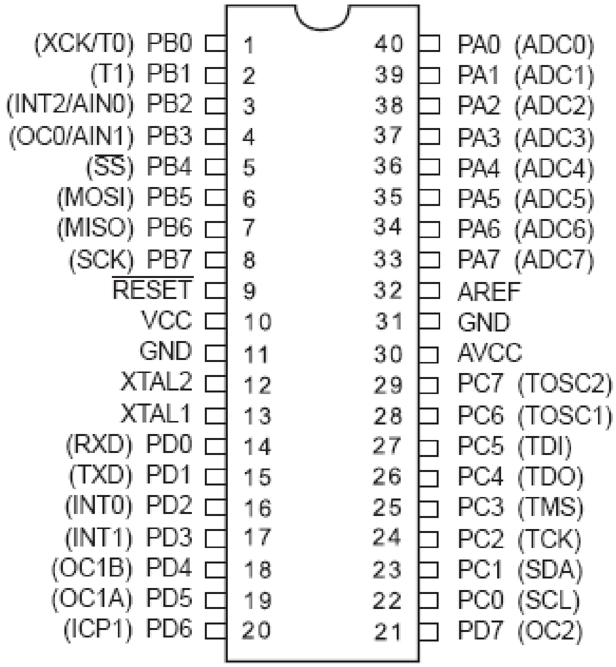


A.2 Clock Generator Schematic



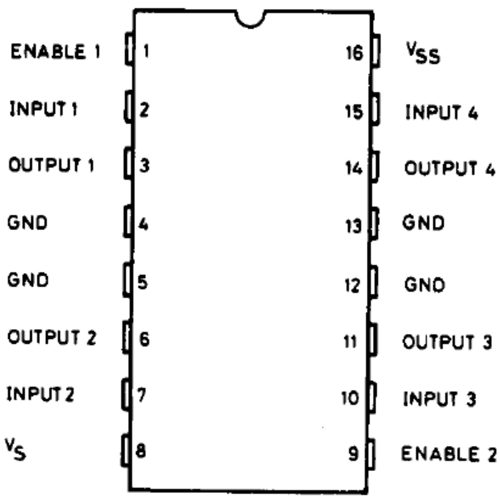
A.3 Microcontroller pin diagram

(source: Datasheet of ATMega 32 Microcontroller)



A.4 L293D pin diagram

(source: datasheet of L293D motor driver)



A.5 **Coding Unit (Parallel port programmer-cum-testing board)**

(source: http://kartikmohta.com/tech/avr/programmer/avr_programmer.png)