# OBSTACLE DETECTION SYSTEM

# FOR RAILWAYS

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Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science

Department of Electrical Engineering

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July 2015

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# ABSTRACT

Trains are one of the oldest transportation systems used in the world. The first steam locomotive was built by Richard Trevithick and first commercial use was on the narrow gauge Middleton Railway in Leeds in 1812. There onwards with the development of railway transportation, locomotives improved in design from steam, diesel powered, electric and to hybrid during two centuries. With the development, more economical high speed locomotives have been introduced to the world.

Every transportation system consists of advantages and disadvantages to the public. The accidents are the most disadvantageous gain from the transportation systems. The railway transportation is one of the conventional system subjects to many accidents annually in most of the countries. High speed locomotives, insecure railway crossing, impatience vehicle drivers and animals are some factors to increase the railway accidents time to time. Comparatively to other transportation systems, accident preventive methods of locomotives are not in best use due to following reasons;

1. Noticing an obstacle on the railway at the correct time.

2. Identifying the braking distance for sufficient braking.

3. Limitation of braking due to derailing of locomotives from the railway.

4. Braking methods used are conventional types due to its complexity.

Therefore, there is a necessity for improving accident preventive methods in locomotives and image based obstacle detection system with driver assisting capabilities is proposed in this research. The objectives of this research are;

1. Design and development of a driver assisting interface with sensing mechanism to detect an obstacle and obtaining minimum distance to stop the locomotive.

2. Development of the overall system and validation.

The prototype comprises with two web cams, personal computer, arduino (UNO) hardware, and a servo motor.

One web camera (side camera) will be mounted to the side window of the locomotive cabin to capture images perpendicular to locomotive motion and the other camera (front camera) will be mounted on the front of the engine focusing the railway and will change its yaw angle by the servo motor connected through controller (arduino (UNO)) hardware to the personal computer.

Further, the front camera detects obstacles using a MATLAB program installed in the personal computer. The detection will be declared by beeping of an audible alarm where driver will be acknowledged the danger of hitting the obstacle instantly and by braking manually, the deceleration can be measured by another MATLAB program by processing the images taken by side camera and yaw of the front camera will be adjusted automatically. Increasing the braking gradually to move the obstacle from the danger zone to the safe zone shown in the front camera images and muting the audible alarm automatically, the locomotive can be stopped without hitting the obstacle.

The system was tested to a normal vehicle and to certain extent of trains since the limitations in testing the system in locomotives in Sri Lanka Railways and found to be satisfactory.

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# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| A.H.V.D | Horizontally- Vertically Different Powered |
| a | Acceleration ( $m/s^2$) |
| B.G. | Broad Gauge |
| CCTV | Closed- Circuit TeleVision |
| COM | Communication Port |
| CPU | Central Processing Unit |
| C1 | Factor to convert kmph to m/s (C1= 0.27777777777778) |
| E | Global Energy Functional |
| F | Focal Length |
| FOE | Focus of Expansion |
| GND | Ground |
| GPRS | General Packet Radio Service |
| HDTV | High Definition TeleVision |
| h | Hieght of the front camera center to ground level |
| ICSP | In- Circuit Serial Bus |
| $I_t$ | Derivative of the image intensity along time |
| $I_x$ | Derivative of the image intensity along x axis |
| $I_y$ | Derivative of the image intensity along y axis |
| K | To convert radian angle to degree angle (K = 57.29577951) |
| LPT | Line Print Terminal |

# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| l | Length from Front Camera Center to considered Sleeper |
| N | $N^{th}$ frame |
| n | $n^{th}$ frame |
| P | Principle Point |
| PWM | Pulse With Modulation |
| RAM | Random Access Memory |
| R’G’B’ | Additive color module, Red, Green & Blue |
| s | $s^{th}$ distance where V=0 |
| U | Velocity of an object at the starting of $s^{th}$ distance |
| USB | Universal Serial Bus |
| u | Horizontal optical flow |
| V | Velocity of an object at $s^{th}$ distance |
| v | Vertical optical flow |
| w | Speed of the Locomotive |
| YUY2 | FOURCC Code for identifying a digital, color- difference component video picture format |
| Y’ | Component of Gamma corrected R’G’B’ |

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# 1.INTRODUCTION

A target of implementing an accident prevention method for the railway locomotives is considered in this thesis. Since locomotives are very predominant transportation method in Sri Lanka, improvement of accident prevention is vital. Comparatively, to prevailing other methods of transportation such as buses, cars, aircrafts and ships, the development of accident preventive methods for locomotives are very few. During past few decades, few researches have been performed in this area and obtained quite successful results.

## 1.1 Literature Review

For first literature review, a study of moving obstacle detection at railway crossing by machine vision has been considered.

This study designs an advanced safety system for obstacle detection by machine vision at railway crossings. The schematic diagram of this system is shown in Fig 1.1. A CCD camera installed at a crossing continuously captures images of vehicles passing over the tracks. When a train approaches, the system constantly transmits the live video feed of the crossing to the locomotive's cab and processes the images to see if there is any obstacle within the crossing boundaries. If such is the case, an alarm signal is promptly sent to draw the engineer's attention. Therefore, the engineer can initiate appropriate measures according to the monitored scene of the crossing ahead. [16]



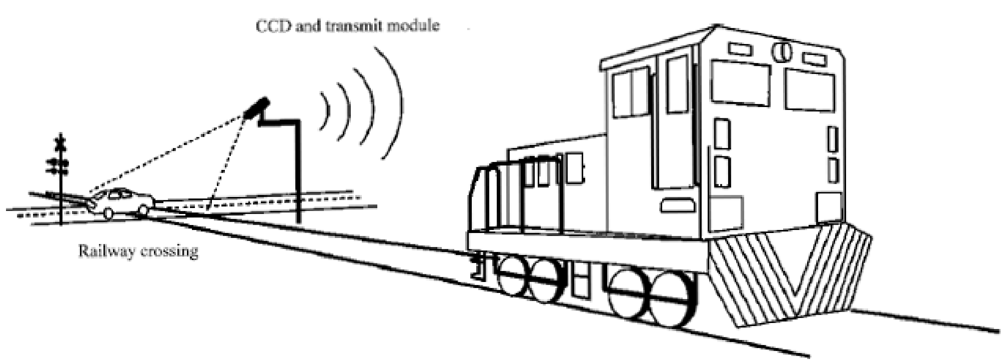


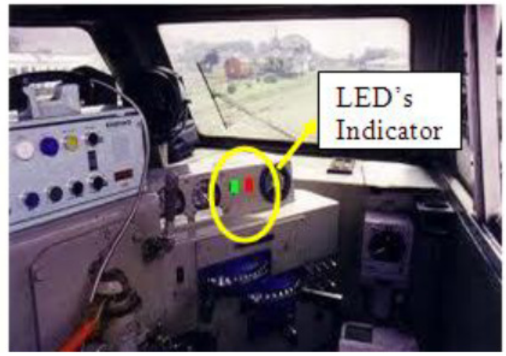

**Fig 1.1 Schematic diagram of the obstacle detection system at a railway crossing**

For second literature review, the design concept of train obstacle detection system in Indonesia has been considered.

The object detection sensor is mounted on the front of the train head and detects obstacles while moving forward. When the train is shifted into forward, the system is armed. Inside the driver room there are 2 LED display the illuminates (green and red), the green LED indicates that obstacle is not detect although the red LED indicates that an obstacle is within the range of the object detection sensor shown in Fig 1.2 A & B.

The object detection sensor is using the infrared range finder system. The Infrared range finder works by emitted and reflected back (or not reflected at all).The light reflected back at an angle that is dependent on the distance of the reflecting object. The reflected light signal are collected by lens and focused onto a photodiode inside the sensor unit. The reflected light shift phase is compared with the reference signal. From the number of shift phase, a required distance is calculated with good accuracy (Fig 1.2 C).[01]


(A)




(B)



**(C)**

A. **The Object Detection Sensor Location**

B. **The Location of LED Indicators**

C. **Object Detection Sensors System**

**Fig 1.2 Sensor Locations & LED Indicators of Train Obstacle Detection System in Indonesia**

As the third literature review, a railway scout was considered.

The railway scout was designed as a concept for reducing railway accidents. A robust scout was sent in front of the locomotive engine distance ahead as shown in Fig 1.3 to identify any obstacle ahead the travelling locomotive. Front and side cameras have been placed in the scout and it transmits the live videos of the surroundings to locomotive engine driver to identify any obstacle ahead the railway. [02]

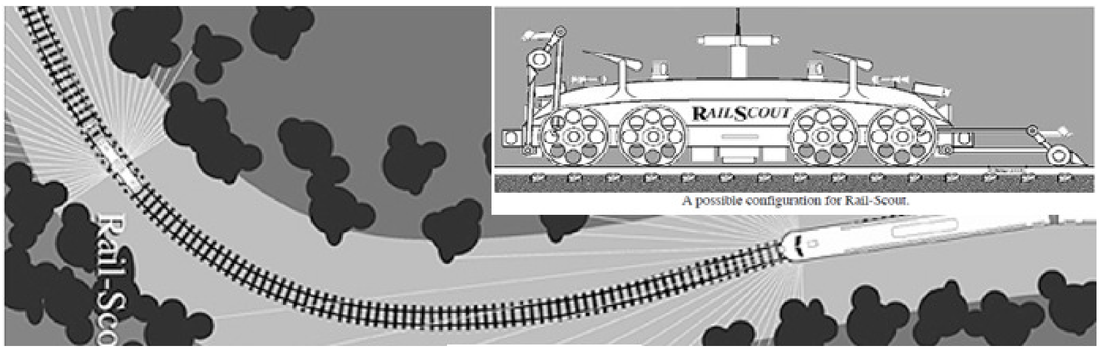



**Fig 1.3 Rail Scout**



As the fourth literature review, collision detection and avoidance in railway using Wi MAX (Worldwide Interoperability for Microwave Access) has been considered.

This paper proposes an approach that is efficient in all the way. The approach will make use of WIMAX base station for sending and receiving the information about locomotives to prevent collision. A locomotive will also send information to calculate difference among them. A computer equipped with WiMAX would receive data from the WiMAX transmitting station, probably using encrypted data keys to prove unauthorized users access. The locomotive will enable WiMAX and find its location with reference to fixed WiMAX base station placed parallel along the track, whose position is known. The fixed base station broadcast messages periodically and WiMAX enabled laptop/tablets fitted in the train use to communicate and can receive information about surrounding and the status of other locomotives. When the locomotive comes in its vicinity or range the base station it sends its information about itself and takes information of other train's to know about the surrounding. This way all the locomotives can get updates about others and collision can be prevented and system will work smoothly. Fig 1.4 shows the data transferring of locomotives running on same track on same direction. [17]

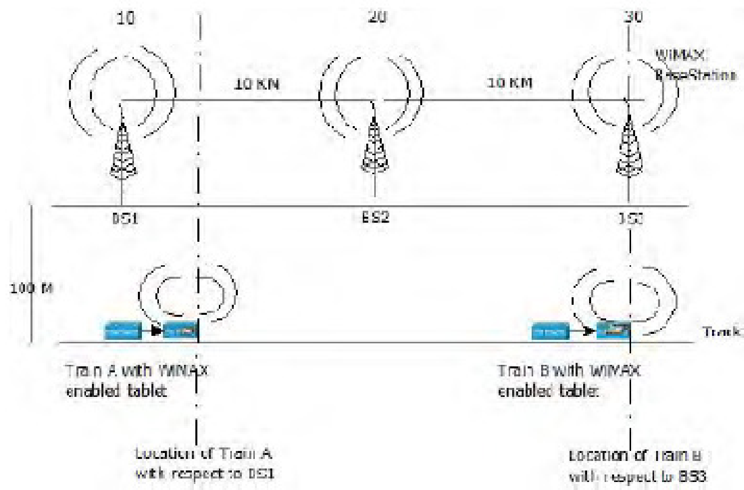


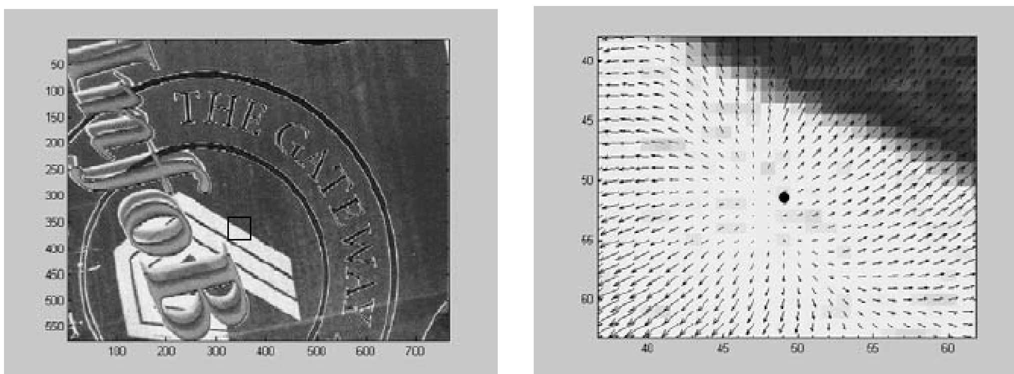

**Fig 1.4 Representation of locomotive's running on same track and in same direction**



As the fifth literature review, a study based on finding the focus of expansion has been considered.

The *focus of expansion* plays an important role in many vision applications such as three-dimensional reconstruction, range estimation, time-to-impact computation, and obstacle avoidance. Most current techniques are based on correspondence or on accurate flow estimation and are therefore considered computationally heavy. In this paper an efficient technique has been presented to find the focus of expansion from optical flow. The technique utilizes a specially designed matched filter that does not require an exact estimation of the optical flow but rather can use a low-quality estimation of it. In addition, based on the location of the focus of expansion and its immediate neighborhood, the paper suggests a way to estimate the range to the focus of expansion. Based on the experimental results, the technique has proved to be both accurate and efficient.

The fifth experiment of this thesis demonstrates range estimation. Fig 1.5 shows the result of the application of the technique to an optical flow image of a camera moving toward a scene. The scene is depicted by Fig. 1.5 A. The size of the image is 576 × 768, and the FOE was estimated using a filter of size 21 × 21. Figure 1.3 B shows the neighborhood of the resulting *FOE* = (378, 363) with 1000 iterations. [10]




(A) (B)



**A.** The neighborhood of the estimated *FOE* = (378, 363) is marked by the *black box.*

**B.** A neighborhood around the estimated FOE. The FOE is marked by a *black dot*

**Fig 1.5 Camera moving towards the scene**

As the sixth literature review, segmentation of moving objects by long term video analysis has been considered.

Motion is a strong cue for unsupervised object-level grouping. In this paper, it is demonstrated that motion will be exploited most effectively, if it is regarded over larger time windows. Opposed to classical two-frame optical flow, point trajectories that span hundreds of frames are less susceptible to short term variations that hinder separating different objects. As a positive side effect, the resulting groupings are temporally consistent over a whole video shot, a property that requires tedious post-processing in the vast majority of existing approaches. It is suggested working with a paradigm that starts with semi-dense motion cues first and that fills up textureless areas afterwards based on color. This paper also contributes the Freiburg-Berkeley motion segmentation (FBMS) dataset,a large, heterogeneous benchmark with 59 sequences and pixel-accurate ground truth annotation of moving objects. [14]

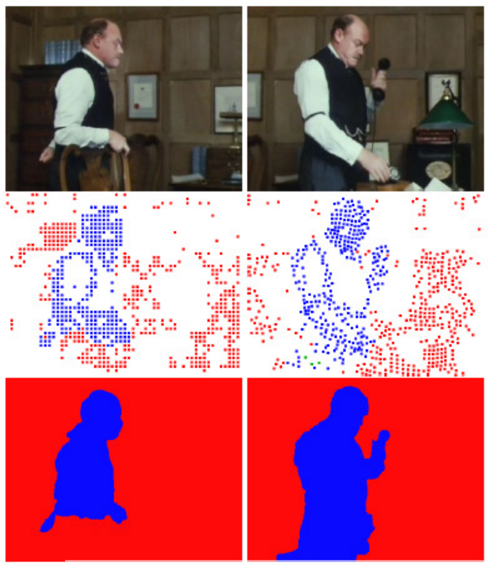


**Fig 1.6 Top:** Two images from a video shot. Color based segmentation would not provide object regions. **Center:** Clustering of point trajectories indicates regions with similar motion. **Bottom:** Segmentation based on these clusters provides object regions.



As the seventh literature review Multiple View Geometry in Computer Vision has been considered.

According to this review, camera calibration should be done to find the location of the image of the absolute conic in an image.

Further, camera matrix can be obtained for a plane z = 0 by,

$$\begin{pmatrix} x \\ y \\ w \end{pmatrix} = \begin{bmatrix} \text{camera matrix} \end{bmatrix}_{3x3} \begin{pmatrix} X \\ Y \\ T \end{pmatrix} \quad [18]$$

**Summary of Literature Reviews**

The first literature review uses a CCTV at each and every railway crossing to capture videos of vehicle movement across the railways. The system implementation is costly since many CCTVs will have to installed and analysis of videos for obstacle detection is very complex to send details to the nearest locomotive engine within a short period to aware obstacles.

The second literature review uses a infrared range finder which works by emitting and reflecting back (or not reflecting at all) the light. The accuracy of the system is much considerable. The advantage of having this system is to trace the distance of the obstacle lying ahead accurately. However, the disadvantage of this system is the emitted light goes and hits on a certain portion of a vertical plane where obstacle is at and if the obstacle is out of range, cannot be detected. Further, only rays have been used, obstacles cannot be identified.



The third literature review uses a railway scout to send signals to locomotive engine. Since the railway scout moves keeping several meters away from the locomotive engine, obstacles can be tracked early before hitting and hitting can be avoided. However, malfunctioning of scout or failures of transmitting signals due to bad weather can create unexpected situations of detecting obstacles far ahead along the track.

The fourth review shows the importance of adopting WiMAX for to send data among locomotives to prevent collisions. However, this system can only be used to avoid collisions of locomotives travelling along the same railway.

The fifth review is on the focus of expansion while travelling towards the objects. This is a very important finding for the present thesis where a front camera is used to detect obstacle while moving towards the obstacle. Further, this is advantageous to identify motion segmentations since different motions of objects have different focus of expansions.

The sixth review is the findings on motion segmentation for moving objects. This review assisted to analyze the present thesis's live video clips received from front camera and side camera for motion segmentation.

The seventh review is the multiple view geometry in computer vision. This review is very important to perform the camera calibration on cameras and to obtain focal length, principal point, skew, distortion and pixel error of a camera.

## 1.2.Motivation and Specific Objectives of the Thesis

### 1.2.1 Motivation

For this thesis, a driver assisting image based obstacle detection system will be considered. Mostly, the design will be based on theories of image processing, servo motor control and MATLAB programs.



### 1.2.2 Specific Objectives

The specific objectives of the thesis are;

1. Design and development of a driver assisting interface with sensing mechanism to detect an obstacle and obtaining minimum distance to stop the locomotive.

2. Development of the overall system and validation.

## 1.3. Sri Lanka Railway

### 1.3.1 Statistics of Railway Accidents

The railway accidents are recorded annually and number of accidents for corresponding years are tabulated in Table 2.1. According to Table 1.1, it is above 30 from year 2000 to year 2011 except for year 2001. It is almost twice than 2008 in 2012.

Most of the accidents can be categorized into following three categories;

1. Accidents without driver's notice.
2. Accidents with driver's notice and not enough time for braking.
3. Accidents with malfunctioned brakes.

Hence, 95% of accidents have been occurred due to No.1 & 2 of above categories.

Further, Table 1.2 compares the occurrence of accidents with its type for two consecutive years 2010 and 2011.



Currently, Sri Lanka Railway uses GPRS system to communicate locomotive drivers to inform obstacle ahead the engine to apply sufficient brakes to avoid accidents. This method is useful to alert drivers about an existing obstacle on a railway for some period.

**Table 1.1 Statistics of Annual Railway Accidents from Year 2000**

| Year | No. of Accidents |
|---|---|
| 2000 | 53 |
| 2001 | 07 |
| 2002 | 30 |
| 2003 | 55 |
| 2004 | 31 |
| 2005 | 60 |
| 2006 | 60 |
| 2007 | 65 |
| 2008 | 43 |
| 2009 | 66 |
| 2010 | 75 |
| 2011 | 82 |
| 2012 (till August) | 84 |

**Table 1.2 Sri Lanka Railway Administrative Report 2011**

| | Accidents | 2010 | 2011 |
|---|---|---|---|
| a) | Collisions | 5 | 5 |
| b) | Other mishaps (such as trailing through points, damage to points) etc., | 8 | 8 |
| c) | Collisions with road vehicles at level crossings | 75 | 82 |
| d) | Cattle run over and killed | 11 | 28 |
| e) | Elephants knocked down and killed | 4 | 6 |
| f) | Terrorist activities | 0 | 0 |



### 1.3.2 Railway Types in Sri Lanaka

Sri Lanka Railway uses mostly B.G. (Broad Gauge) railways. The standard rail curvature used for B.G. railways are shown in Fig 1.7. The maximum degree of curvature for B.G. railways is $10^{o}$ for a minimum radius of 175m.

Further, the most of the railways in Sri Lanka are straight. Therefore, implementing a driver assisting image based obstacle detection system for the Sri Lanka Railway is much convenient to improve the railway safety.

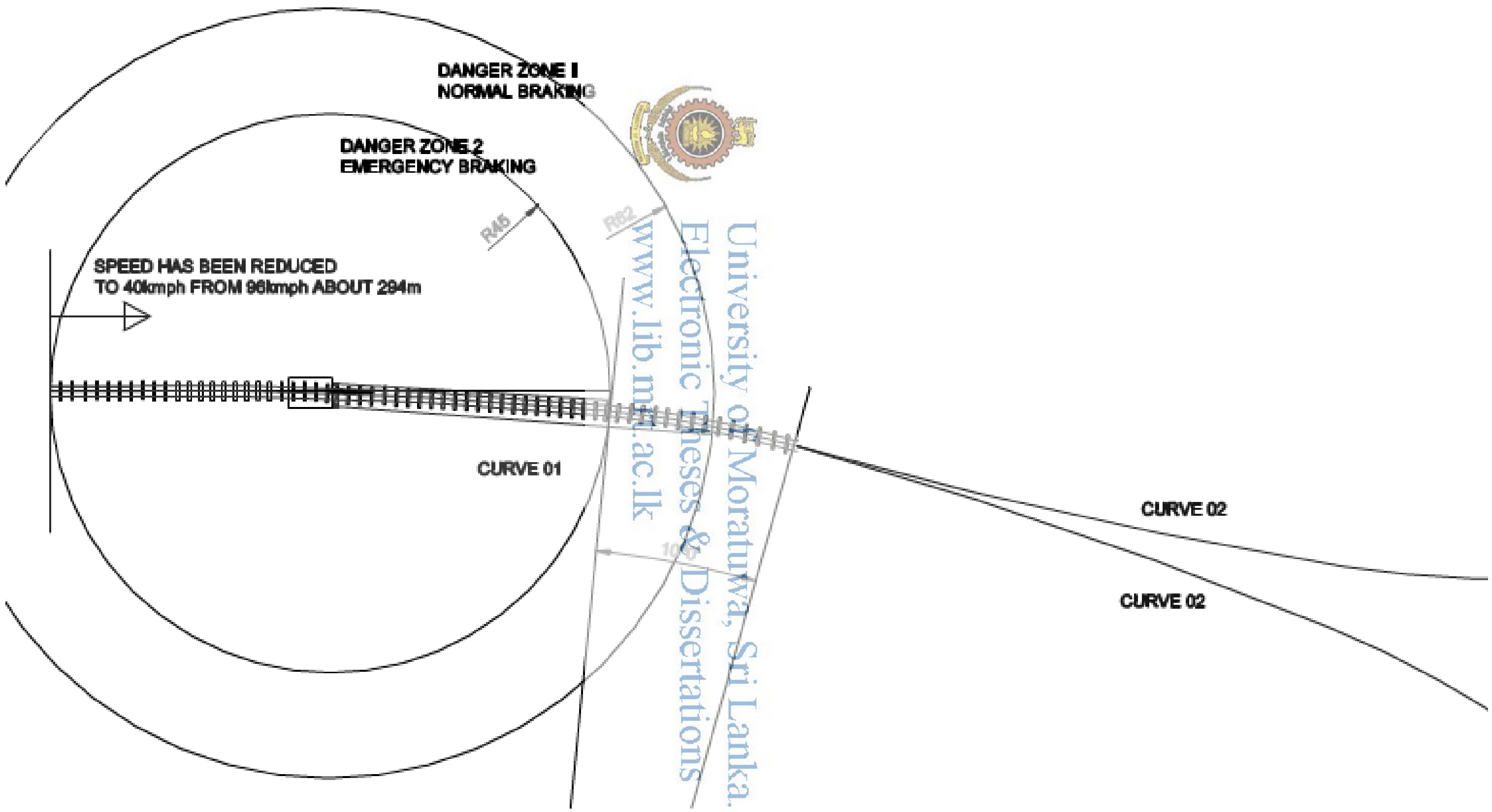





**Figure 1.7 Broad Gauge Railway Curvatures**

# 2.DESIGN OF OBSTACLE DETECTION SYSTEM FOR ASSISTING DRIVERS

## 2.1 Concept of the Design

A detection of an obstacle from a locomotive front camera will be carried out within a fraction of a second and a beep will be alarmed to warn the driver as shown in Fig.2.1. The locomotive will be braked by the driver manually as much as possible. The front camera yaw will be determined by considering the decelerations of the locomotive based on the images of the perpendicular motion. The front camera will be then focused automatically to the new yaw by the servo motor coupled to computer via Arduino (UNO) hardware. If still the beep sound heard, the obstacle is in danger zone and the driver will have to apply more brakes. The procedures should be repeated till the beeping disappeared. Fig.2.2 shows the flow chart of the obstacle detection system.



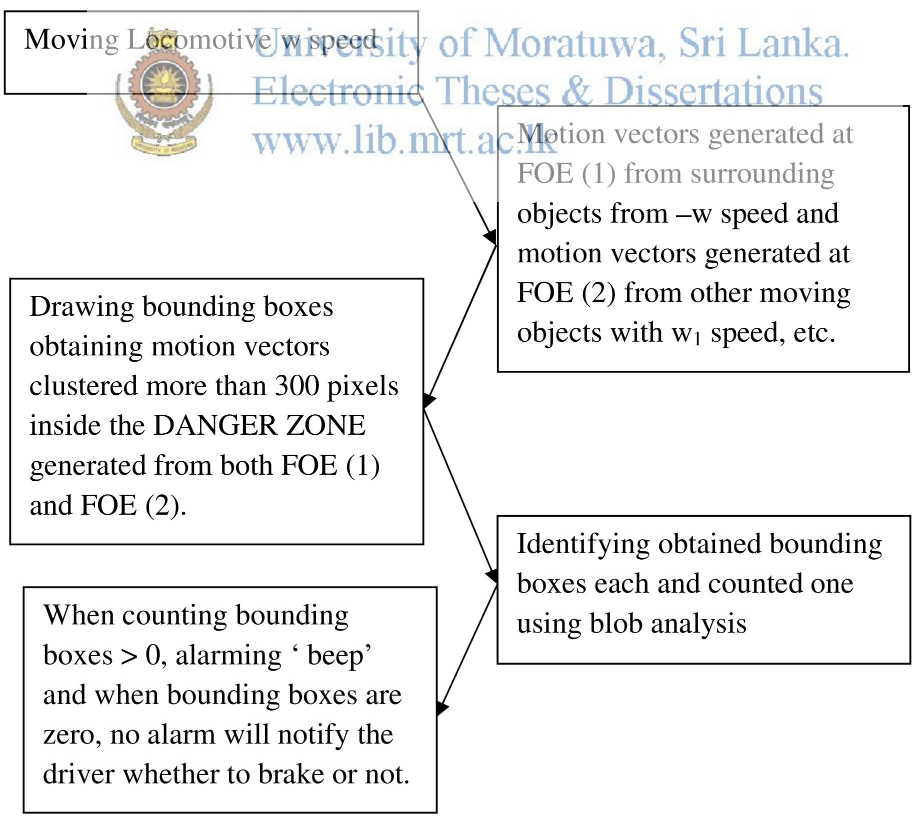



**Fig 2.1 Detection of Obstacle at DANGER ZONE and alarming**

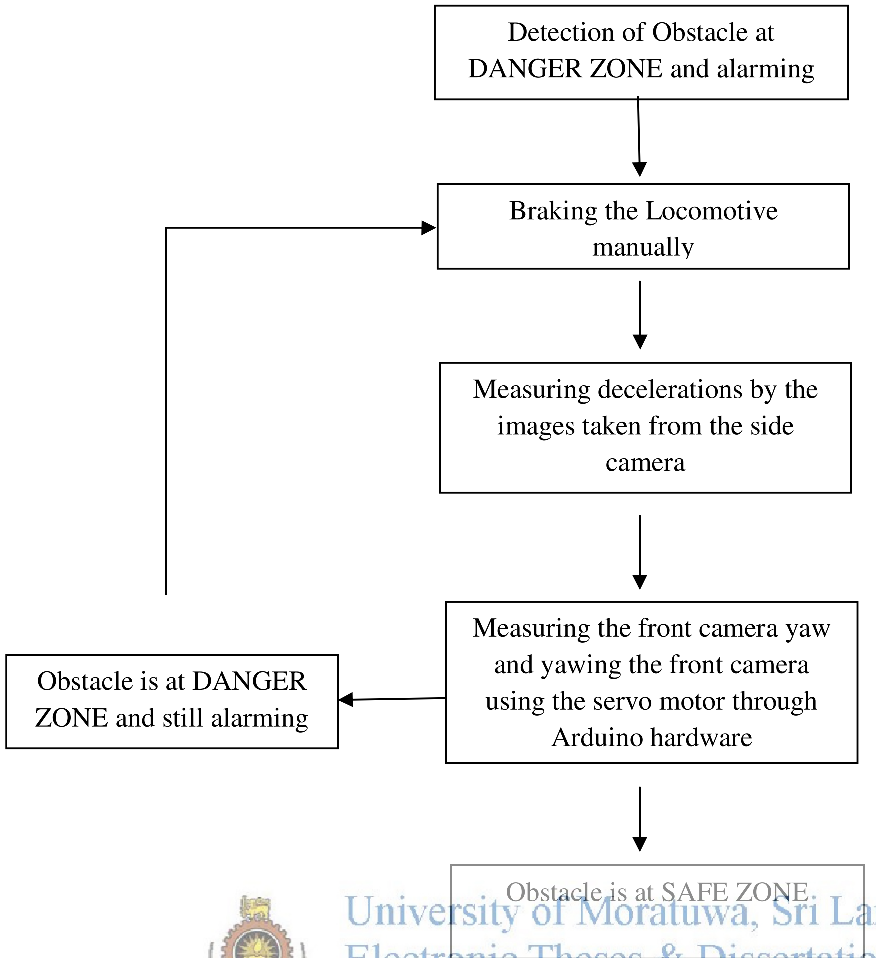





**Fig 2.2 Functional Flow of the Proposed System in Assisting Driver**

### 2.2 System Overview and Major Components

The major components of the design are,

1. Front Camera
2. Servo Motor
3. Arduino Hardware
4. Personal Computer
5. Side Camera

Assembled system is shown in Fig 2.3 & Fig 2.4.

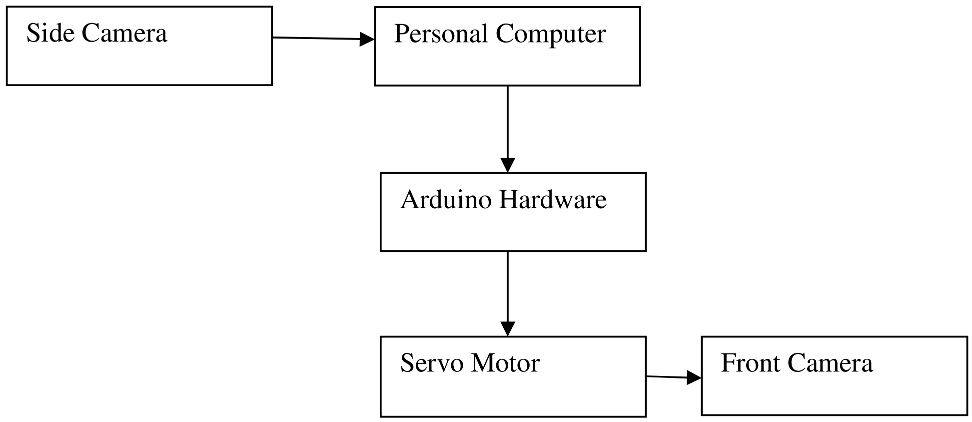



**Fig 2.3 Hardware Connection**



**Fig 2.4 Built up Model Assembled in Locomotive Engine 861 of Sri Lanka Railways**

### 2.2.1 Front Camera

Front camera (Fig 2.5) is a robust camera which can be used to rotate along horizontal axis by varying its yaw. For the modeling purpose a web cam has been selected. However, a CCTV camera [13] should be adapted as the front camera to capture high definition videos for image processing work.

The robust camera base is firmly mounted on the dash board of the locomotive engine cabin. MATLAB Simulation 01 is used to process the videos captured by the front camera to detect obstacles. The detection of obstacles and alarming using MATLAB Simulation 01 is explained in detail in section 2.4.1. The front camera is connected to simulink block “ Input 1, From Video Device” of Image Acquisition Tool Box.

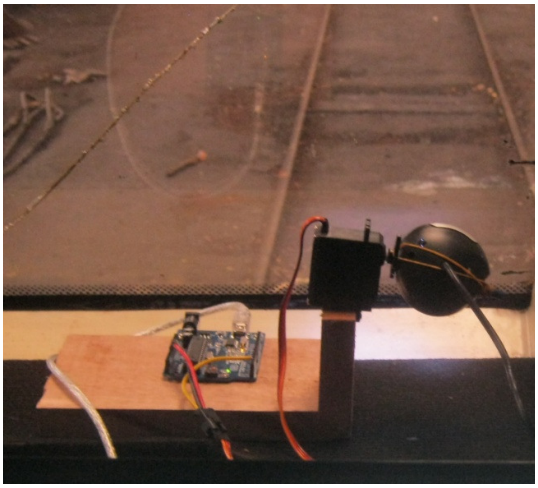


**Fig 2.5 Front Camera**



### 2.2.2 Servo Motor

A servo motor (Fig 2.6) is used to change the yaws of the front camera. Relevent signals for changing the yaw of the camera are fed by the MATLAB Simulation 03 which will be explained in detail in section 2.4.3, through Arduino (UNO) Hardware.

The identification of the servo motor used is;

TowerPro SG-5010 (Double ball bearing)

The servo motor has three wires. Wires can be identified as follows;

Brown wire : GND (ground)

Red wire : + 5V

Orange wire : control signal

Above wires are connected to Arduino (UNO) as follows;

Brown wire : GND (ground)

Red wire : + 5V

Orange wire : 2

The control signal which is a pulse-width modulation (PWM) fed to the servo motor through Arduino (UNO) hardware according to the angle assigned from MATLAB Simulation 03 during braking of locomotive engine.

Minimum: 1 millisecond corresponds to $0^o$ rotation angle

Maximum: 2 millisecond corresponds to $180^o$ rotation angle

Any length of pulse in between above will rotate the servo shaft to its corresponding angle. Fig 2.7 shows the servo motor angles with their corresponding durations.

The simulink block of "continuous servo write" with pin 2 has been selected for the MATLAB Simulation 03 to integrate servo motor with the MATLAB Simulation 03 through Arduino (UNO) hardware.




**Fig 2.6 Servo Motor- TowerPro (SG-5010)**

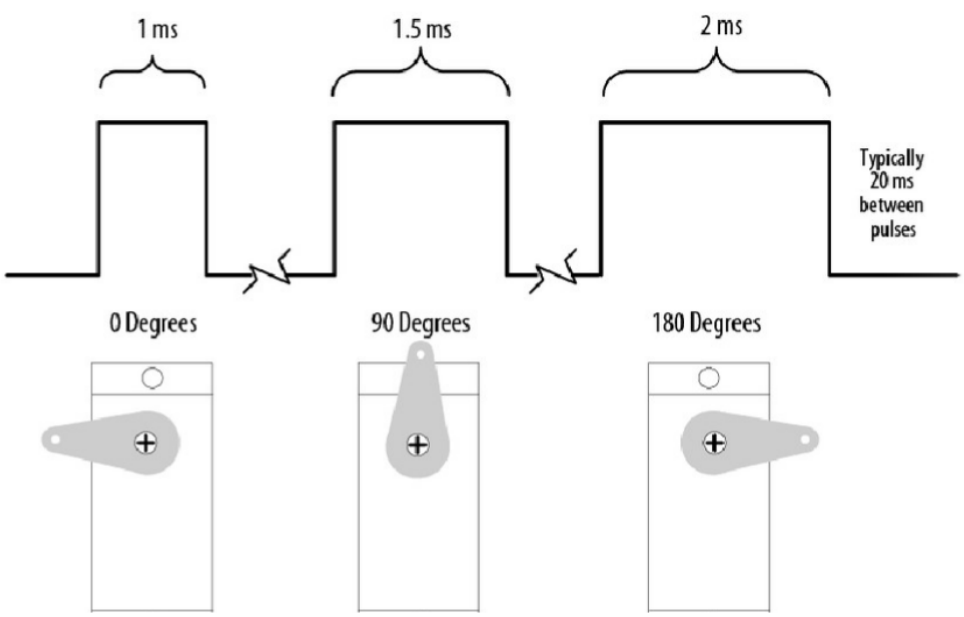



**Fig 2.7 Servo Motor Angles and Corrosponding Durations**

### 2.2.3 Controller: Arduino Hardware (UNO)

Lakduino (UNO) Rev4 has been used as Arduino Hardware (UNO). This is a compatible hardware of Arduino Hardware (UNO) which can be easily link with MATLAB Programs.



The features of the hardware are as follows;

1. Built-in USB connectivity and power supply of +5 V.
2. Atmega328 Microcontroller with UNO bootloader.
3. All Arduino shields supported.
4. ICSP socket for easy in-circuit programming.
5. Designed on a high quality dual-layer PCB.
6. Windows 8 compatible.

The manufacturer is LankaTronics Trading (Pvt) Ltd., No. 34/1, Old Kesbewa Road, Rattanapitiya, boralesgamuwa, Sri Lanka.

The computer architecture of the Lakduino (UNO) Rev4 is as follows;

First Lakduino (UNO) Rev4 driver, PL2303_Prolific_DriverInstaller_v1_9_0 should be installed to the computer after downloading from the Manufacturer's web. Then the hardware will be connected to the computer via usb cable and computer device manager is checked for connection at Ports (COM & LPT) for COM No. Then open MATLAB Simulation 03 and set the COM No. setting to the connected Lakduino COM No. manually. Now, Lakduino (UNO) hardware is ready to use.

Fig 2.8 shows a view of a Lakduino (UNO) hardware used for the field work of this thesis.


**Fig 2.8 Lakduino UNO Rev4 Hardware**

### 2.2.4 Personal Computer

A personal computer (Fig 2.9) used for the field test comprises with following features;

1. Processor : Intel(R) Core(TM) i5-2450M CPU @ 2.50GHz 2.50Ghz

2. Installed Memory (RAM): 4.00 GB (2.74 GB usable)

3. System type : 32-bit operating System

The RAM of the personal computer used for the field tests should be as much as high to get results instantly from the MATLAB simulations. Since, vast number of iterations involved the speed of the personal computer must be adequate enough to give results within a fraction of a second.

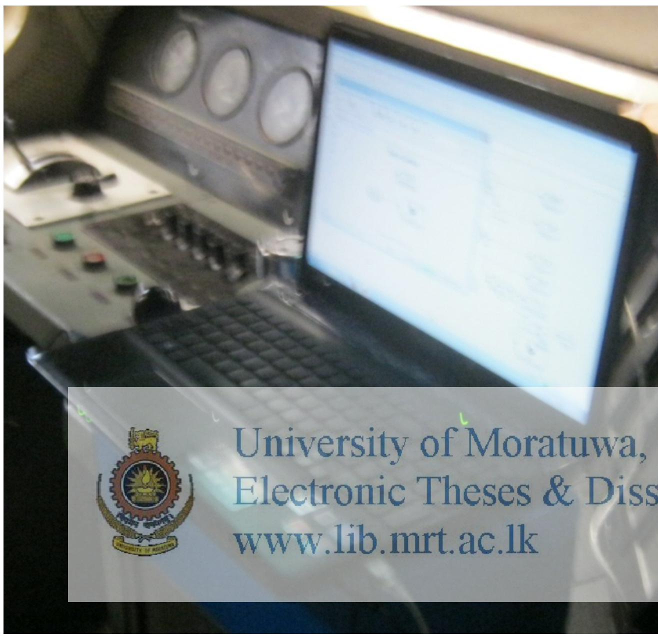




**Fig 2.9 Personal Computer**

### 2.2.5 Side Camera

Side camera (Fig 2.10) is an idling camera which can be used to capture videos perpendicular to the locomotive motion. For the modeling purpose a web cam has been selected. The side camera can be mounted on a side window pane of the locomotive engine cabin. However, a CCTV camera should be adapted as the side camera to capture high definition videos for image processing work. MATLAB Simulation 02 is used to process the videos captured by the side camera to determine the optical flow using "Horn- Schunck" method. The calculations of MATLAB Simulation 02 is explained in detail in section 2.3.2. The side camera is connected to simulink block " Input 2, From Video Device" of Image Acquisition Tool Box.

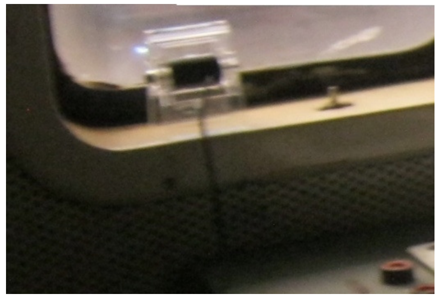


**Fig 2.10 Side Camera**

### 2.3 Algorithms of the System

### 2.3.1 Obstacle Detection

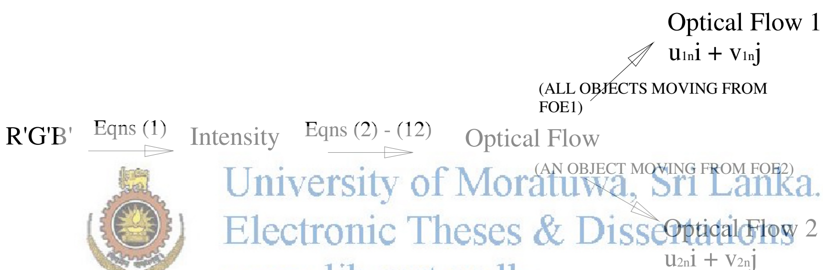





**Fig 2.11 Flow Chart and Link Equations of Section 2.3.1**

Conversion of R'G'B' to intensity of video frames capture from front camera,

Consider $n^{th}$ and $(n+1)^{th}$ frames,

Using LUMA coding in video systems,

$$Y' = 0.2126R' + 0.7152G' + 0.0722B' \qquad (1)$$

(Color coefficients 0.2126 (Red) 0.7152 (Green) 0.0722(Blue) according to ITU-R BT.709 standard used for HDTV)

Using Horn-Schunck algorithm,

$$E = \iint [ I_x u + I_y v + I_t)^2 + \alpha^2 (\|\nabla u\|^2 + \|\nabla v\|^2)] \, dxdy \qquad (2)$$

Optical flow vector,

$$\tilde{V} = [u\ (x\ y)\ ,\ v\ (x,y)]^T \quad (3)$$

From Euler- Lagrange equations,

$$\partial L/\partial u - \partial/\partial x(\partial L/\partial u_x) - \partial/\partial y(\partial L/\partial u_y) = 0 \quad (4)$$

$$\partial L/\partial v - \partial/\partial x(\partial L/\partial v_x) - \partial/\partial y(\partial L/\partial v_y) = 0 \quad (5)$$

$$I_x(I_x u + I_y v + I_t) - \alpha^2 \Delta u = 0 \quad (6)$$

$$I_y(I_x u + I_y v + I_t) - \alpha^2 \Delta v = 0 \quad (7)$$

$$\Delta u(x,y) = \bar{u}(x,y) - u(x,y) \quad (8)$$

From (6), (7) & (8),

$$(I_x^2 + \alpha^2)u + I_x I_y v = \alpha^2\ \bar{u} - I_x I_t \quad (9)$$

$$I_x I_y u + (I_y^2 + \alpha^2)v = \alpha^2\ \bar{v} - I_y I_t \quad (10)$$



$$u^{n+1} = \bar{u}^n - I_x(I_x\ \bar{u}^n + I_y\ \bar{v}^n + I_t)/\ \alpha^2 + I_x^2 + I_y^2 \quad (11)$$

$$v^{n+1} = \bar{v}^n - I_y(I_x\ \bar{u}^n + I_y\ \bar{v}^n + I_t)/\ \alpha^2 + I_x^2 + I_y^2 \quad (12)$$

Since the video frame 160 x 120 pixels selected,

For a w speed of the locomotive,

Velocity matrix obtained by (11) & (12),

$$\bar{w} = \begin{pmatrix} (u_{11}i + v_{11}j) & (u_{12}i + v_{12}j) & (u_{13}i + v_{13}j) & \ldots\ldots \\ (u_{14}i + v_{14}j) & \boxed{\mathbf{(u_{21}i + v_{21}j)}} & \boxed{\mathbf{(u_{22}i + v_{22}j)}} & (u_{15}i + v_{15}j) \\ (u_{16}i + v_{16}j) & \boxed{\mathbf{(u_{23}i + v_{23}j)}} & \boxed{\mathbf{(u_{24}i + v_{24}j)}} & \ldots\ldots \\ (u_{17}i + v_{17}j) & (u_{18}i + v_{18}j) & (u_{19}i + v_{19}j) & \ldots\ldots \\ \ldots\ldots & & & \end{pmatrix}_{160 \times 120}$$

In above matrix, all the objects in front camera move in locomotive engine speed $u_{1n}i + v_{1n}j$ from the Focus of Expansion (FOE1) of the moving locomotive engine, but there is an obstacle which moves in $u_{2n}i + v_{2n}j$ speed from a different FOE2. This scenario leads to obstacles which propagates in size on railway and moves in $u_{2n}i + v_{2n}j$ inside the danger zone, to count 1 or more from blob analysis and to alarm the beeping continuously. [11]

Due to reason mentioned below, for blob analysis, 300 pixels area covering an obstacle has been selected as the number of minimum pixels for blob analysis.

If an obstacle on the sleeper at the railway which is at s distance considered, [18]

From,

$$\begin{pmatrix} fX + ZP_x \\ fY + ZP_y \\ Z \end{pmatrix} = \begin{pmatrix} f & 0 & P_x & 0 \\ 0 & f & P_y & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix}$$



and since plane $Z = 0$,

Sleeper (image) is 10.192 pixels and the Obstacle (image) is minimum 300 pixels.

Therefore, MATLAB Simulation 01 detect the area with $u_{2n}i + v_{2n}j$ as an obstacle and count 1.

This will be done for other obstacles simultaneously and count the number of obstacles at the danger zone and beep the alarm.

As the danger zone, using a MATLAB script, only the area fallen to railway ahead is considered.

[03]

### 2.3.2 Locomotive Speed Detection, Minimum Distance for Braking & Minimum Angle of Front Camera during Braking

#### 2.3.2.1 Locomotive Speed Detection

R'G'B' —Eqns (1)→ Intensity —Eqns (2) - (14)→ Optical Flow

—Eqns (15)→ Optical Flow² —Eqns (16)→ sqrt Optical Flow²

—Eqns (17)→ sum ( sqrt Optical Flow² )

—Eqns (18)→ sum ( sqrt Optical Flow² ) / [160 x 120]



**Fig 2.12 Flow Chart and Link Equations of Section 2.3.2.1**

Conversion of R’G’B’ to intensity of video frames capture from side camera,

Consider $n^{th}$ and $(n+1)^{th}$ frames,

Using LUMA coding in video systems,

$$Y' = 0.2126R' + 0.7152G' + 0.0722B' \qquad (1)$$

(Color coefficients 0.2126 (Red) 0.7152 (Green) 0.0722(Blue) according to ITU-R BT.709 standard used for HDTV)

Using Horn-Schunck algorithm,

$$E = \iint [ I_x u + I_y v + I_t)^2 + \alpha^2 (\|\nabla u\|^2 + \|\nabla v\|^2)] \, dxdy \qquad (2)$$

Optical flow vector,

$$\tilde{V} = [u\ (x\ y)\ ,\ v\ (x,y)]^T \qquad (3)$$

From Euler- Lagrange equations,

$$\partial L/\partial u - \partial/\partial x(\partial L/\partial u_x) - \partial/\partial y(\partial L/\partial u_y) = 0 \qquad (4)$$

$$\partial L/\partial v - \partial/\partial x(\partial L/\partial v_x) - \partial/\partial y(\partial L/\partial v_y) = 0 \qquad (5)$$

$$I_x(I_x u + I_y v + I_t) - \alpha^2 \Delta u = 0 \qquad (6)$$

$$I_y(I_x u + I_y v + I_t) - \alpha^2 \Delta v = 0 \qquad (7)$$

$$\Delta u(x,y) = \bar{u}(x,y) - u(x,y) \qquad (8)$$

From (6), (7) & (8),

$$(I_x^2 + \alpha^2)u + I_x I_y v = \alpha^2\ \bar{u} - I_x I_t \qquad (9)$$

$$I_x I_y u + (I_y^2 + \alpha^2)v = \alpha^2\ \bar{v} - I_y I_t \qquad (10)$$



$$u^{n+1} = \bar{u}^n - I_x(I_x\ \bar{u}^n + I_y\ \bar{v}^n + I_t)/\ \alpha^2 + I_x^2 + I_y^2 \qquad (11)$$

$$v^{n+1} = \bar{v}^n - I_y(I_x\ \bar{u}^n + I_y\ \bar{v}^n + I_t)/\ \alpha^2 + I_x^2 + I_y^2 \qquad (12)$$

Since the video frame 160 x 120 pixels selected,

For a w speed of the locomotive,

Velocity matrix obtained by (11) & (12),

$$\bar{w} = \begin{pmatrix} (u_{11}i + v_{11}j) & (u_{11}i + v_{11}j) & (u_{11}i + v_{11}j) & \ldots\ldots \\ (u_{11}i + v_{11}j) & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \boxed{(\mathbf{u_{12}i + v_{12}j})} & (u_{11}i + v_{11}j) \\ (u_{11}i + v_{11}j) & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \ldots\ldots \\ (u_{11}i + v_{11}j) & (u_{11}i + v_{11}j) & (u_{11}i + v_{11}j) & \ldots\ldots \\ \ldots\ldots & & & \end{pmatrix}_{160 \times 120} \qquad (13)$$

Since $v_{11} = 0$, only horizontal movement of the locomotive considered,

$$\bar{w} = \begin{pmatrix} (u_{11}i + 0) & (u_{11}i + 0j) & (u_{11}i + 0j) & \ldots\ldots\ldots\ldots \\ (u_{11}i + 0j) & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \boxed{(\mathbf{u_{12}i + v_{12}j})} & (u_{11}i + 0j) \\ (u_{11}i + 0j) & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \boxed{(\mathbf{u_{12}i + v_{12}j})} & \ldots\ldots\ldots\ldots \\ (u_{11}i + 0j) & (u_{11}i + 0j) & (u_{11}i + 0j) & \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots & & & \end{pmatrix}_{160 \times 120} \qquad (14)$$

160 x 120

$$w^2 = \begin{pmatrix} u_{11}^{2} & u_{11}^{2} & u_{11}^{2} & \ldots\ldots\ldots\ldots \\ u_{11}^{2} & (u_{12}^{2} + v_{12}^{2}) & (u_{12}^{2} + v_{12}^{2}) & u_{11}^{2} \\ u_{11}^{2} & (u_{12}^{2} + v_{12}^{2}) & (u_{12}^{2} + v_{12}^{2}) & \ldots\ldots\ldots\ldots \\ u_{11}^{2} & u_{11}^{2} & u_{11}^{2} & \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots & & & \end{pmatrix} \qquad (15)$$



160 x 120

$$\sqrt{w^2} = \begin{pmatrix} u_{11} & u_{11} & u_{11} & \ldots\ldots\ldots\ldots \\ u_{11} & \boxed{\sqrt{(\mathbf{u_{12}^{2} + v_{12}^{2}})}} & \boxed{\sqrt{(\mathbf{u_{12}^{2} + v_{12}^{2}})}} & u_{11} \\ u_{11} & \boxed{\sqrt{(\mathbf{u_{12}^{2} + v_{12}^{2}})}} & \boxed{\sqrt{(\mathbf{u_{12}^{2} + v_{12}^{2}})}} & \ldots\ldots\ldots\ldots \\ u_{11} & u_{11} & u_{11} & \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots & & & \end{pmatrix} \qquad (16)$$

160 x 120

$$\Sigma\sqrt{w^2} = [u_{11} + u_{11} + u_{11} + \ldots\ldots\ldots\ldots\sqrt{(\mathbf{u_{12}}^2 + \mathbf{v_{12}}^2)} + \ldots\ldots\ldots u_{11} + u_{11}\ldots\ldots\ldots]_{160 \times 120}$$

(17)

$$\Sigma\sqrt{w^2} / [160 \times 120] = u_{locomotive\ speed} \quad (18)$$

[03]

### 2.3.2.2 Synchronizing $u_{locomotive}$ speed with Actual Speed of the Locomotive Engine

Locomotive engine set to run at constant speed, 40 kmph,

MATLAB Simulation 02 will iterate $u_{locomotive\ speed}$,

By feeding actual speed to the MATLAB Simulation 02,

$$\text{Reality Factor} = \text{Actual Speed} / u_{locomotive\ speed} \quad (19)$$



The Reality Factor obtained, will be used as a factor to multiply $u_{locomotive\ speed}$ get actual speed of the locomotive for further calculations of MATLAB Simulation 02.

$$u = u_{locomotive\ speed} \times \text{Reality Factor} \quad (20)$$

### 2.3.3 Deceleration, Minimum Distance Braking & Angle of the Front Camera

From equations of motion,

$$v^2 = u^2 + 2as \quad (21)$$

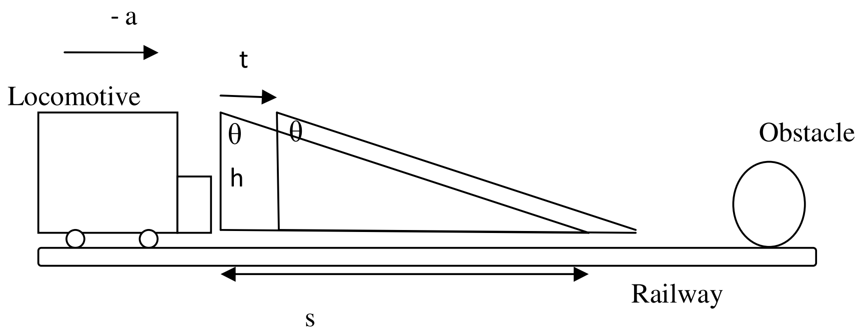
For minimum braking,

$$s = u^2 / 2(-a) \quad (\text{since, } v = 0,) \quad (22)$$

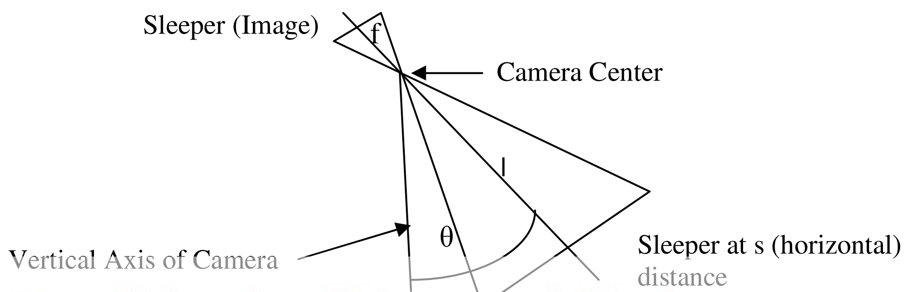
Consider Fig 2.13(a.),

$$\tan\theta = s / h \quad (23)$$

$\theta \quad = \tan^{-1}[s / h]$ (24)




**(a.) Equations of Motion Applied to Locomotive Engine**






**(b.) Sleeper at s distance**

**Fig 2.13 Front Camera Geometry**

Therefore, after having n iterations of MATLAB Simulation 02 & 03,

Deceleration = $(-a)_n$ (25)

Minimum Distance Braking $= s_n$ (26)

Angle of the Front Camera $= \theta_n$ (27)

Consider Fig 2.13 (b.),

Length of Sleeper (Image) / f = length of Sleeper (Actual)/ l (28)

Length of Sleeper (Image) = (length of Sleeper (Actual)/ l) x f (29)

From MATLAB camera calibration f can be found.

Determining length of Sleeper (Image), it can be identified using MATLAB on the video frame and the distance of obstacle (if any) on the Sleeper is at the same distance s.

## 2.4 MATLAB Simulation

### 2.4.1 MATLAB Simulation 01

Consider Fig 2.14;

The front camera is connected to simulink block " Input 1, From Video Device" of Image Acquisition Tool Box.

Settings are,

Video format: YUY2_160x120

Output color space: rgb

Block sample time: 1/30

Ports mode: One multidimensional signal

Data type: single



Next simulink block is R'G'B' to intensity.

Settings are,

Conversion: R'G'B' to intensity

Image Signal; One multidimensional signal

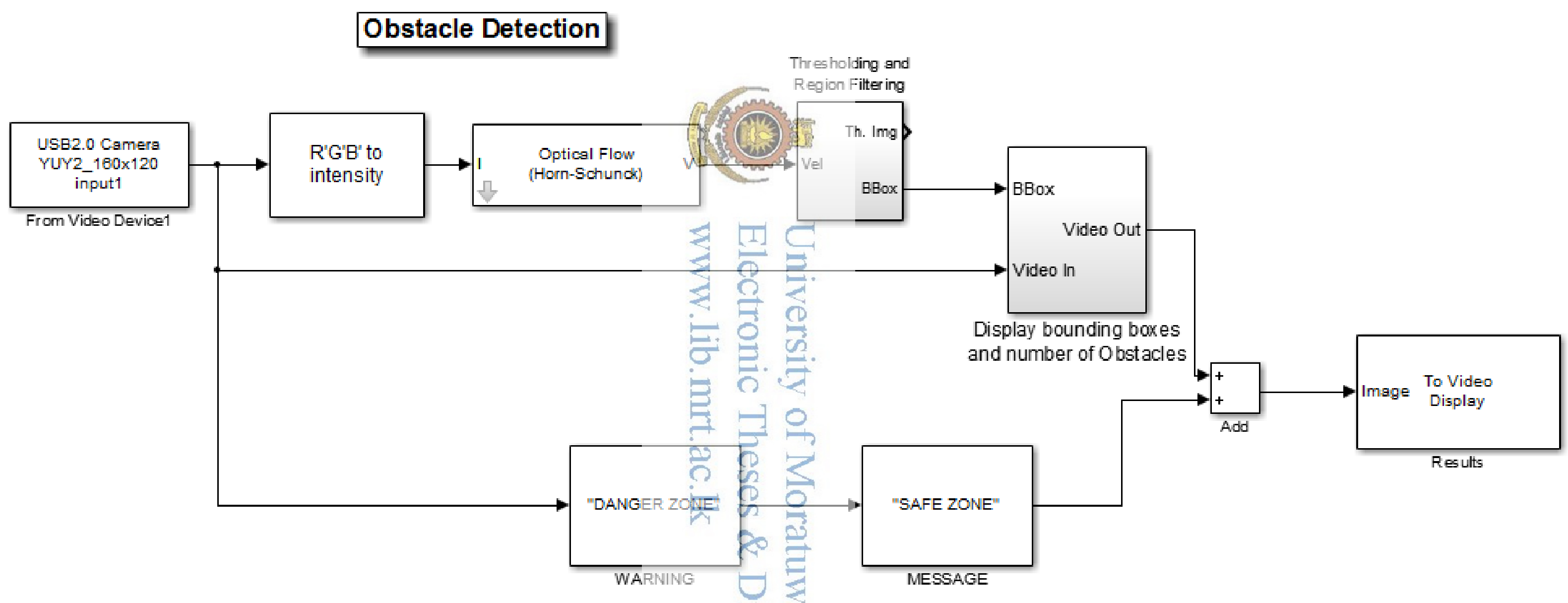





Fig 2.14 MATLAB Simulation 01

Next simulink block is Optical Flow.

Settings are,

Method: Horn-Schunck

Compute optical flow between: current frame and N-th frame back

N: 1

Smoothness factor: 1

Maximum number of iterations: 10

Velocity output: Horizontal and vertical components in complex form

Next simulink block is Thresholding and Region Filtering Consider Fig 2.15,

1. Velocity input block
2. Velocity squared block
3. Velocity Threshold block
4. Comparison block
5. Median Filter block
6. Closing (mask) (link) block
7. Region Filtering block



MATLAB script for Sub Matrix block,

```
function y = fcn(u, line_row)
%#codegen

l=size(u);
```

```
y = u(line_row:l(1),:);
```

MATLAB script for MATLAB Function block,

```
function y = fcn(u, line_row)
%#codegen
dim=size(u);
repVector = zeros(dim);
repVector=repmat([0 line_row 0 0],dim(1),1);

y = int32(u+int32(repVector));
```

Blob Analysis block,

Statistics: Bounding box

Statistic output data: double

Connectivity: 8

Maximum number of blobs: 80

Specify minimum blob area in pixels: 300

Specify maximum blob area in pixels: 3600 [07]

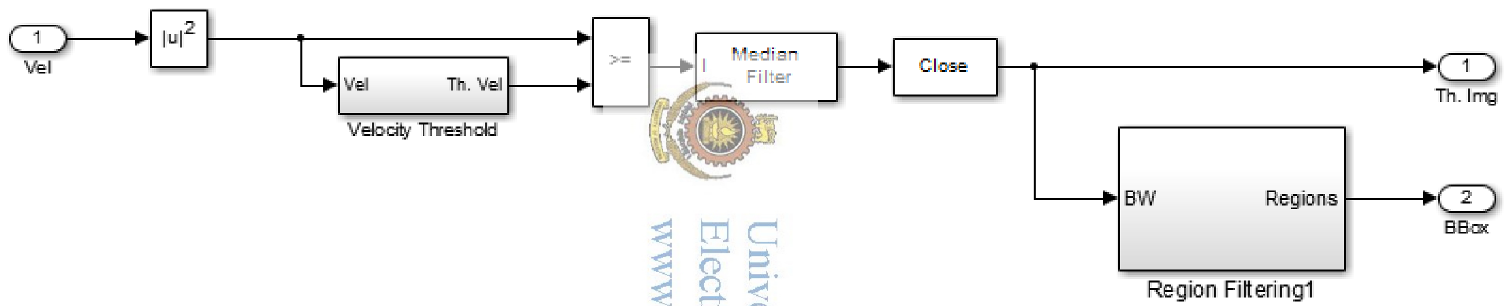



Fig 2.15 Thresholding and Filtering of MATLAB Simulation 01

8. Output block for BBox block

Next Simulink Block is Display Bounding Boxes and Number of Obstacles.

Consider Fig 2.16,

1. Simulink block 'Video in'

2. Draw shapes block

Settings are,

Shape: Rectangles

Border color source: Specify via dialog

Border color: User-specified value

Draw shapes in: Entire image

Image Signal: One multidimensional signal



3. Create white line block

4. Black back ground for count block

5. Left dead zone block

6. Right dead zone block

7. Probe block

Settings are,

Select 'Probe signal dimensions'

Data type for signal dimensions: double

8. Selector block

Settings are,

Number of input dimensions: 2

Index mode: one-based

Index vector (dialog): 1

Index vector (dialog): 1

9. MATLAB Function block for audible alarm 'beep'

```
function y = fcn(u)
coder.extrinsic('beep')
y=u;
if u>0;
beep;
end
```

10. Unit8 block

Settings are,



Input and output to have equal: Real World Value (RWV)

Integer rounding mode: Floor

Sample time: -1

11. Insert Text block

Settings are,

Text: '%4d'

Color value source: specify via dialog

Color value: [1 1 1]

Location source: Specify via dialog

Location [x y]: [1 1]

Opacity source: Specify via dialog

Opacity: 1.0

Image signal: One multidimensional signal

12. Video out block

Next simulink block is ‘Results’

Simulink blocks ‘ Display bounding boxes and number of Obstacles’, ‘DANGER ZONE’ and ‘SAFE ZONE’ are added to the ‘Results’ block via simulink block ‘Add’. Final video comprising all features assigned will be displayed in the personal computer.

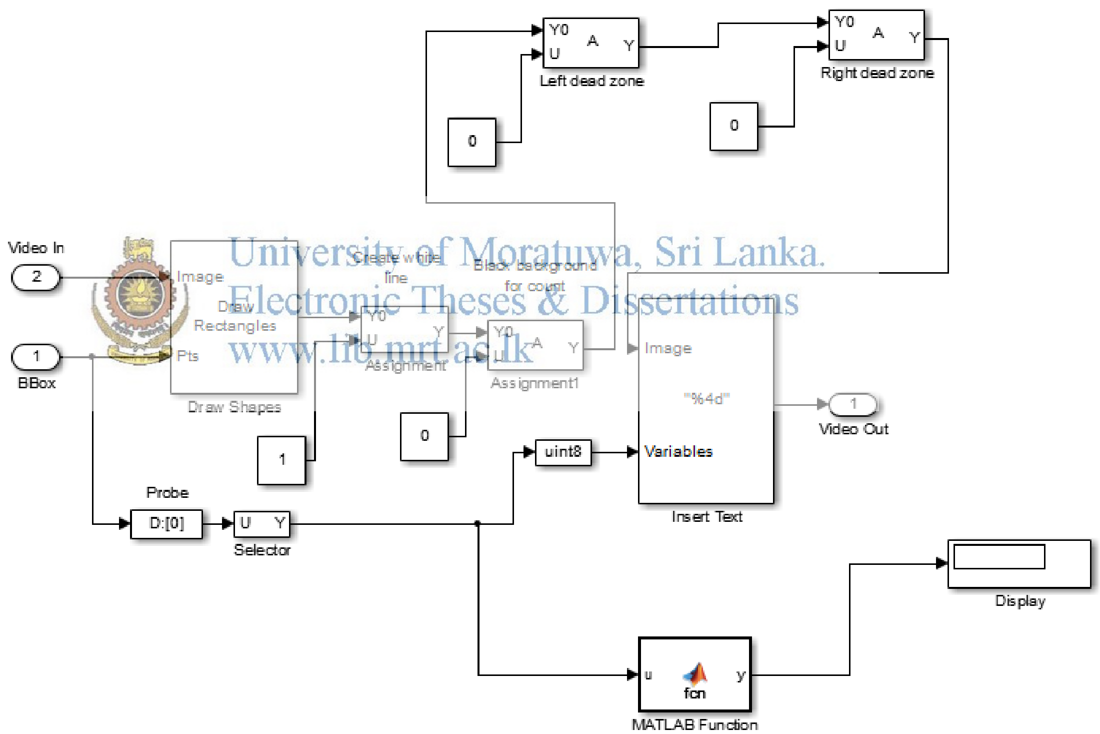




**Fig 2.16 Display Bounding Boxes and Number of Obstacles of MATLAB Simulation 01**

### 2.4.2 MATLAB Simulation 02

Consider Fig 2.17,

The side camera is connected to simulink block "Input 1, From Video Device" of Image Acquisition Tool Box.

Settings are,

Video format: YUY2_160x120

Output color space: rgb

Block sample time: 1/30

Ports mode: One multidimensional signal

Data type: single



Next simulink block is R'G'B' to intensity.

Settings are,

Conversion: R'G'B' to intensity

Image Signal; One multidimensional signal

Next simulink block is Optical Flow.

Settings are,

Method: Horn-Schunck

Compute optical flow between: current frame and N-th frame back

N: 50

Smoothness factor: 1

Maximum number of iterations: 10

Velocity output: Magnitude-squared

Next simulink blocks are as follows;

Sqrt: square root

Matrix Sum: Sum of the velocity matrix

No. of Matrix: Size of the matrix. Since selected pixels are 160 x 120,

Size = 19200

Divide2 : Division of Matrix Sum from No. of Matrix



Reality Factor: Factor obtained by synchronizing optical flow velocity with actual velocity for 40 kmph. Reality factor can be seen from the display.

Product 1: Multiplication of reality factor with optical flow velocity.

Manual Switch1 : Separate the system for velocity synchronizing.

Velocity: Display for velocity

Product: Multiplication for velocity squared

du/dt: Derivative for linearization of velocity to obtain deceleration.

Divide: Division of velocity squared by deceleration

Gain1: Multiplication of $u^2$/ (-a) from 0.5

Constant: Hieght of the front camera focal point to the ground.

Divide3: Multiplication of Gain1 by Constant

Trigonometric Function: atan of Divide3 to determine the required angle to focus the front camera to analyze the destination is free from obstacles

Gain3: To convert radian angle to degree angle. K= 57.29577951

Front Camera Angle deg: Display for front camera angle degree.

Manual Switch3: To discontinue running system to send data to MATLAB Simulation 03.

Discrete Sample Hold1: Selecting an angle value and hold for sending to MATLAB Simulation 03.

To File: Sending data to MATLAB Simulation 03 file as input values.

For finding Reality Factor,

Actual Speed: 40 kmph is given to the block

Constant1: Factor to convert kmph to $ms^{-1}$. C1= 0.2777777777777778



Product2: Multiplication of Actual Speed by C1 to convert kmph to $ms^{-1}$

Manual Switch: To stop iterations after finding the reality factor

Divide1: Actual speed is divided by the optical flow speed to generate the reality factor

Discrete Sample & Hold: After disconnecting the manual switch final value obtained by iterations will be hold as the reality factor.

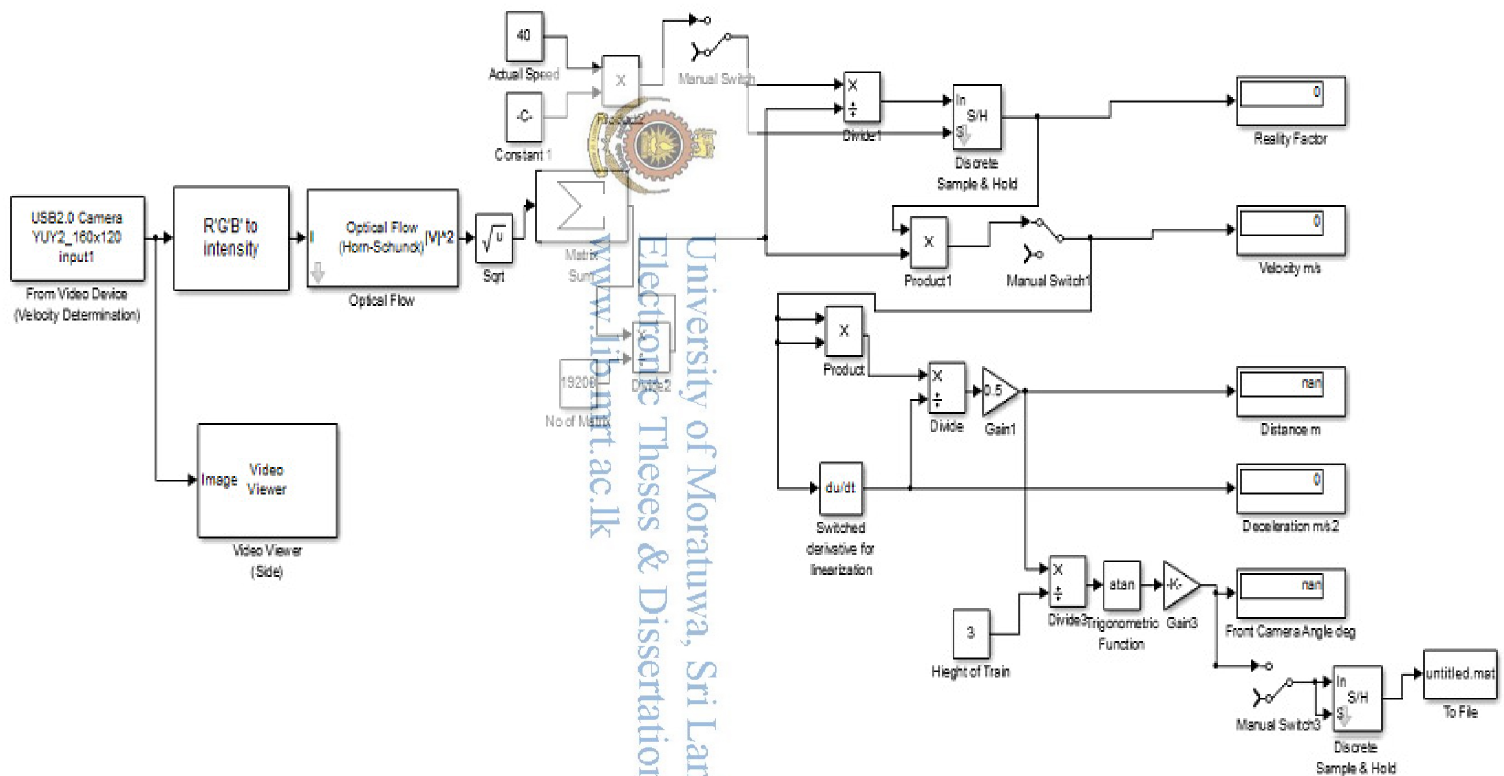



Fig 2.17 MATLAB Simulation 02

### 2.4.3 MATLAB Simulation 03

Consider Fig 2.18,

Following simulink blocks are used for the MATLAB Simulation 03,

From File: Angle received from MATLAB Simulation 02.

Front Camera Angle deg: Display of angle value

Arduino Continuous Servo Write1: Simulink block to connect with Arduino (UNO) hardware.

Setting is,

Pin Number: 2

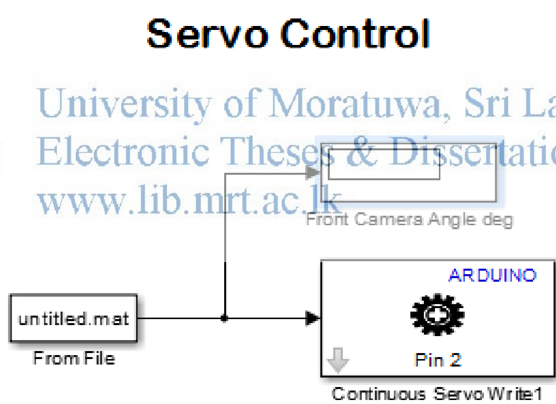





**Fig 2.18 MATLAB Simulation 03**

# 3.Field Tests

## 3.1 Field Tests of MATLAB Simulation 01

MATLAB Simulation 01 for obstacle detection has been tested using following scenarios;

CASE 01: Using finger tip;

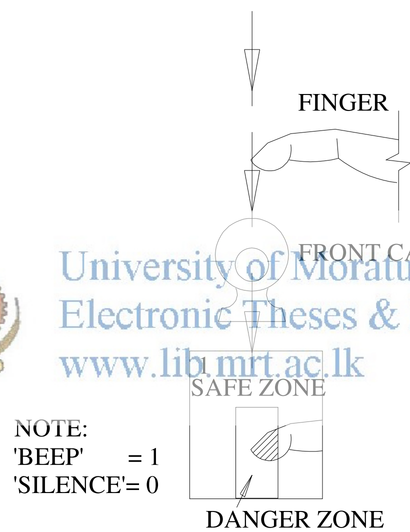




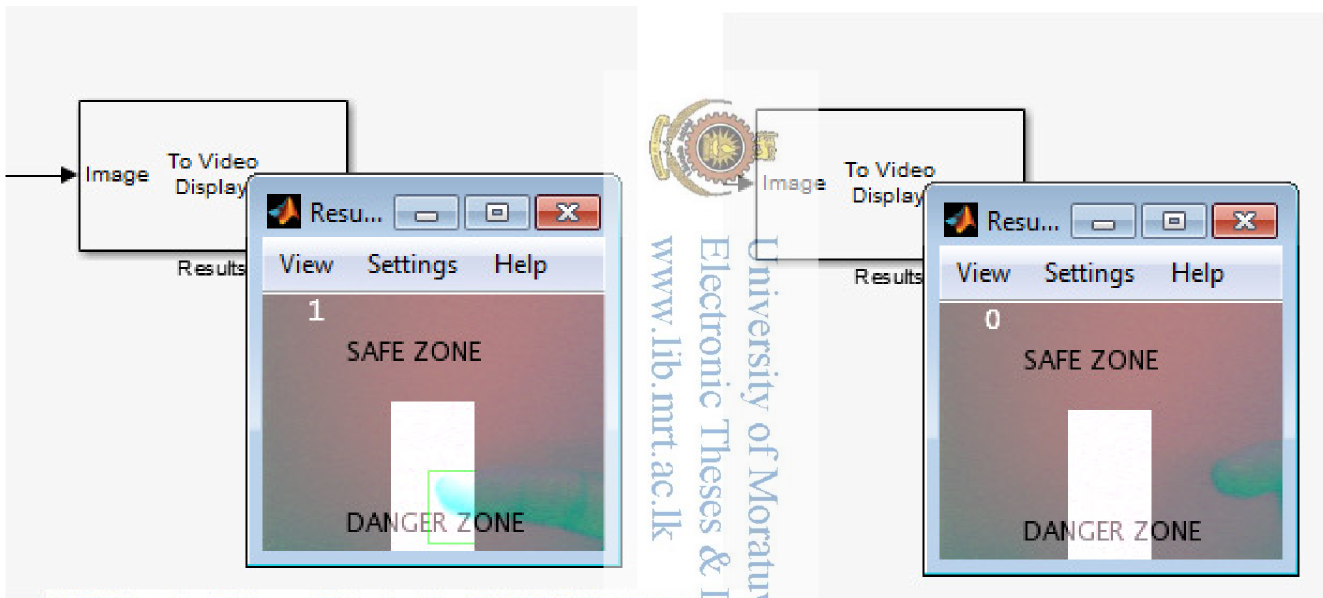

**Fig 3.1 Overall Arrangement of Finger Tip Test**

MATLAB Simulation 01 has been run connecting a web cam and the video was tested using the finger tip. (see Fig 3.1 and Fig 3.2)

1.) When moving the finger tip at SAFE ZONE, counter shows zero and no beep sound heard.

2.) When moving the finger tip inside the DANGER ZONE, counter shows one and beep sound heard.

Variation of parameters from the actual case is the background is idling.




(a.) Moving Finger Tip inside DANGER ZONE, '1' shows beeping

(b.) Moving Finger Tip inside SAFE ZONE, '0' shows silent



Fig 3.2 Verification Test of MATLAB Simulation 01

CASE 02: Using Various Railway Videos

Two types of railway videos have been selected from the internet and screened to personal computer and captured the video using web cam attached to MATLAB Simulation 01.

Videos were recorded focusing the front camera to rail way.

1.) Locomotive engine travels at certain speed without engaging into an accident.

    Consider Fig 3.3,

    MATLAB Simulation 01 ran most of the time without alarming since no obstacles were found along the railway. However, some bridge crossings were considered as obstacles and beeping was heard till the locomotive engine passes the said bridge.

SNAP SHOT

DANGER ZONE = 1/

SAFE ZONE = 0



**Fig 3.3 Locomotive Travels at Constant Speed**

2.) Collision

Consider Fig 3.4,

A video clip was run where two locomotive engines were collided together. No beeping was heard till the locomotive engine comes towards, reached the DANGER ZONE.

After reaching and till the collision, beeping was heard.




**Fig 3.4 Collision of Two Locomotive Engines**

CASE 03: Measuring Obstacle Distance from the Front Camera using Sri Lanka Railway Locomotives

The previous case study shows generally the distance of an obstacle from the front camera during the first detection. However, it is very important to test the system assembling to a locomotive engine and to measure an obstacle distance for the first ‘beep’. Here, collision of two locomotive engines was considered.

Venue: Motive Power Sub Department of Sri Lanka Railways

Date: 03rd February 2015.

Locomotive Engine Class Y 689 Load R was used to assemble the system as in Fig 3.5.



**Fig 3.5 Built up Model Assembled in Locomotive Engine Class Y 689 Load R for Testing**

Locomotive Engine Class S1 1SD 16308 was selected as the obstacle idling at the same rail as in Fig 3.6.


**Fig 3.6 Selected Obstacle, Locomotive Engine Class S1 1SD 16308**

Four Trials were performed by moving Locomotive Engine Class Y 689 Load R towards the Locomotive Engine Class S1 1SD 16308, slow speed 5 kmph and distances were measured for first continuous 'beep' during the detection of Locomotive Engine Class S1 1SD 16308 as an obstacle at danger zone of front camera and tabulated as in Table 3.1.



**Table 3.1 Obstacle Detection Distance**

| Trial No. | Obstacle Detection Distance (ft) | Remarks |
|---|---|---|
| 01 | 50 | Web Cam live video capturing was very poor due to sun light and low definition of the camera |
| 02 | 55 | |
| 03 | 59 | |
| 04 | 69 | |

The results, obtained from the assembled system was not up to the desirable level for braking due to following reasons;

1.) Front Camera is a web cam where only low definition videos can be produced.

2.) Due to sun light web cam video capturing is very poor (since there is no auto white balance for particular web camera).

Above results can be improved to the desirable level by using a HD CCTV camera as the Front Camera.

### 3.2 Field Tests for MATLAB Simulation 02

CASE 01: Testing the actual speed reduction with the optical flow velocity reduction using Sri Lanka Railway Locomotives

The speed reduction test was carried out using MATLAB Simulation 02. The test was carried out for a locomotive with some prevailing limitations of Sri Lanka Railways.

Venue: Motive Power Sub Department of Sri Lanka Railways

Date: 03rd February 2015.



Locomotive Engine: Class Y 689 Load R

Maximum Speed Allowed: 5 kmph

The system was assembled to Locomotive Engine, Class Y 689 Load R.

First, MATLAB Simulation 02 was set to run.

The Locomotive engine speed was increased up to 5kmph and moved on constant speed.

The reality factor was obtained during this period using the running MATLAB Simulation 02.

Table 3.2 shows a trial of varying speed of Locomotive Engine, Class Y 689 Load R after synchronizing to actual speed using the obtained reality factor by running MATLAB Simulation 02.

**Table 3.2 Trial of Varying Speed of Locomotive Engine, Class Y 689 Load R**

| Trial No. | Speed (m/s) | Distance for Braking (m) | Front Camera Angle (deg) | Remarks |
|---|---|---|---|---|
| 01 | 20 | 1.6 | 40 | Reality Factor= 31670 |
| | 23 | 3.64 | 67.63 | |
| | 45 | 2228 | 89.96 | |

Above results clearly shows when speed of the locomotive engine increases the braking distance increases subsequently front camera angle increases till $90^0$.

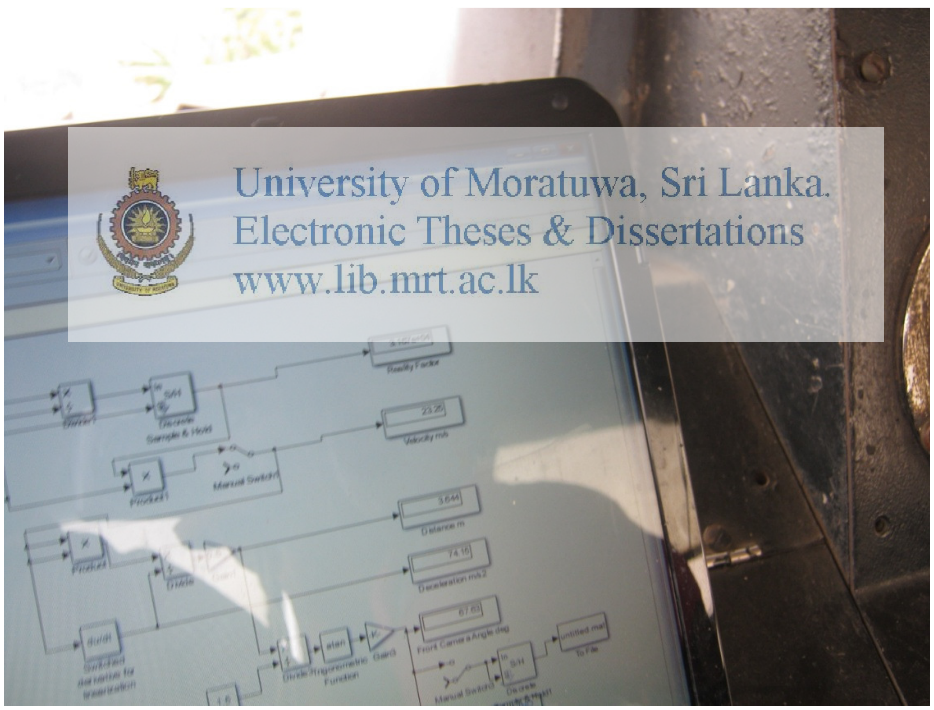



**Fig 3.7 Display of MATLAB Simulation 02 for 2nd Set of Data**

Fig 3.7 shows the 2nd set of data inclusive of the reality factor clarified in Table 3.3.

### 3.3 Field Tests for MATLAB Simulation 03

CASE 01: Testing Servo Motor Angle with the MATLAB Simulation 03

The front camera angles using the servo motor through arduino (UNO) hardware while changing MATLAB Simulation 03 were checked.

Venue: MALABE Cinec Campus Road

Date: 31st March 2014

While running the 4WD double cab, several angles were given to MATLAB Simulation 03.

The angles are 20°, 40°, 60° and 90°,

The servo motor through arduino (UNO) hardware kept it angles at the instructed positions by the MATLAB Simulation 03.

Fig 3.8 shows some examples of the said work.




**Fig 3.8 Changing Angle from 40deg to 20deg**

### 3.4 Field Tests for Overall System

CASE 01: Testing the Overall System

Venue: MALABE Cinec Campus Road

Date: 31st March 2014

Overall system was checked assembling the system to a 4WD double cab for the validation. Following results have been obtained;

1.) The fluctuations in front camera angle in MATLAB Simulation 02 are very high and could link to the MATLAB Simulation 03 as the input values.

2.) The front camera yaw variation is very high due to the fluctuation of input values received from MATLAB Simulation 02.

3.) The front camera continuous yaw variation does not obstruct viewing of the vehicle front view.

4.) However, arduino (UNO) hardware malfunctioned and overflow condition occurred at 'Continuous Servo Write 1' simulink block.

### 3.5 Tests for Motion Fields (Vector Fields) and Motion Segmentation

The safety zone margins of the MATLAB simulation 04 have been improved as in Fig 3.9 to obtain better results during the tests for motion fields (vector fields) and motion segmentation.

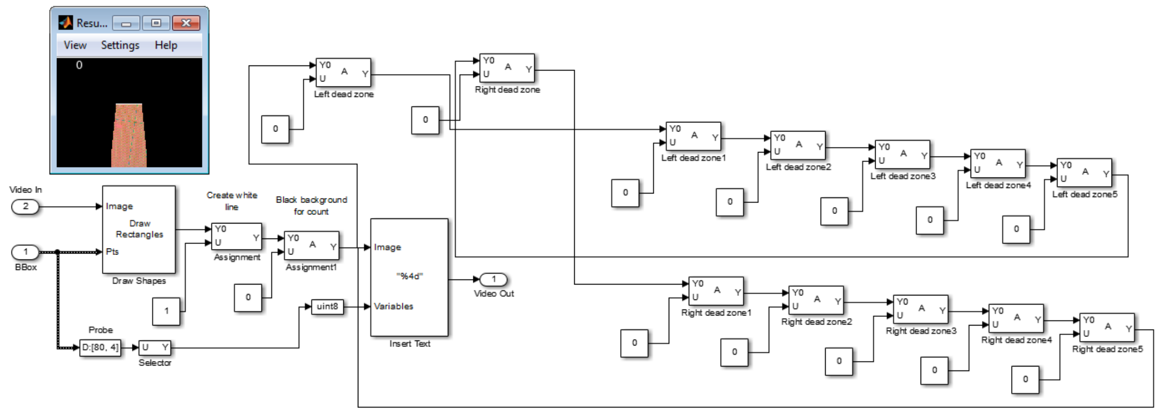



**Fig 3.9: Improvement of SAFETY ZONE Margins by Modifying MATLAB Simulation 01**

Furthermore, identification of Focus of Expansion (FOE) has been shown in Fig 3.10, since FOE is a very important parameter in motion field.



As per the Fig 3.10, with the Focus of Expansion (FOE), motion vectors generated on poles, trees and vehicles beside the railway which will be falling into the Safe Zone. Since very few motion vectors generated on the railway and within the Danger Zone when there is no obstacle along the railway, encountering less pixels than the minimum nos of pixels given to the blob analysis where no beeping is heard[10][12]

.

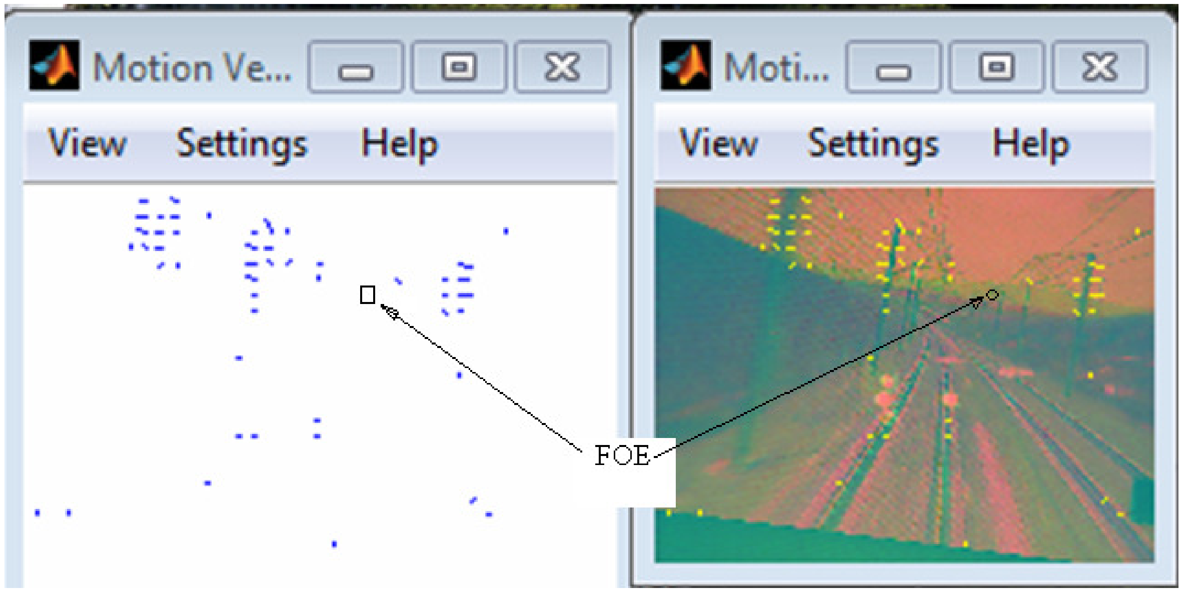



**Fig 3.10 Identifying the Focus of Expansion from Motion Vector Fields**

Therefore, motion segmentation can be categorized as follows;

1.) Motion vectors are appeared from the Focus of Expansion (FOE) of the moving front camera towards the scenery from poles, trees, idling vehicles beside the railway. These are not counted by blob analysis since it distributed inside the safe zone.



2.) Since the railway most of the time, continuously connected to the Focus of Expansion (FOE) of the front camera to the locomotive engine, very few motion vectors can be seen.

3.) The Obstacle coming towards the locomotive engine can be seen with higher number of motion vectors due to obstacle's own speeds and propagation in size within an instant and when it enters danger zone, from blob analysis, number of blobs are counted and beeping will be heard.

[09][10][14]

Further studies were carried out below to check the validation of the obstacle detection system introduced in this thesis since the object detection is done with a moving background. Therefore, several railway accident videos obtained from locomotive cabin front cameras have been analyzed using a special MATLAB simulation shown in fig 3.11 for the generation of motion vectors due to different FOEs and checked whether beeping really occurred due to the identified obstacle ahead the locomotive engine.

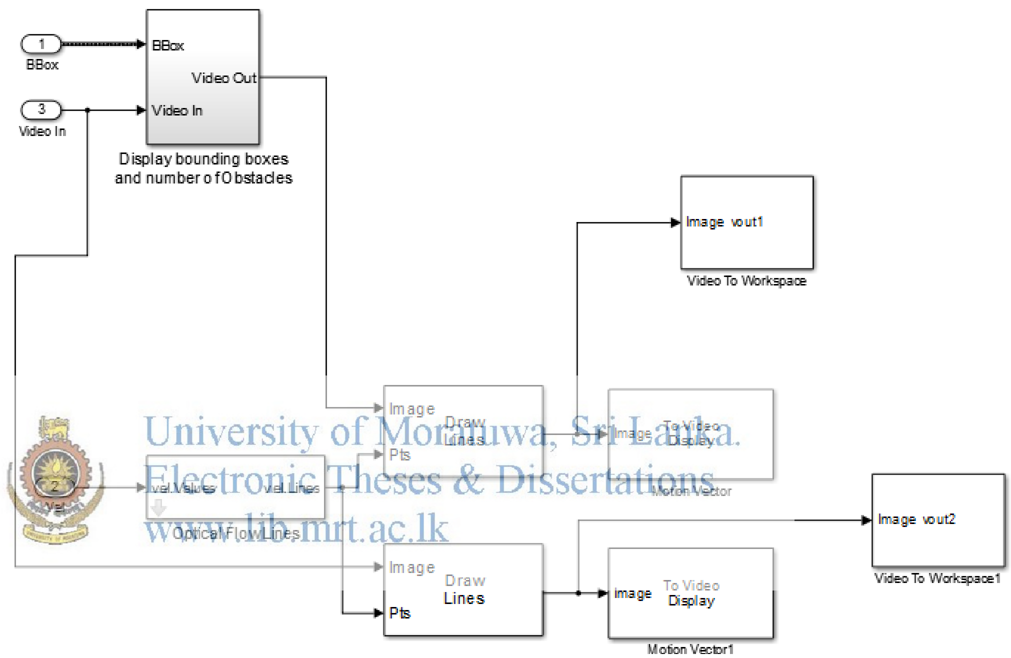





**Fig 3.11: Adapting Video to Workspace, Simulink Block for analyzing Final 10 nos. of Frames**

### 3.5.1 Determination of Focal Length of the Front Camera using Camera Calibration

Twenty numbers of Checker Board images with different angles have been used for the camera calibration. The main purpose of this calibration is to find the accuracy of the image capturing by the camera and to determine the focal length. Performed calibration test for each image is shown as follows;

Image 01: Captured Image

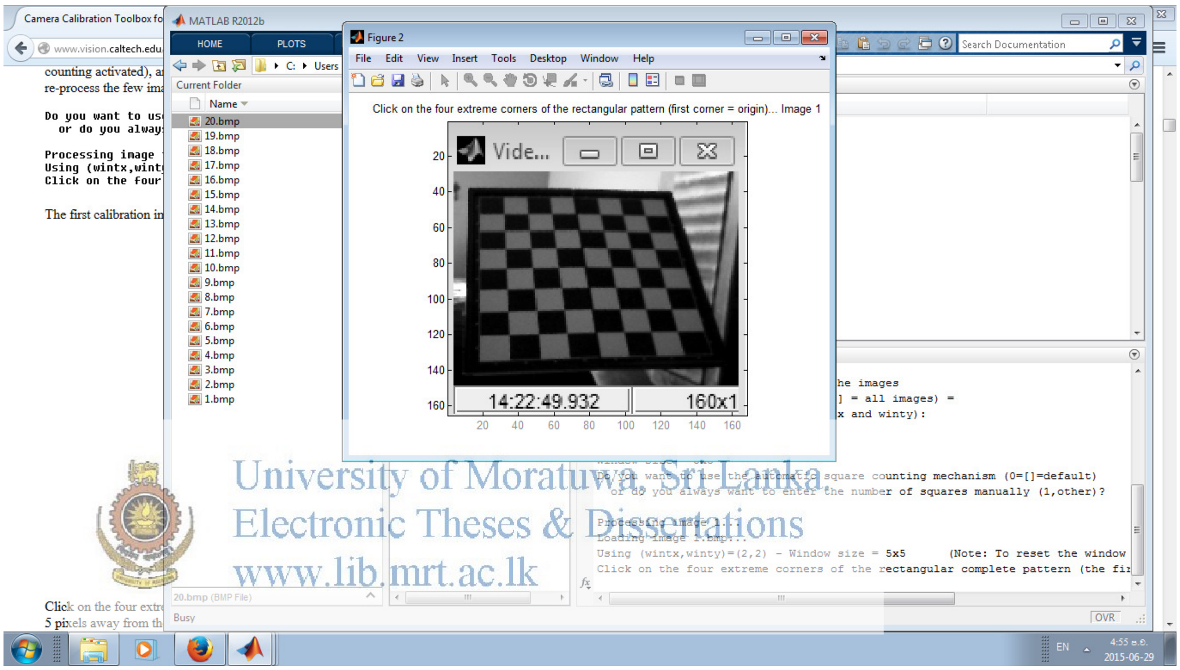


Image 01: Selecting Extreme Corners

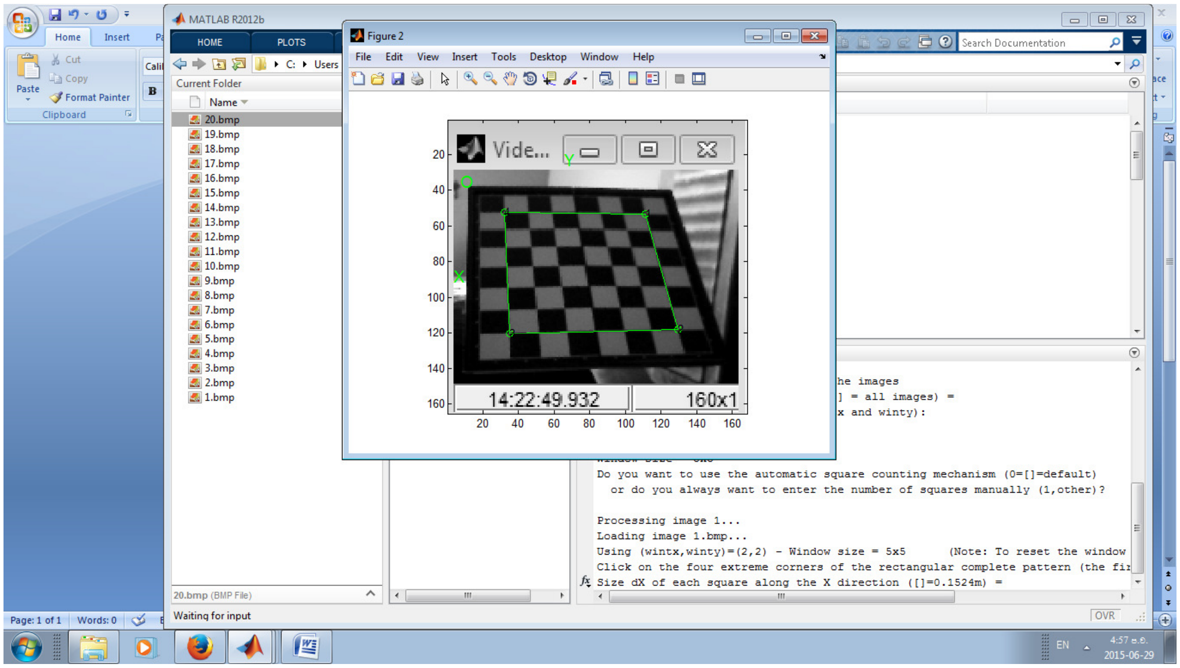



Image 01: Red Crosses

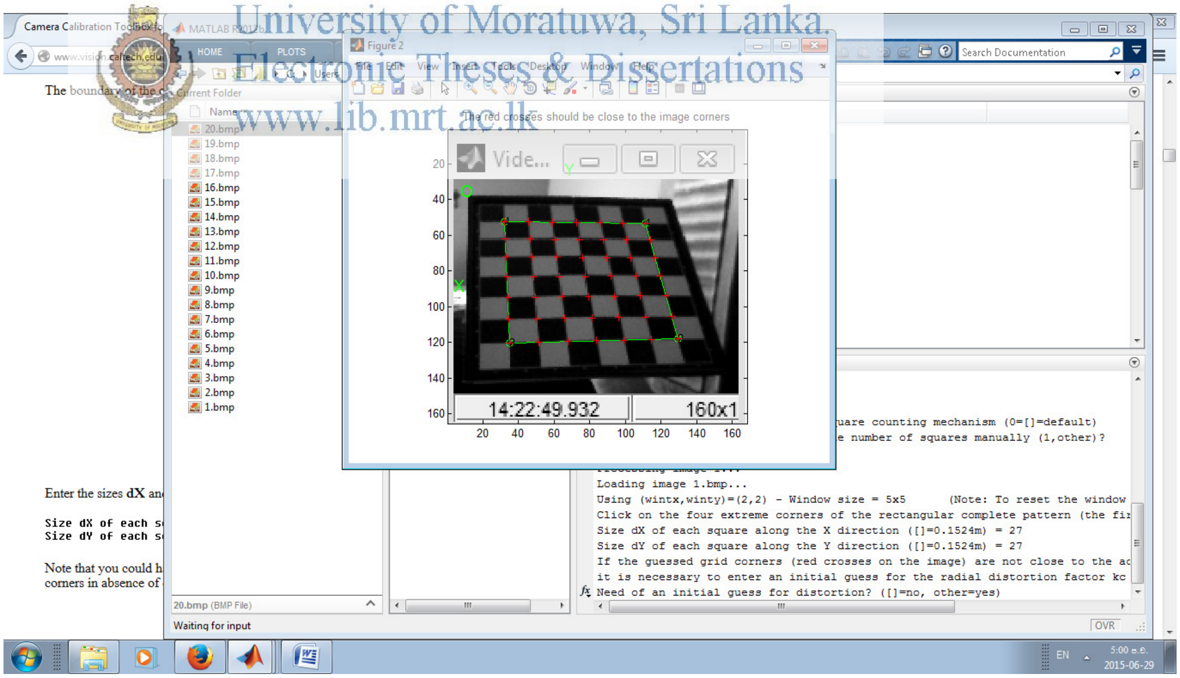


Image 01: Extracted Corners

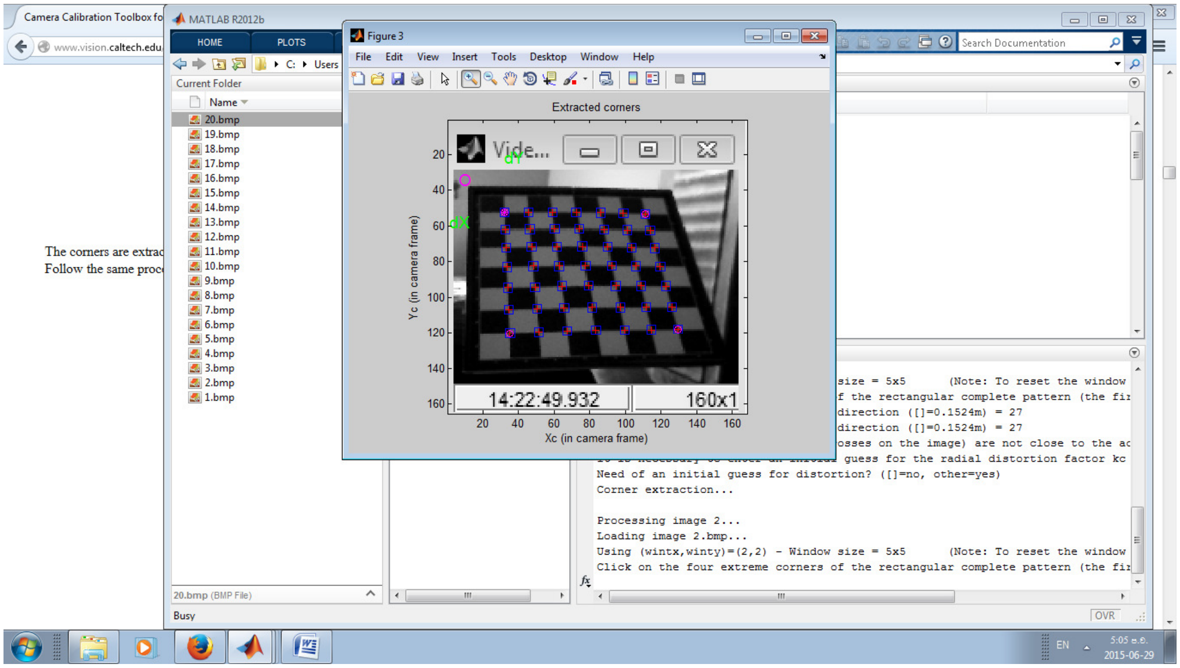



Image 02: Selecting Extreme Corners



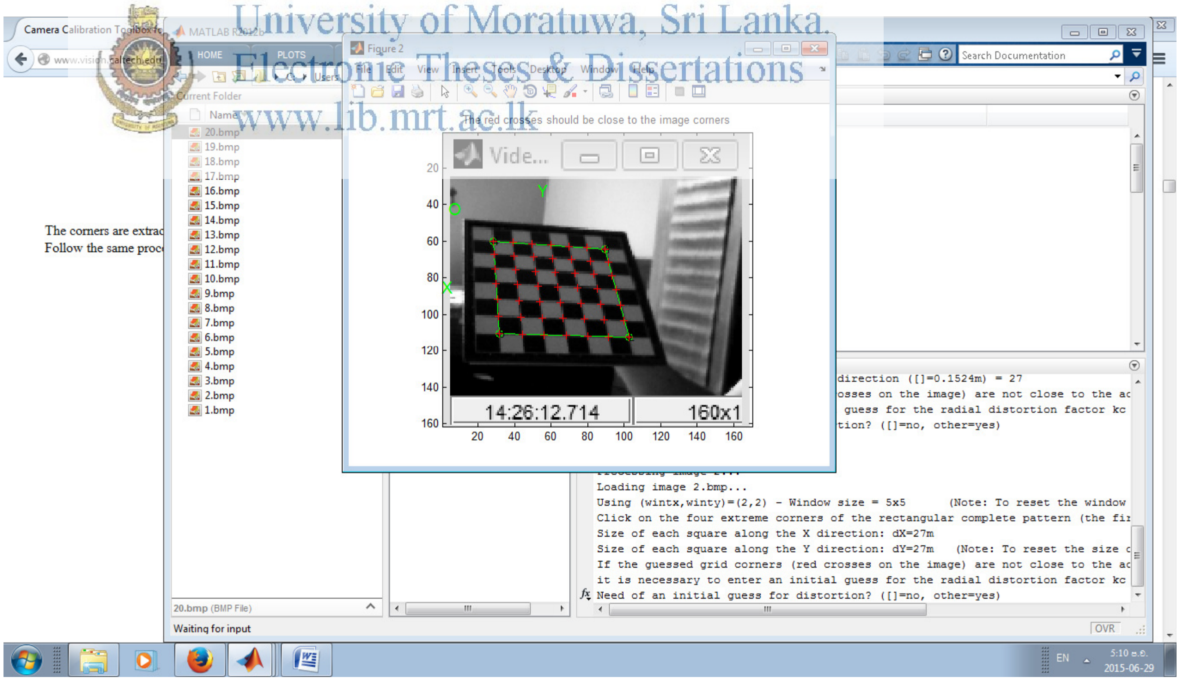


Image 03: Selecting Extreme Corners

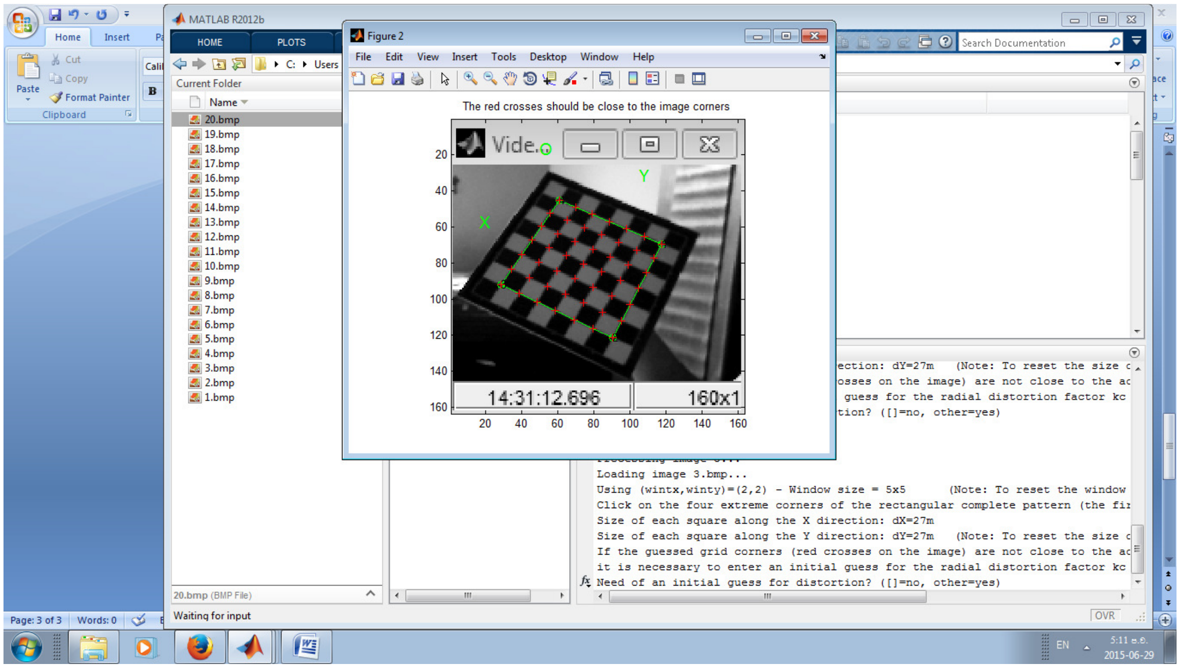



Image 04: Selecting Extreme Corners



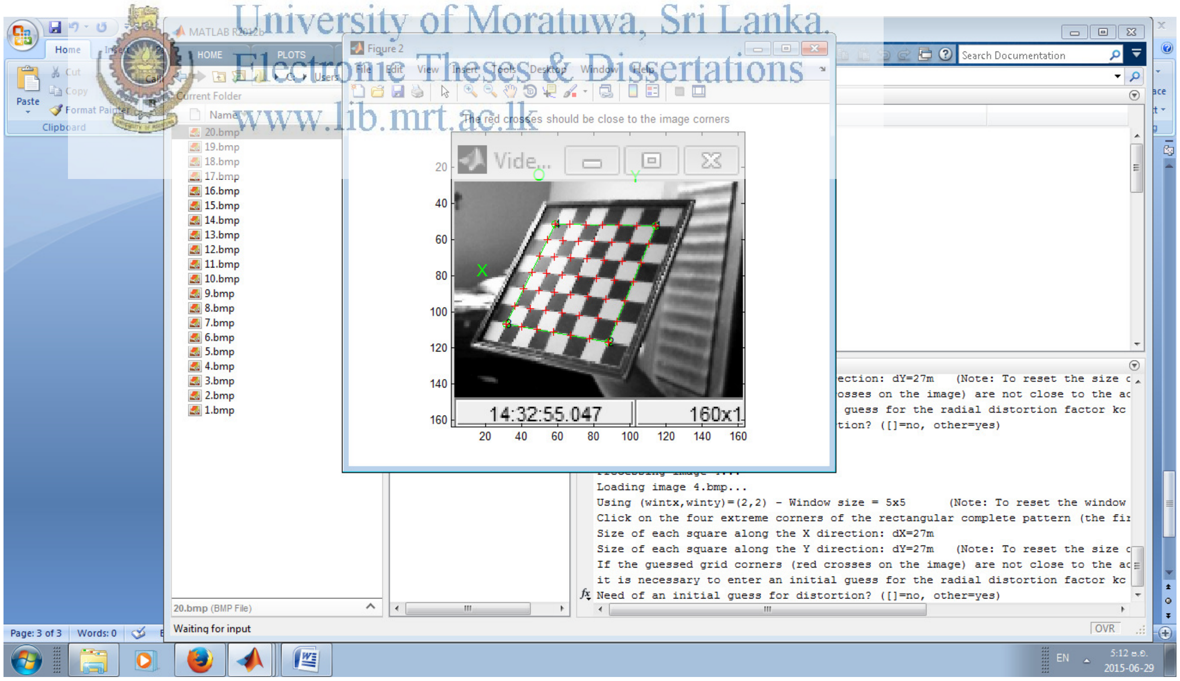


Image 05: Selecting Extreme Corners

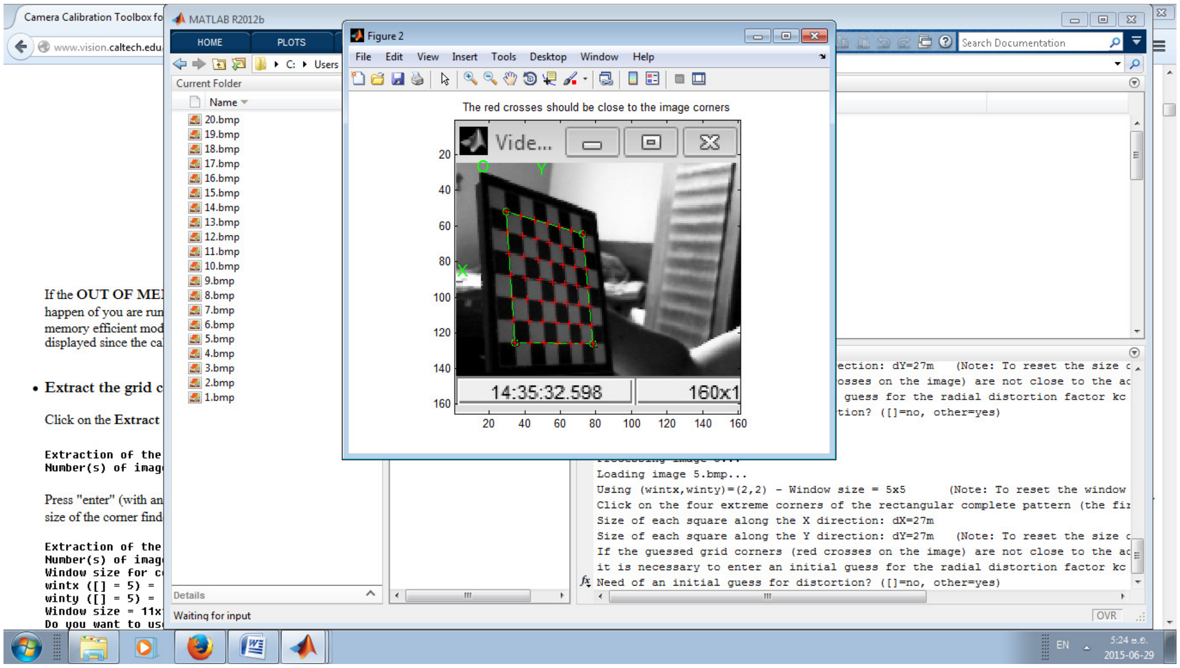



Image 06: Selecting Extreme Corners



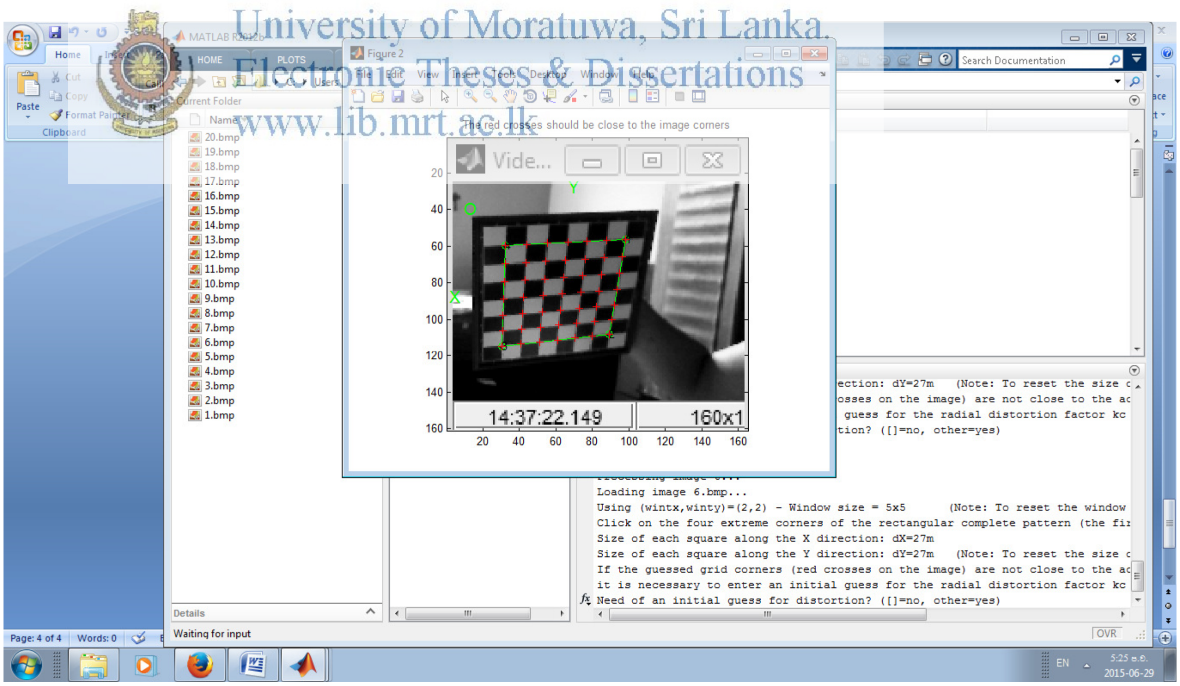


Image 07: Selecting Extreme Corners

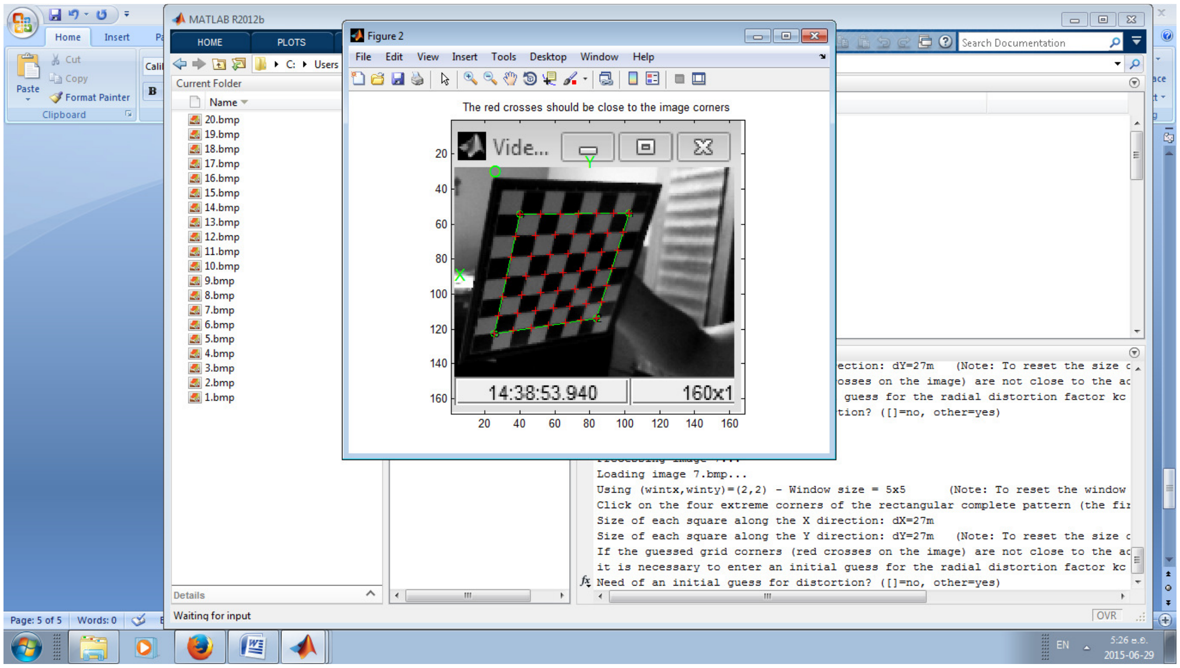



Image 08: Selecting Extreme Corners



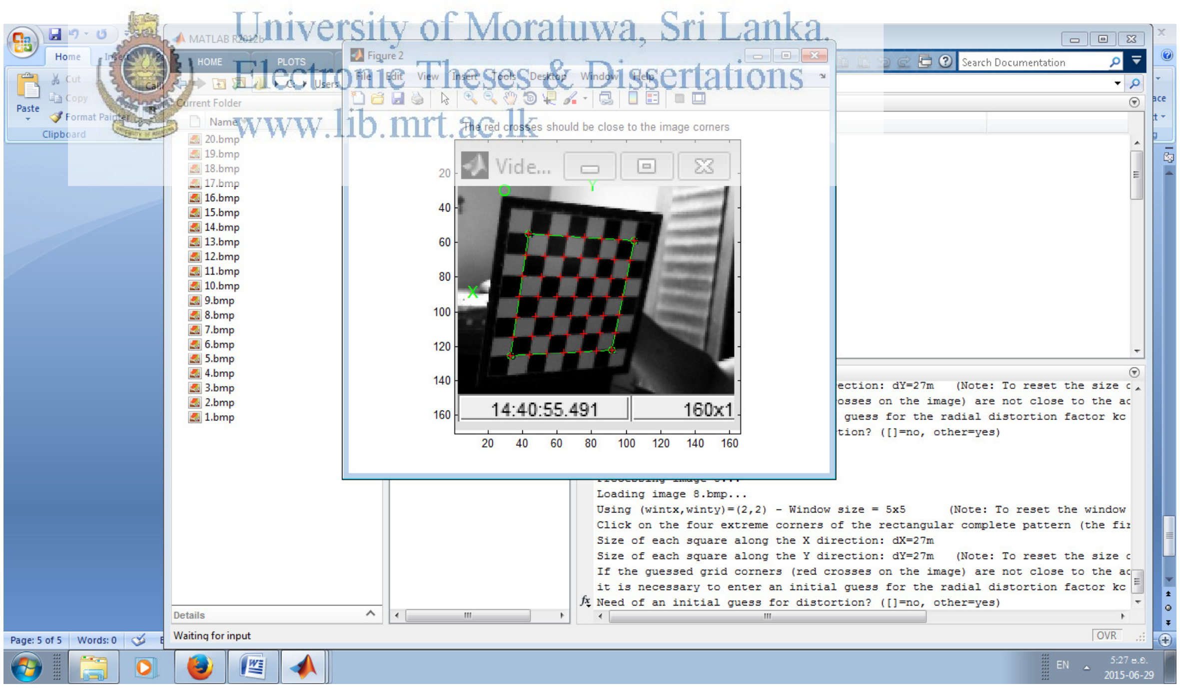


Image 09: Selecting Extreme Corners

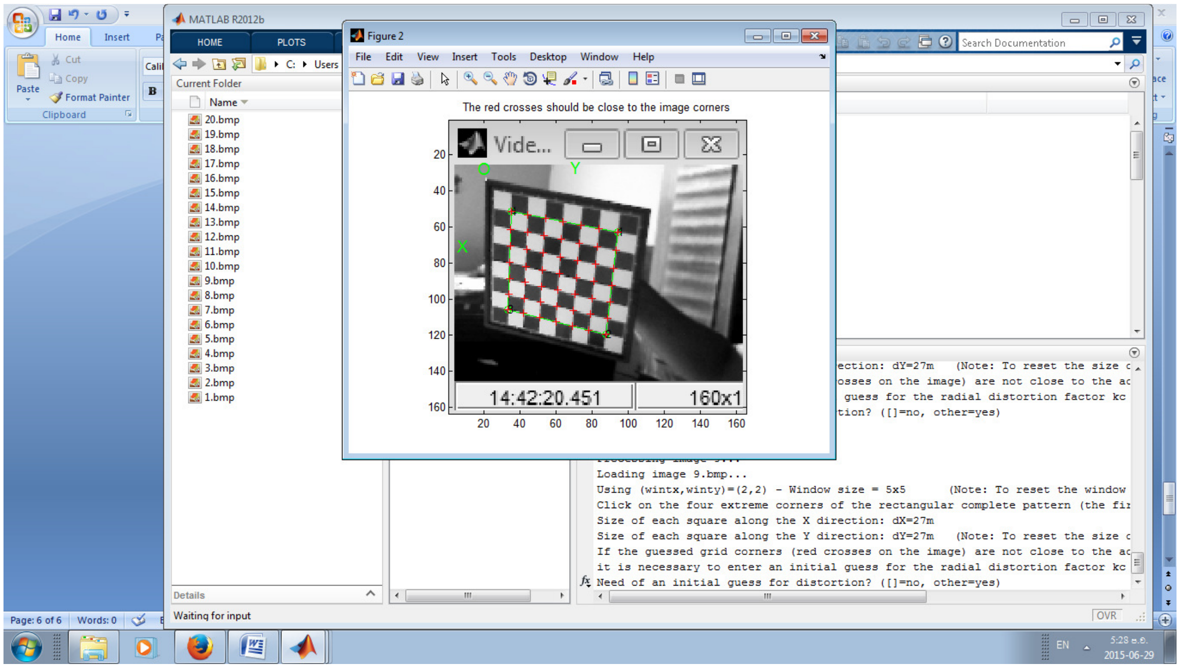



Image 10: Selecting Extreme Corners



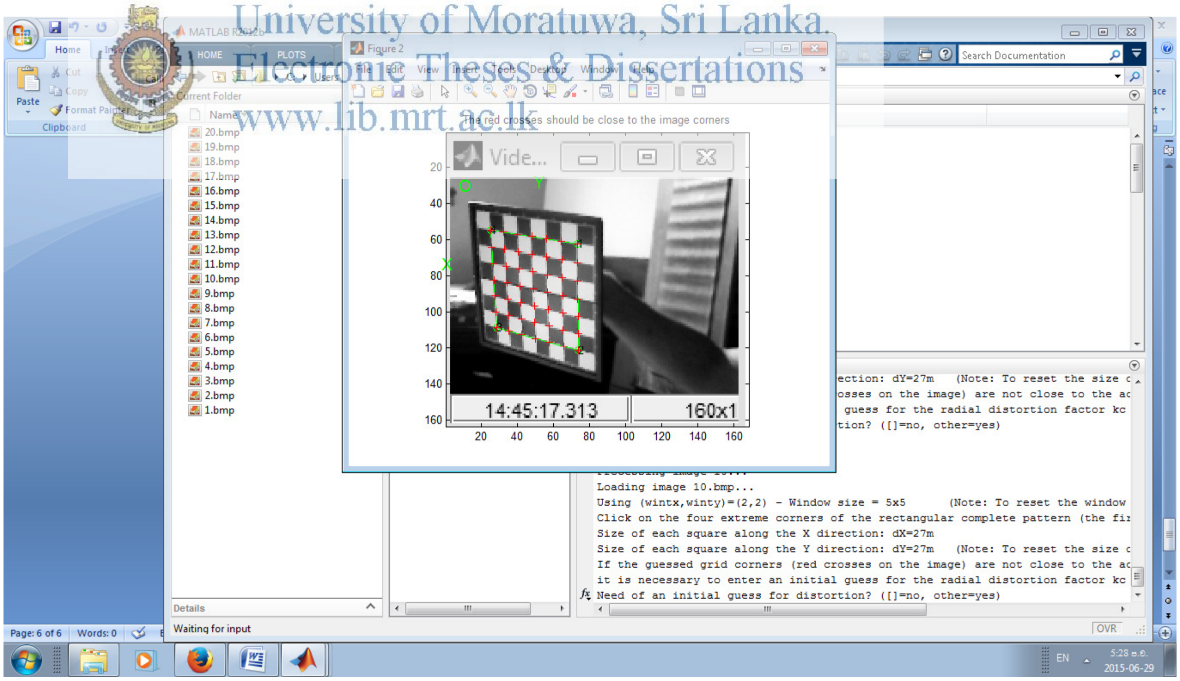


Image 11: Selecting Extreme Corners

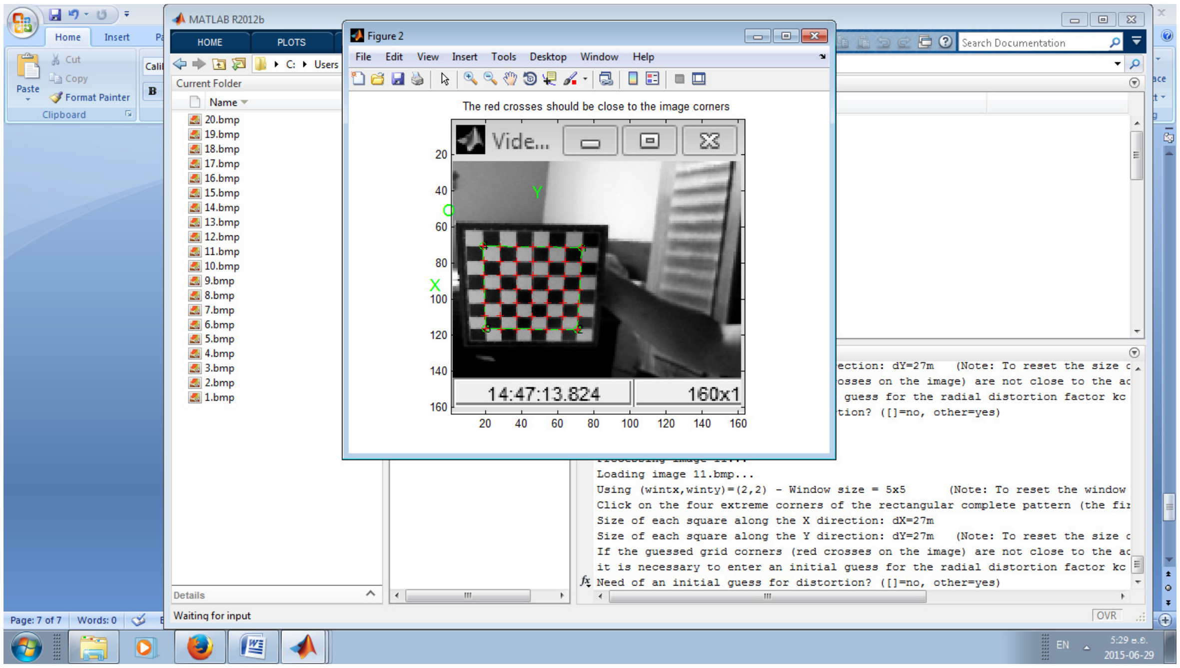



Image 12: Selecting Extreme Corners



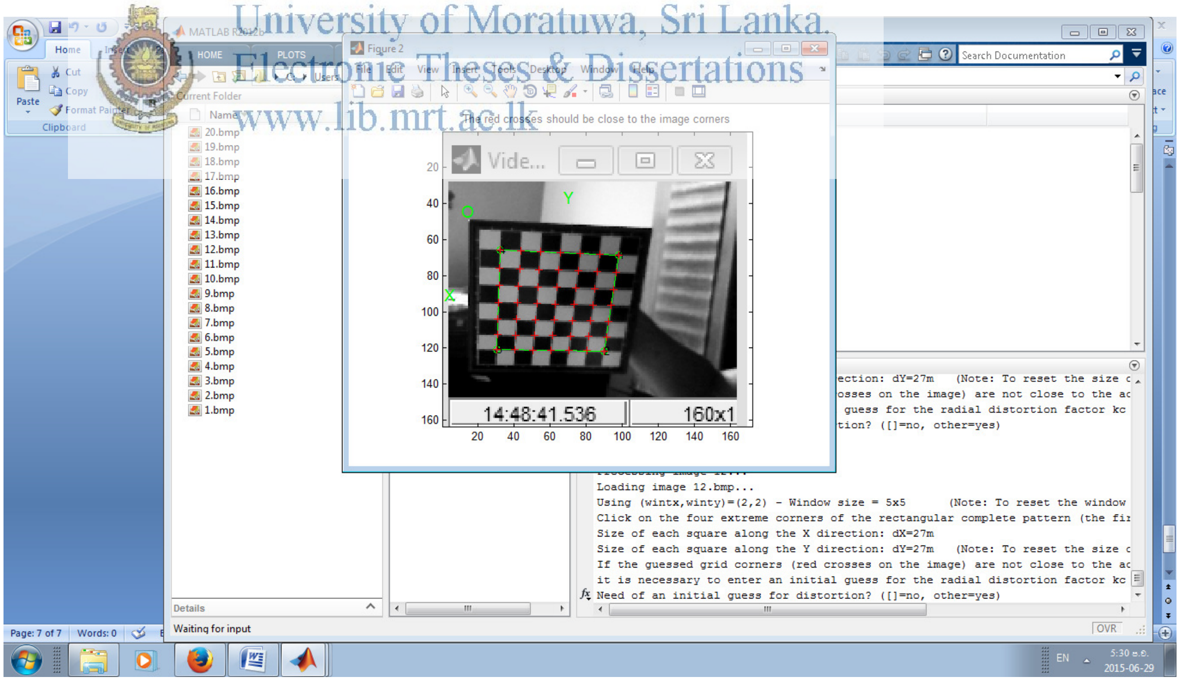


Image 13: Selecting Extreme Corners

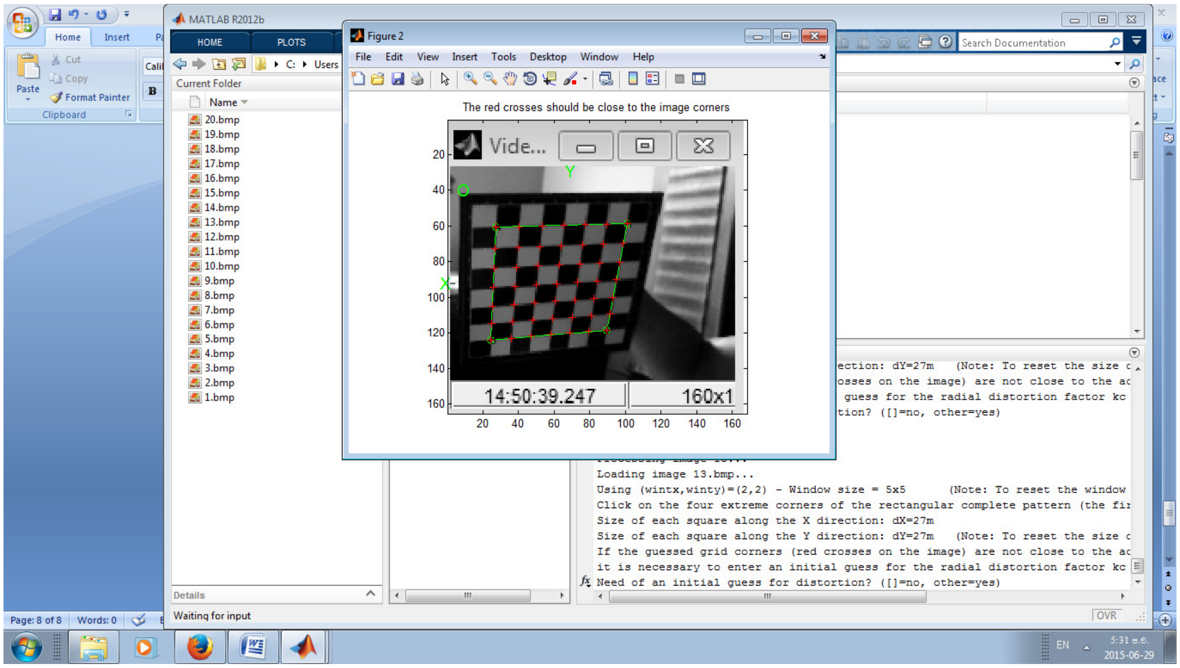



Image 14: Selecting Extreme Corners



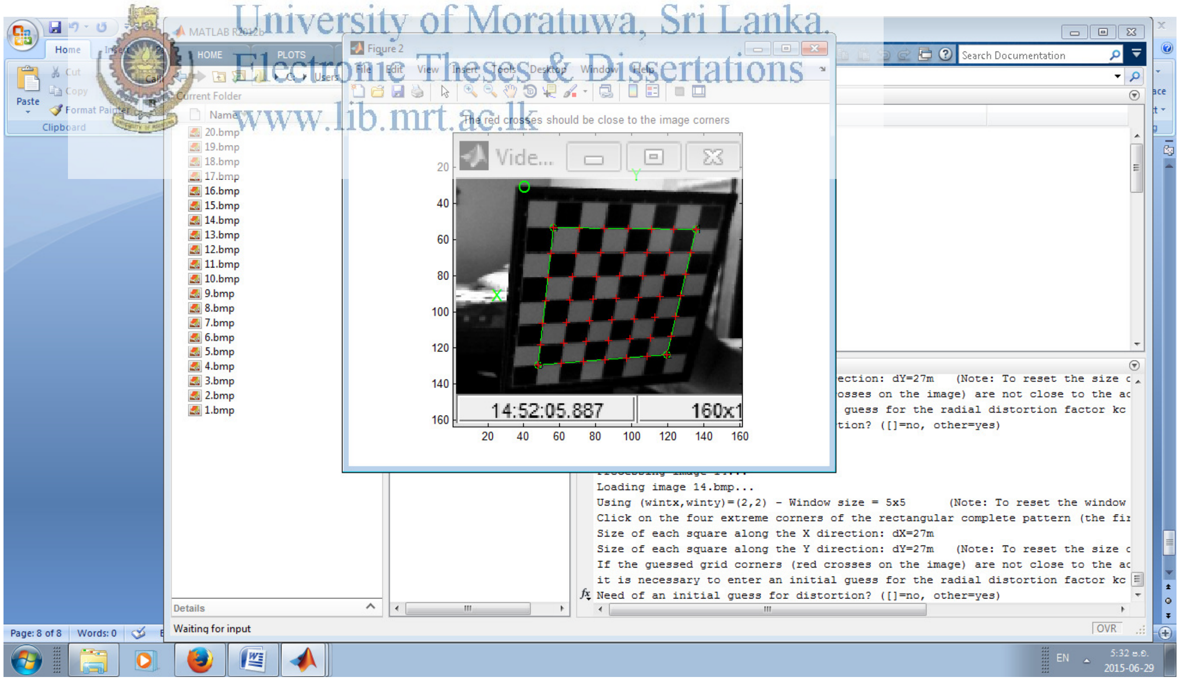


Image 15: Selecting Extreme Corners

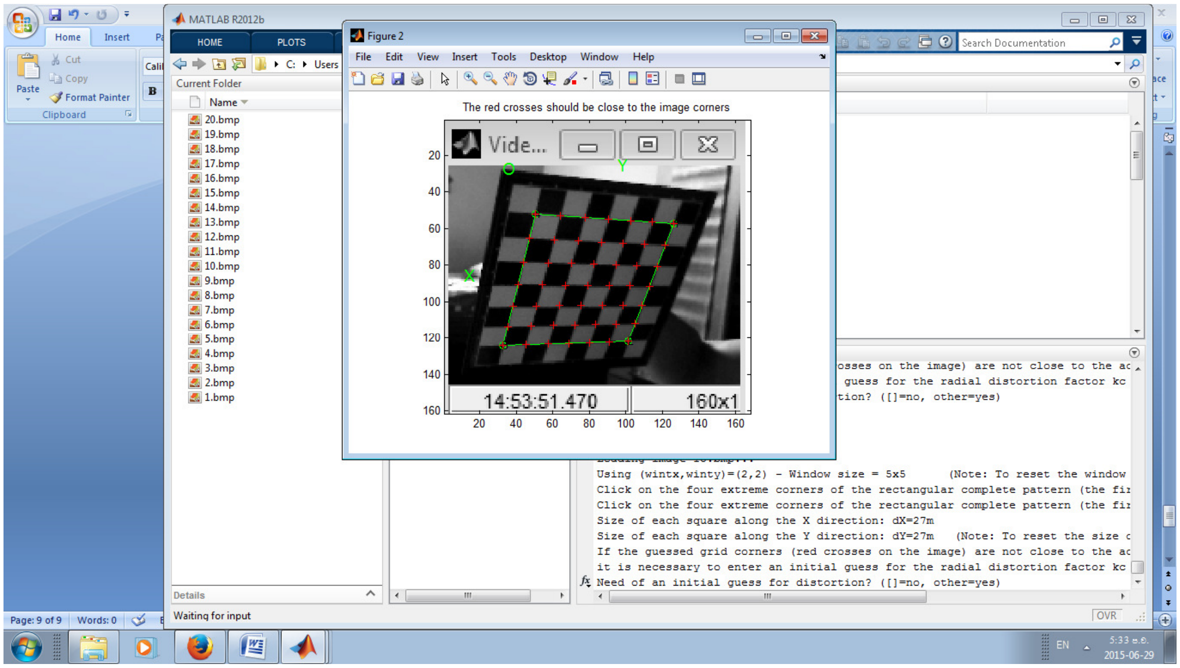



Image 16: Selecting Extreme Corners



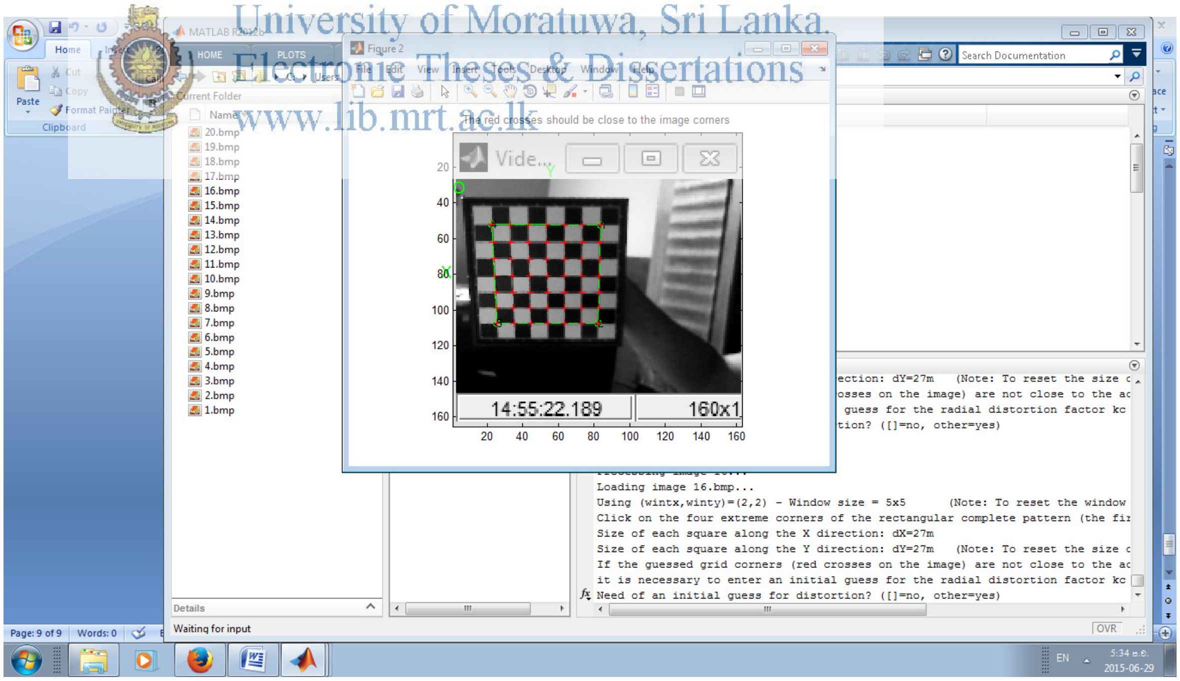


Image 17: Selecting Extreme Corners

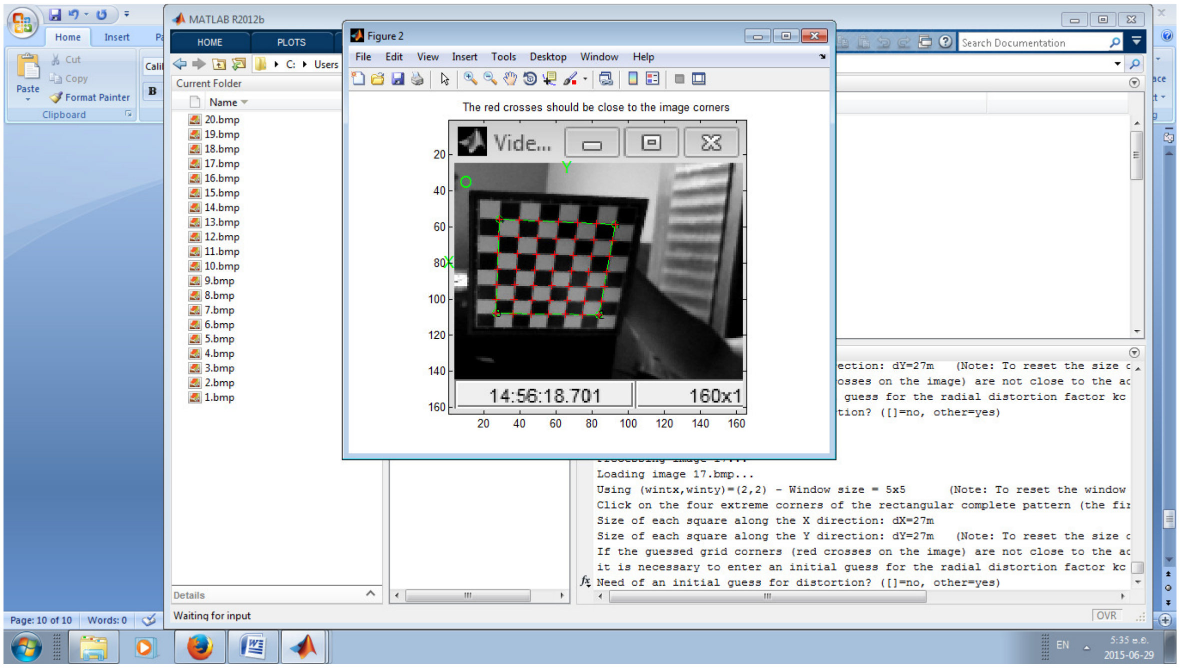



Image 17: Extracted Corners



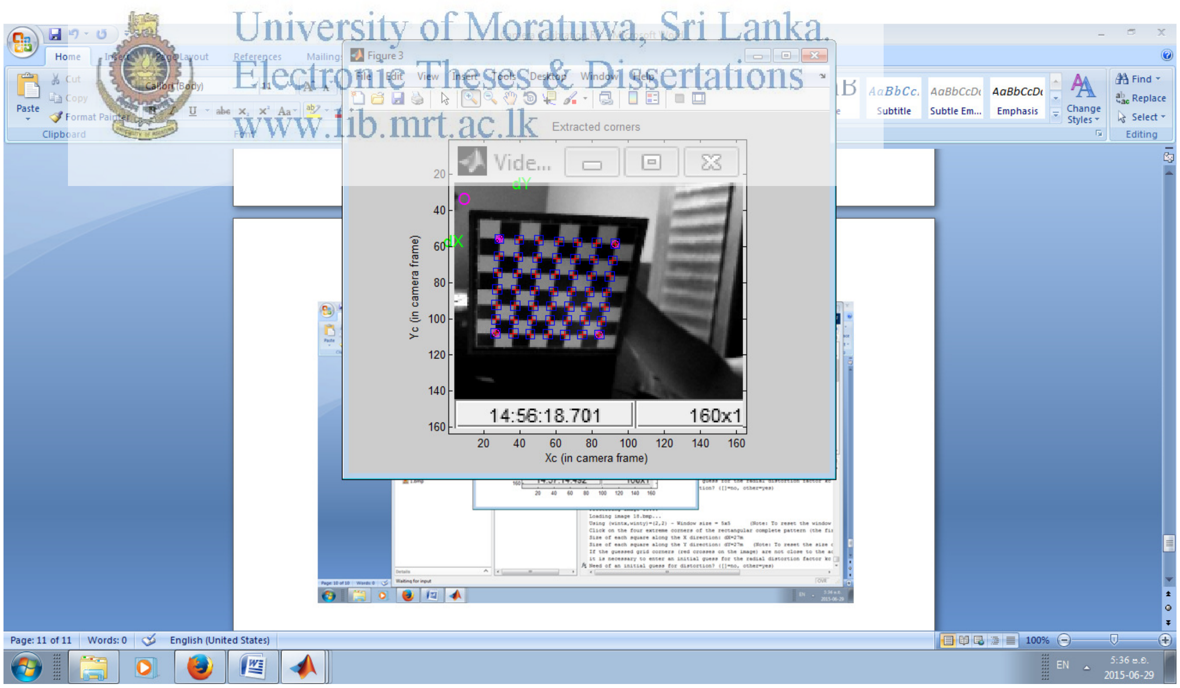


Image 18: Selecting Extreme Corners

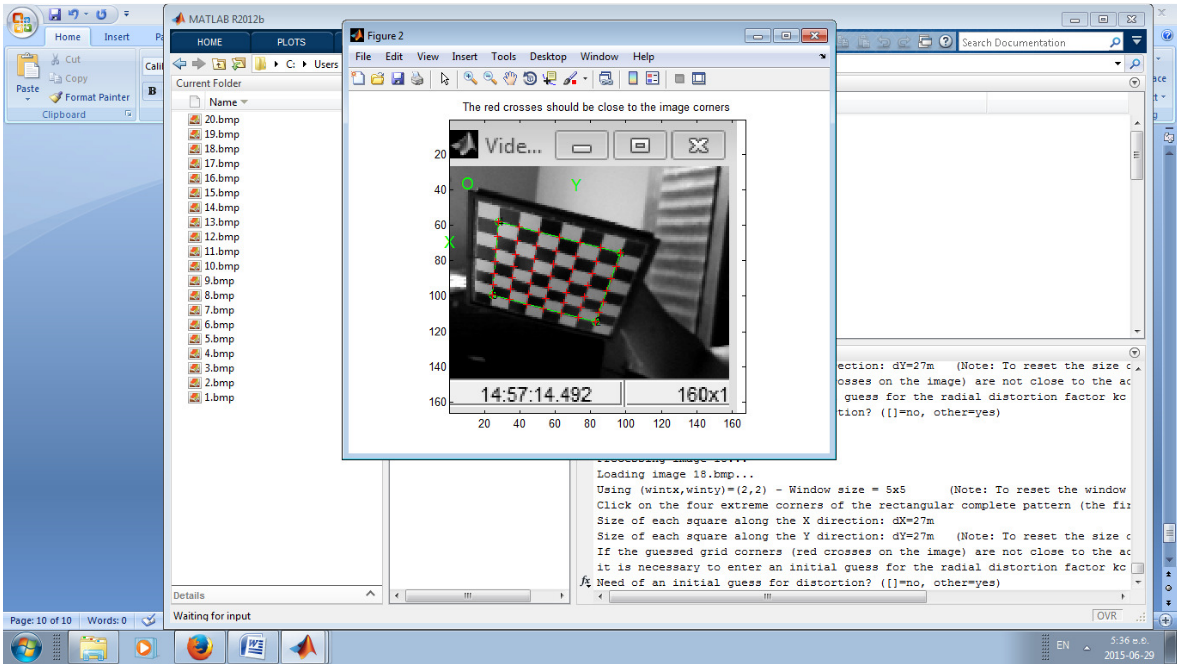



Image 18: Extracted Corners



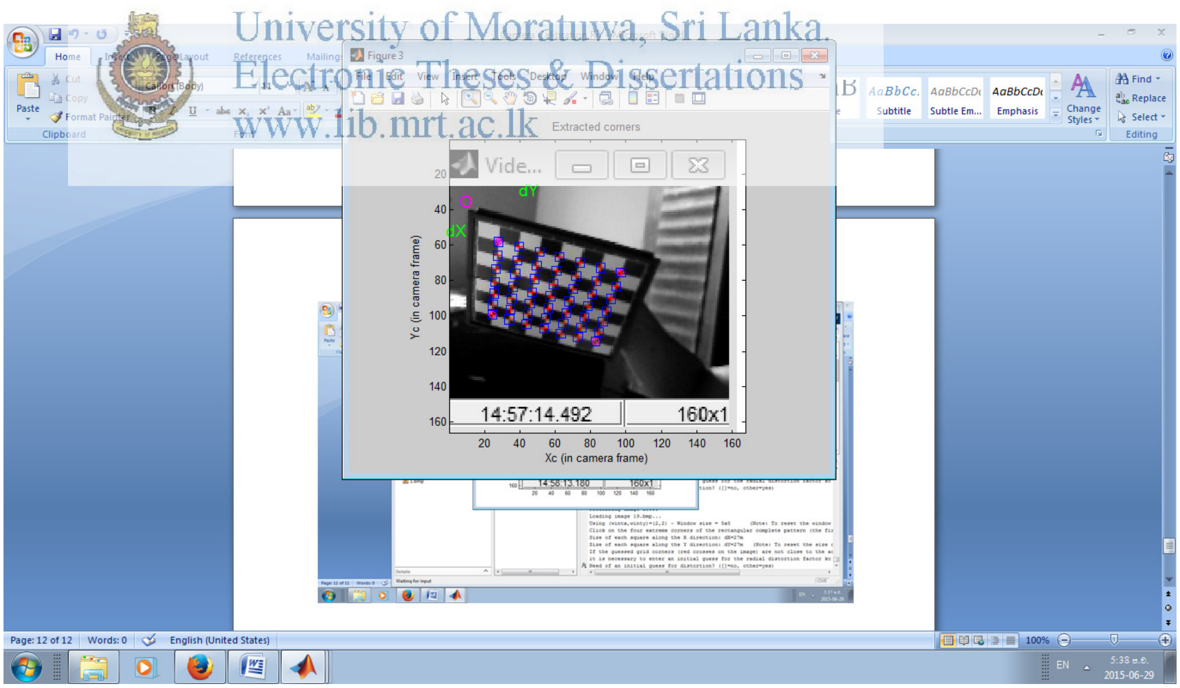


Image 19: Selecting Extreme Corners

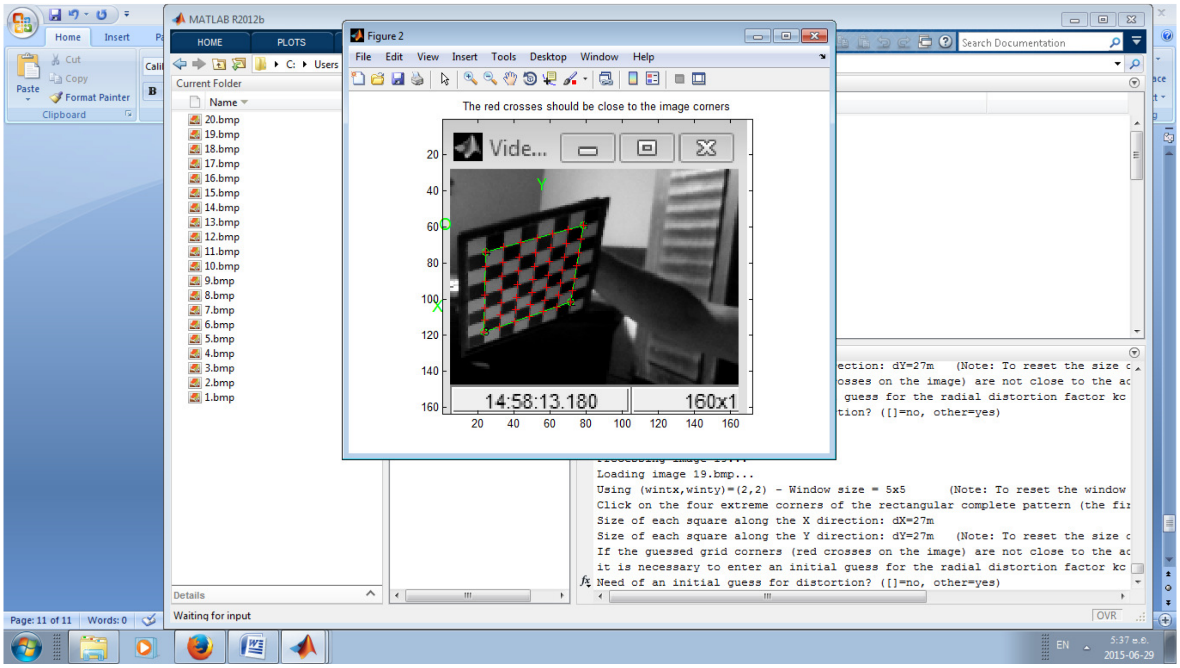



Image 19: Extracted Corners



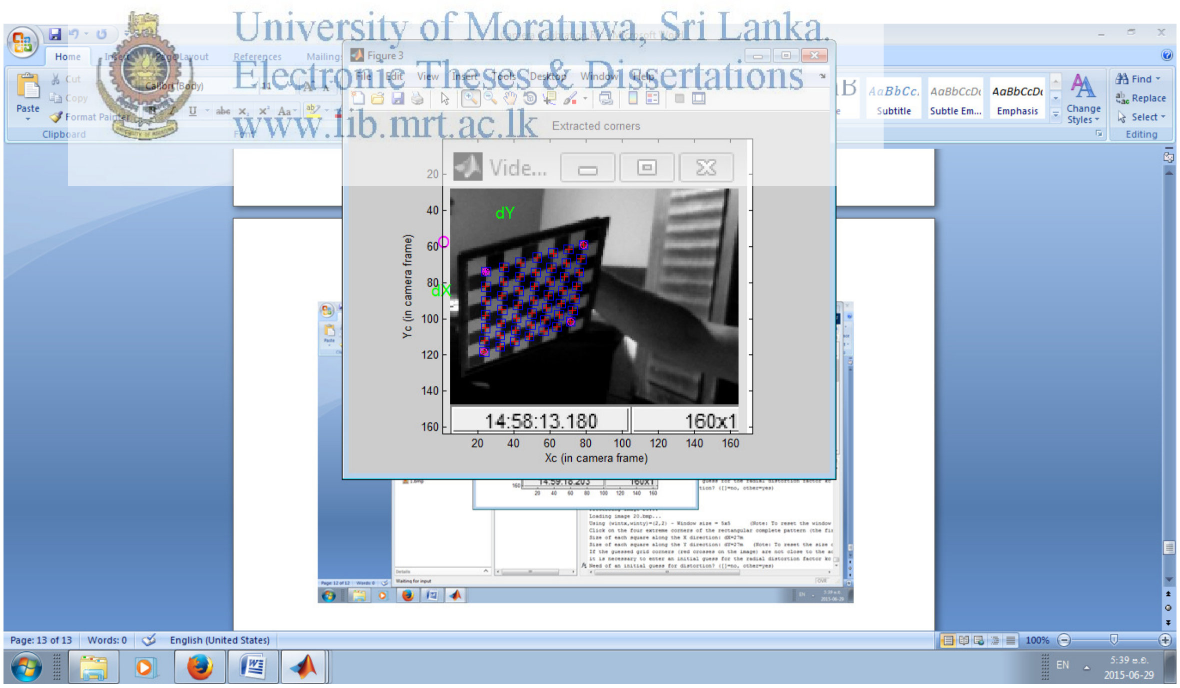


Image 20: Selecting Extreme Corners

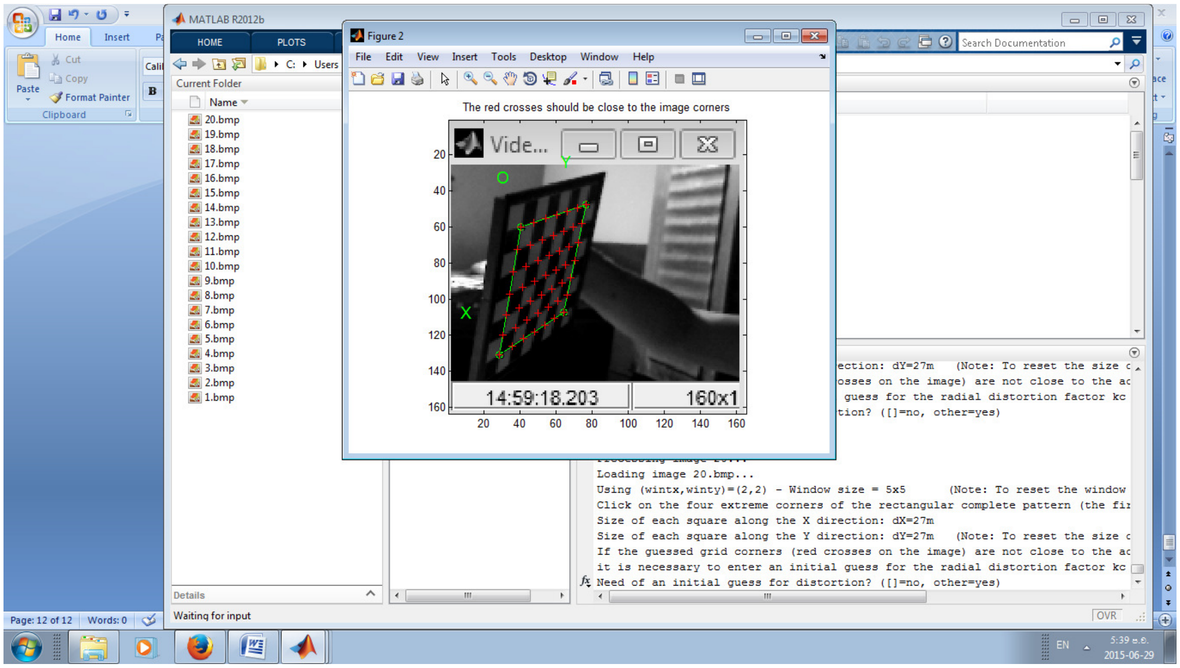
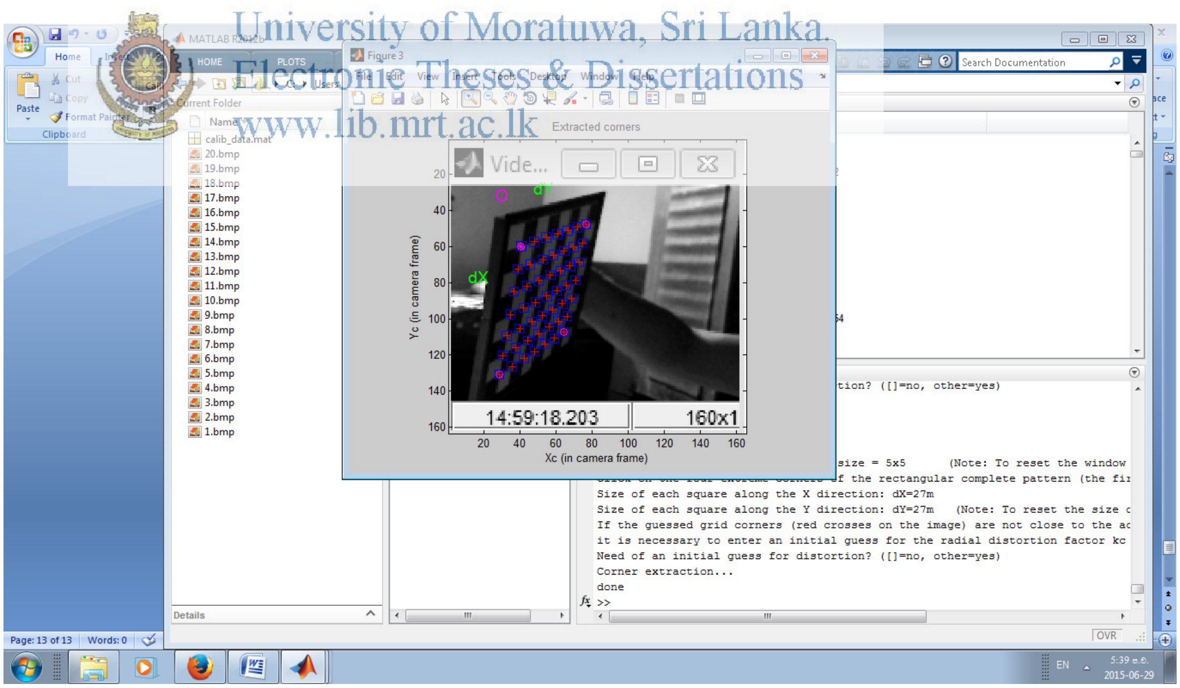
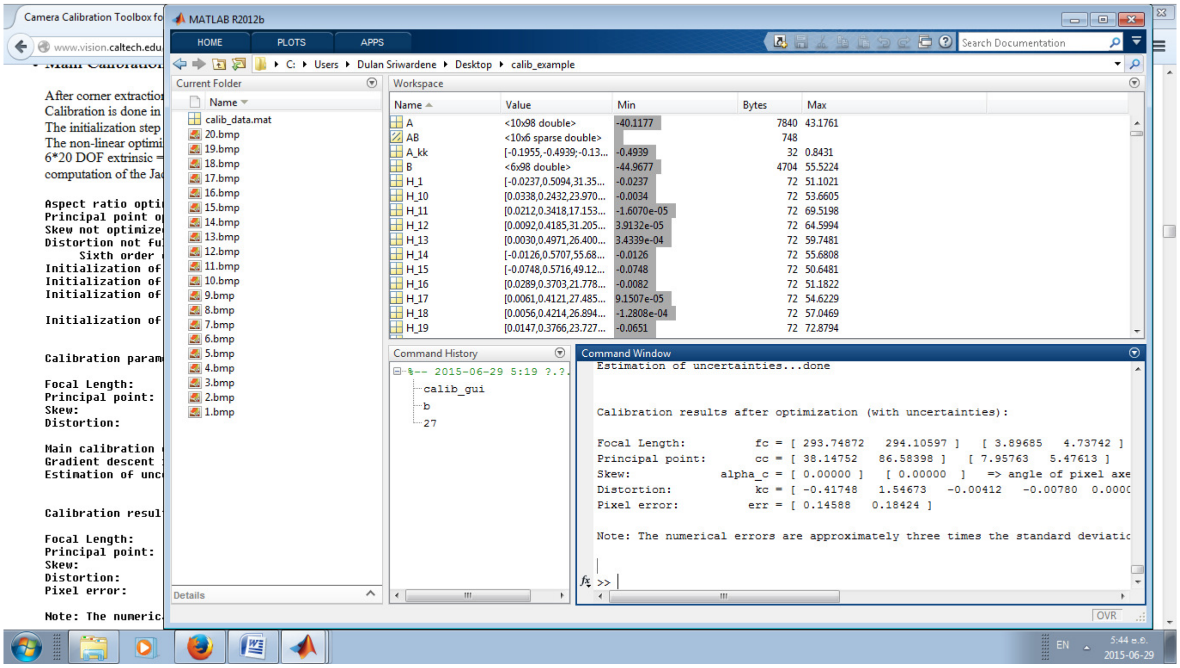


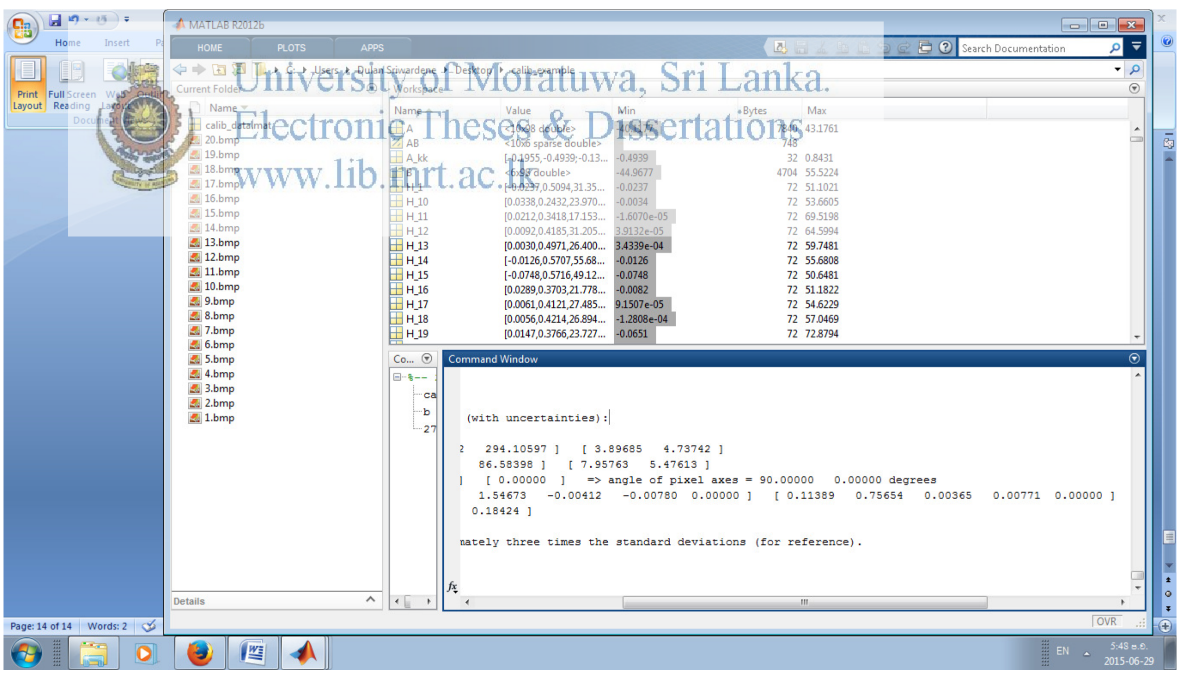

Image 20: Extracted Corners



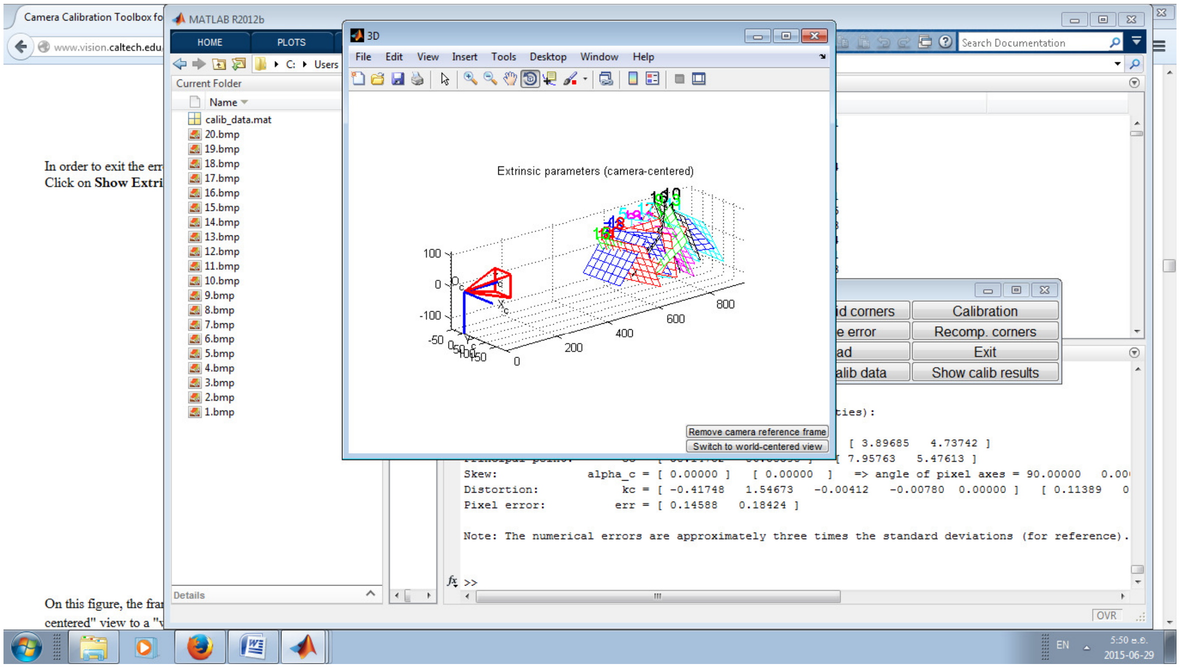


Calibration Results

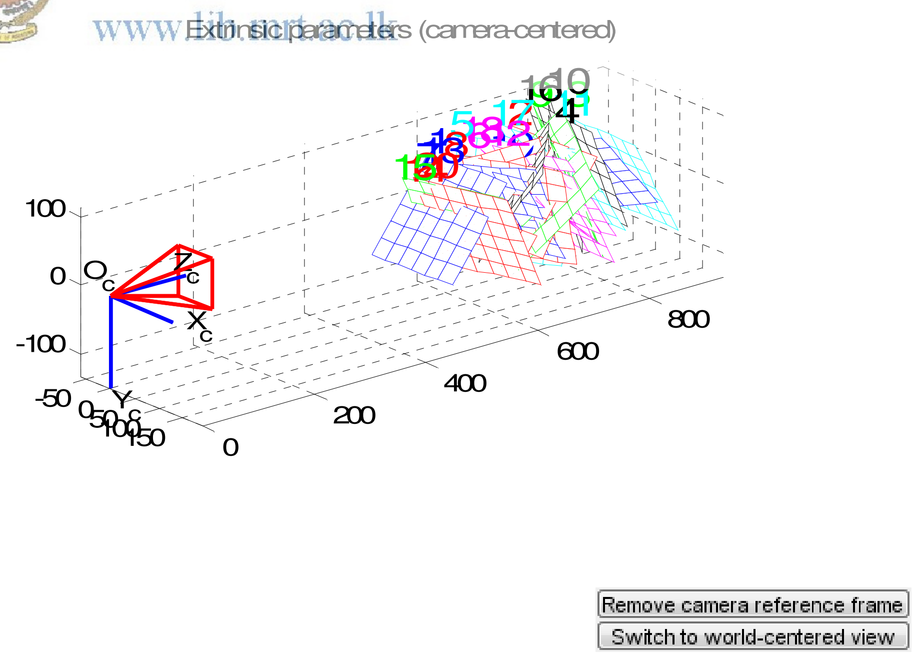


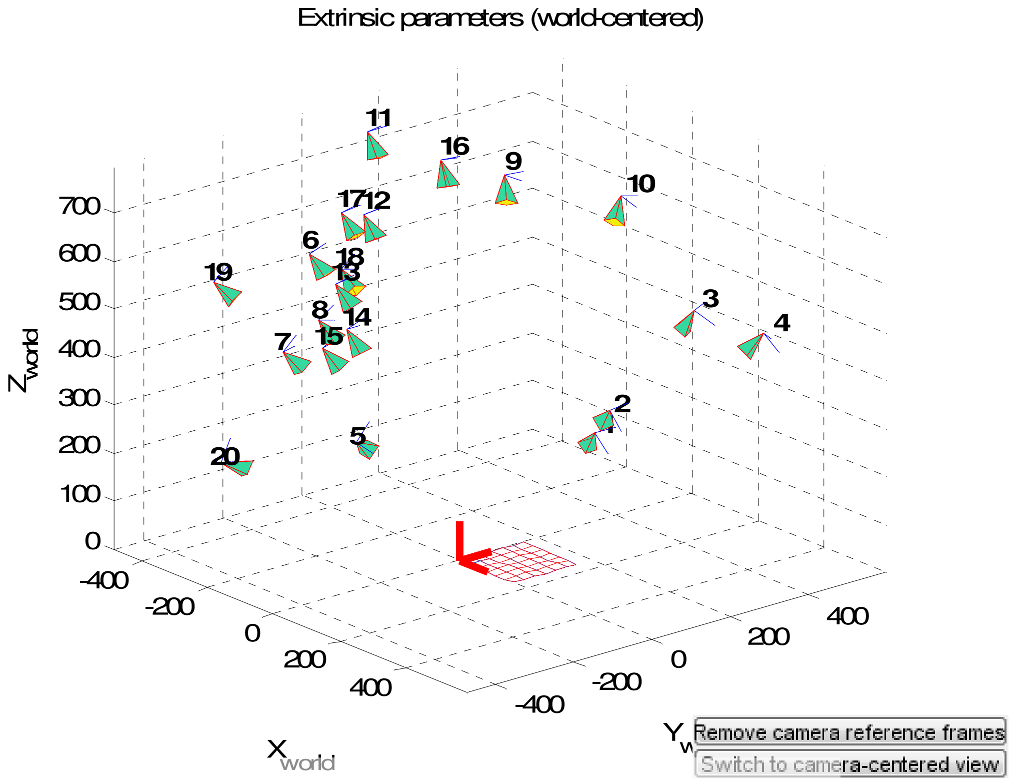



Show Exentric

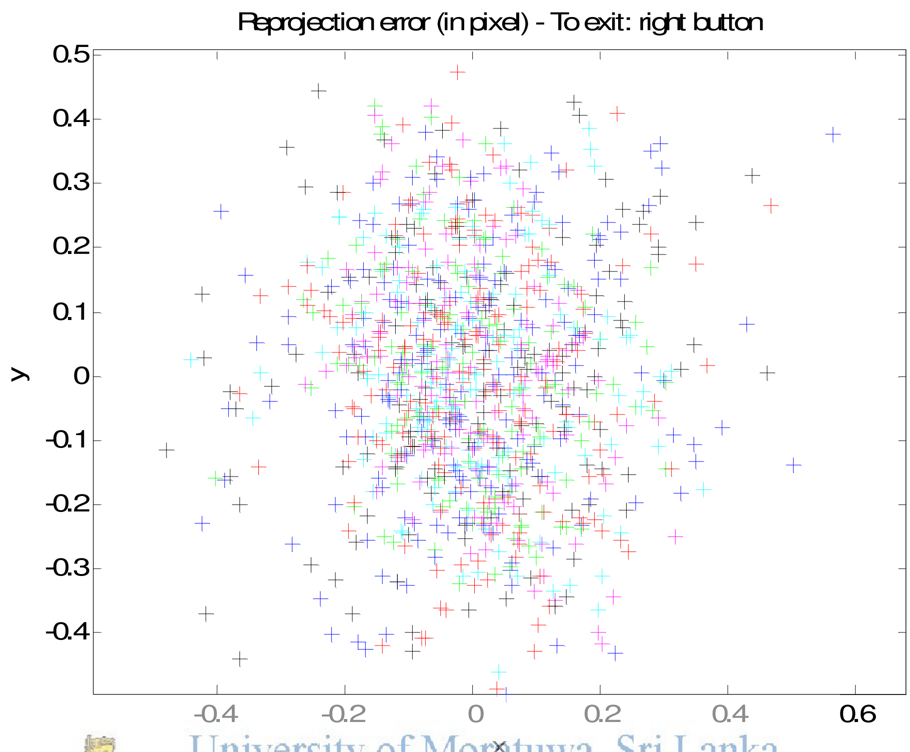




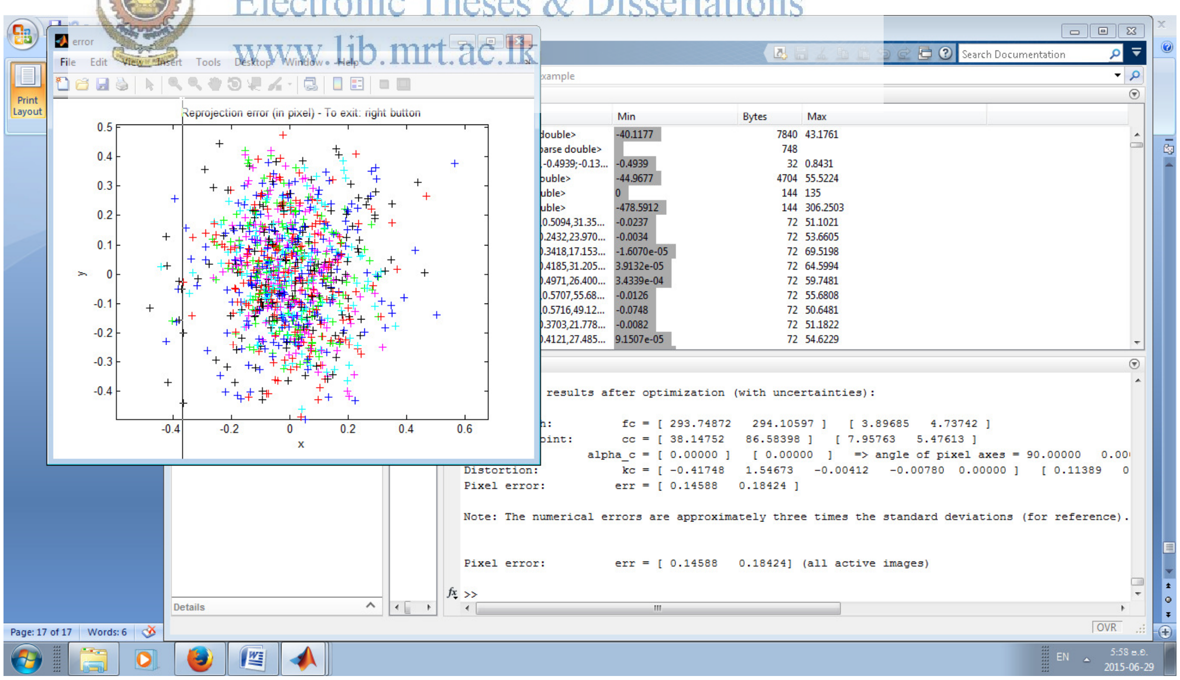




Extrinsic parameters (world-centered)
11
16
9
10
17
12
6
18
13
19
8
14
7
15
3
4
2
5
20
700
600
500
400
300
200
100
0
Zworld
-400
-200
0
200
400
Xworld
-400
-200
0
200
400
Remove camera reference frames
Switch to camera-centered view

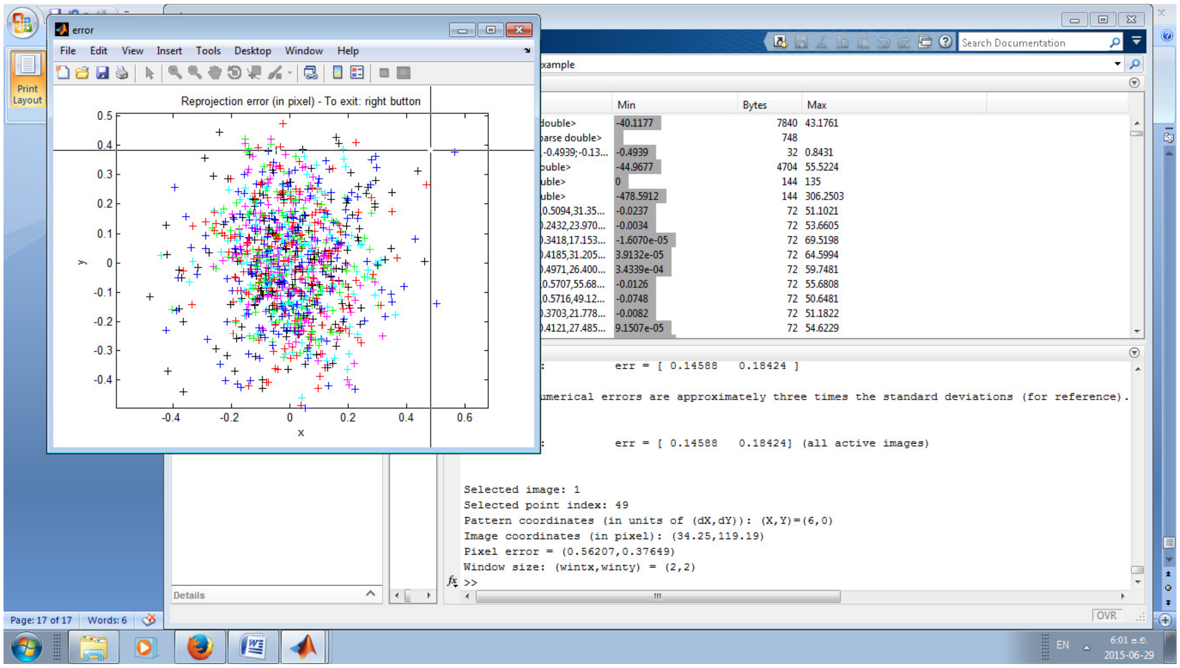
Analyze Error





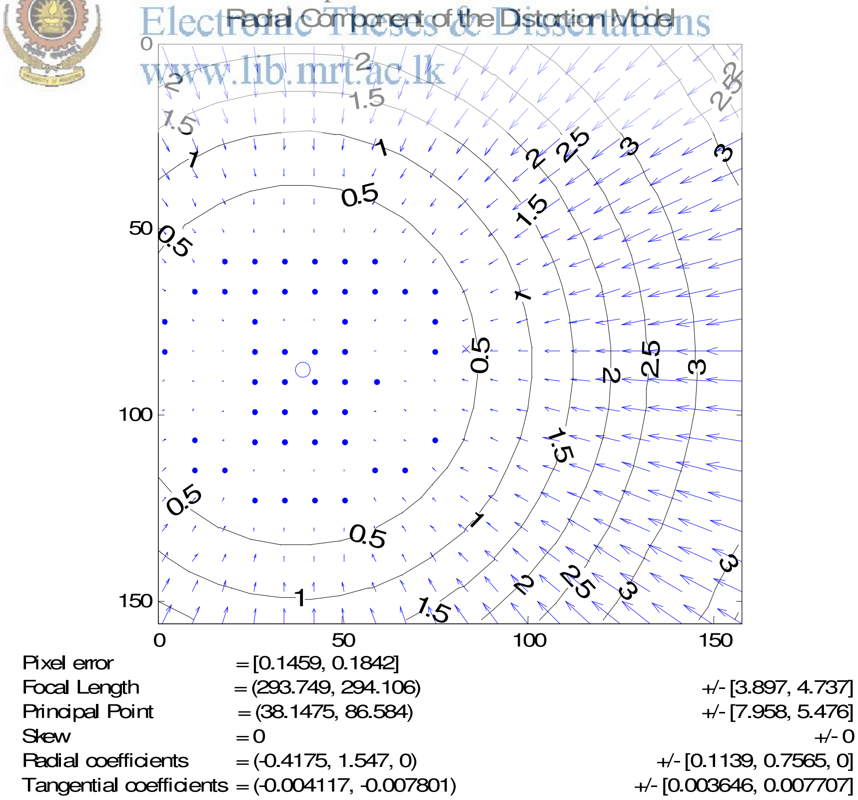



Finding the error at cursor point

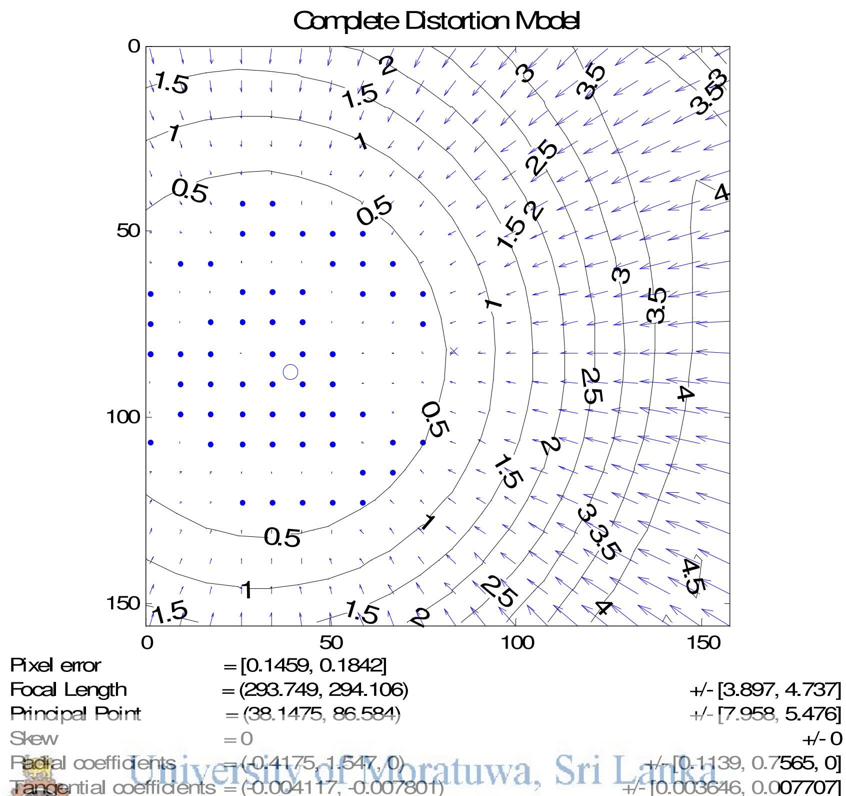



Visualize Distortions- Radial Component of the Distortion Model

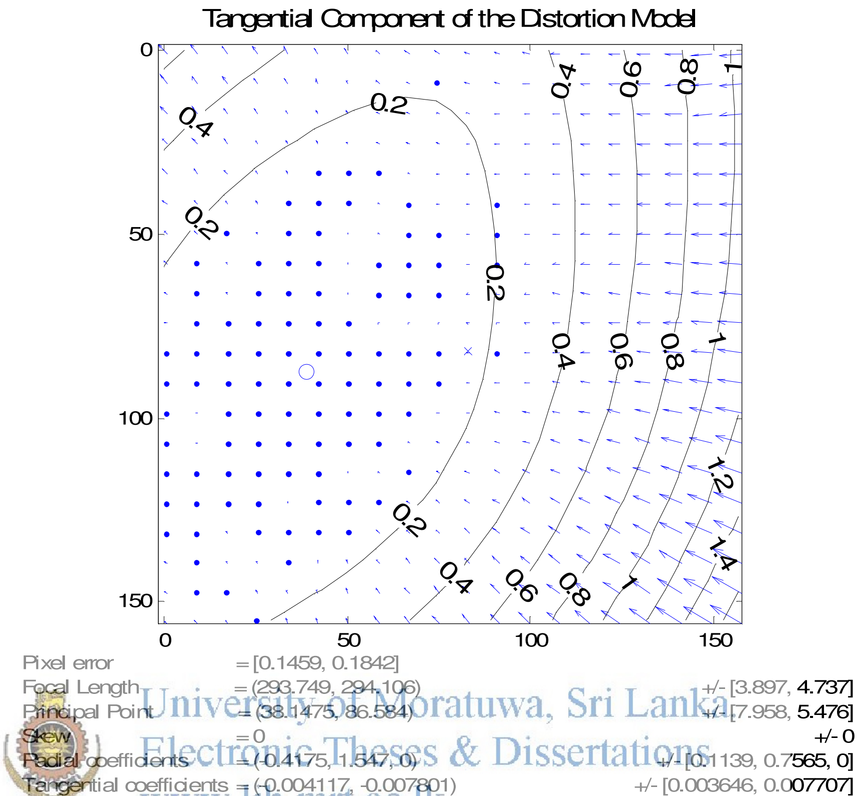




Visualize Distortions- Complete Distortion Model



Visualize Distortions- Tangential Component of the Distortion Model






### 3.5.2. Determination of Actual Height of Objects for the Front Camera

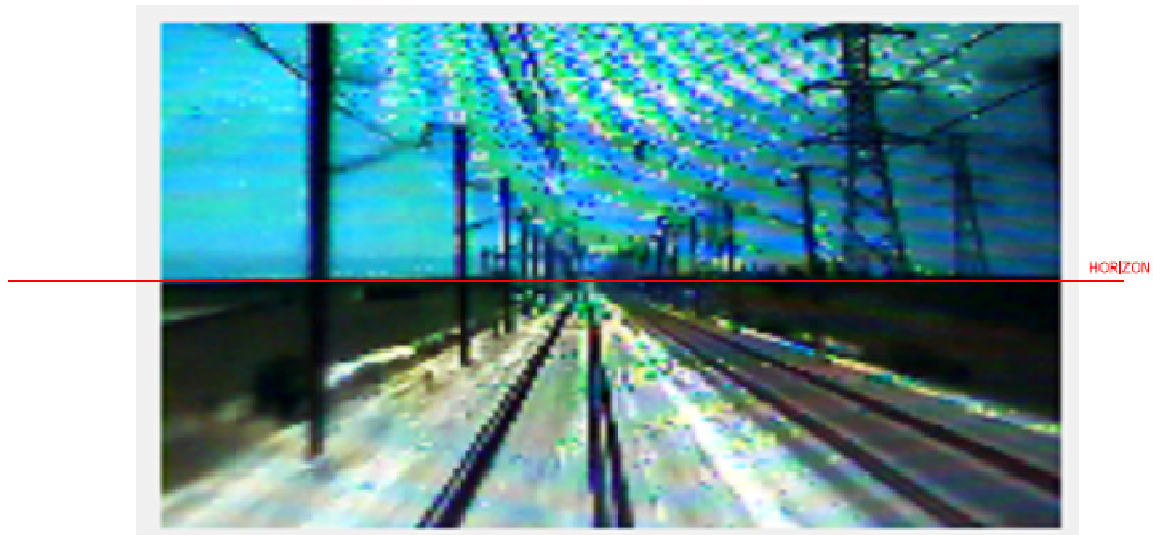
Object : Tube well post lying x distance from camera

Calibrator : A vertical ruler with mm scale

Methodology: A vertical ruler kept at y distance from camera and picture was taken capturing the vertical ruler on ground and the tube well on ground.

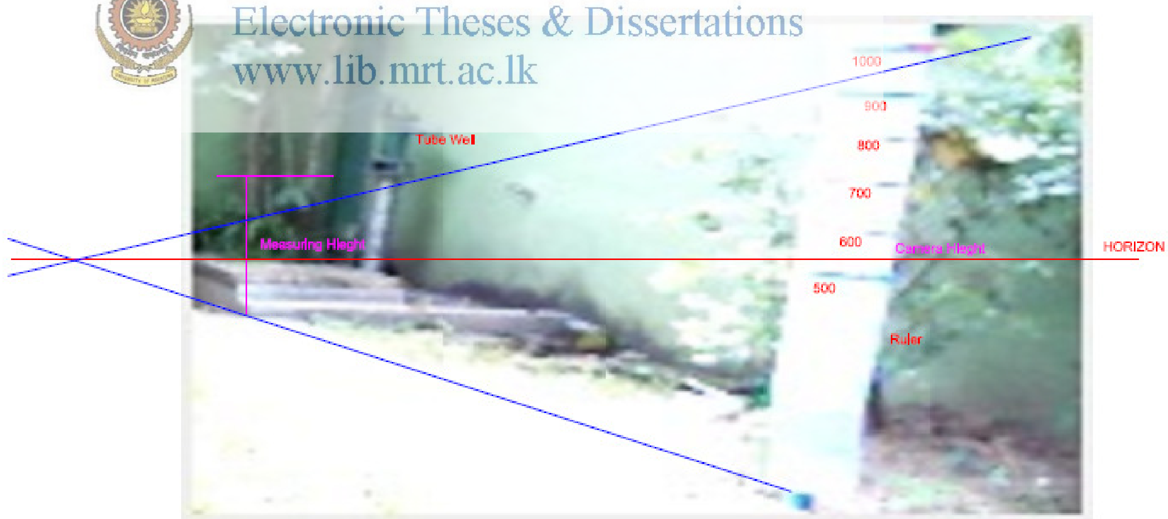
The Horizon of the camera was marked for a railway video frame (Fig 3.12 (a)).

Since the ground plane and horizontal planes of up most heights of objects intersect at horizon of the camera which was found by Fig 3.12 (a.) and by maintaining similar conditions at camera end, height of the tube well from the ground level can be geometrically found as in Fig 3.12 (b.).[18]




(a.) Marking the horizon of a video frame






| | |
|---|---|
| Camera Height | = Approx. 520mm |
| Considered Height of Tube Well Post | = Approx. 975mm |

(b.) Determination of Actual Height of an Object

**Fig 3.12 : Measuring Actual Heights of Objects captured from Web Camera**

### 3.5.3. Determination of Minimum Area (300 Pixels) for Blob Analysis

Focal length after camera calibration = 294 pixels

Confirmation of focal length determined by the camera calibration using an approximation;

Object: Square Hard Board 100mm x 100mm (10000 $mm^2$) kept 1100mm distance from front camera

Actual length of square hard board center from camera center = 1100 mm

According to Fig 3.13,

Image height =27 pixels

Focal length (Approxi.) according 100mm x 100mm square hard board calculations

= 27 x 1100 /100 pixels

= 297 pixels



Length of a common railway sleeper = 2600mm

Width of a common railway sleeper = 275mm

Length in between two sleepers = 550mm

Consider a sleeper 75m ahead from the camera center point,

Image (sleeper) length = 2.6/75 x 294 pixels

= 10.192 pixels

For 300 pixels image (Obstacle) on considered sleeper about two times of sleeper length,

Image height = 300/(10.192x2) pixels

= 14.717 pixels

Actual height of the Obstacle = 14.717/294 x 75 m

= 3.75 m

**Therefore for blob analysis, 300 pixels (minimum) have been considered to track the object for drawing bounding box and for beeping.**

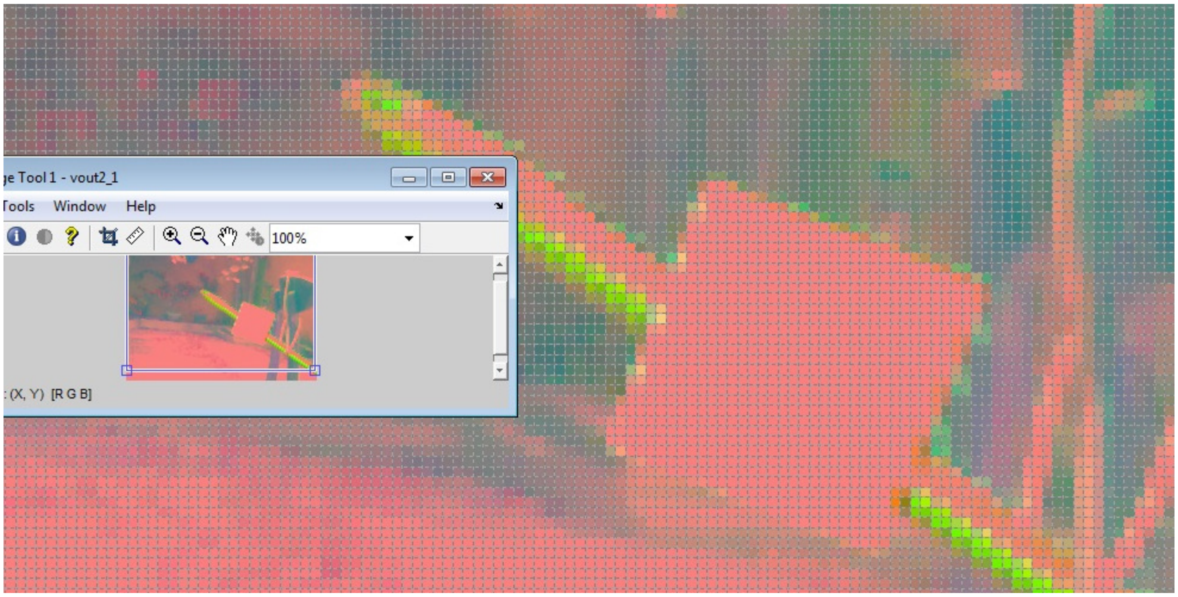



**Fig 3.13: Image of Square Hard Board (100mm x 100mm) at 1100mm Distance**

**Case 01: Locomotive Moves on Constant Speed**



A locomotive engine moves on a constant speed has been considered in this section. Ten consecutive video frames have been analyzed for motion segmentation and since no obstacle ahead the railway, very few motion vector fields have been found.

**VideoClip:**file:///F:/Videostrain/Strasbourg%20to%20Paris%20Driver%27s%20eye %20view%20preview.webm

**Fig 3.14: Locomotive engine travels in a constant speed**

Yellow pixels shows the motion vectors generated due to FOEs. Since a cluster of motion vectors bounded by connecting yellow pixels with connectivity parameter 8 have been considered to compare minimum required blob area pixels (300).



**Checking no. of yellow pixels;**

According to $10^{th}$ frame, cursor position shows motion vector covers two yellow pixels (fig 3.15).

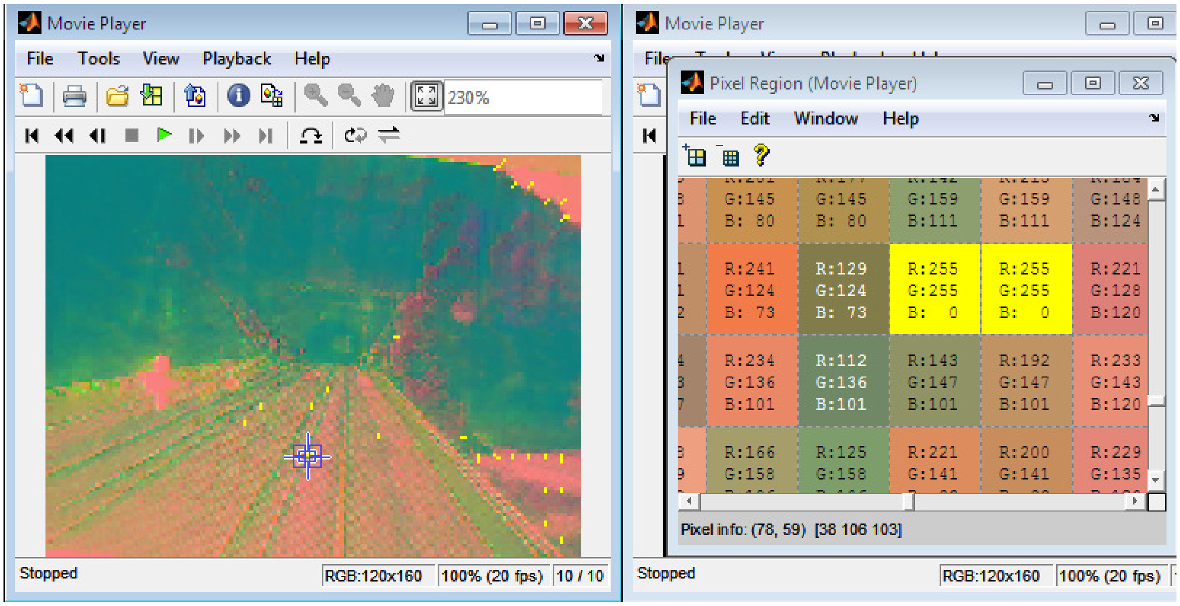
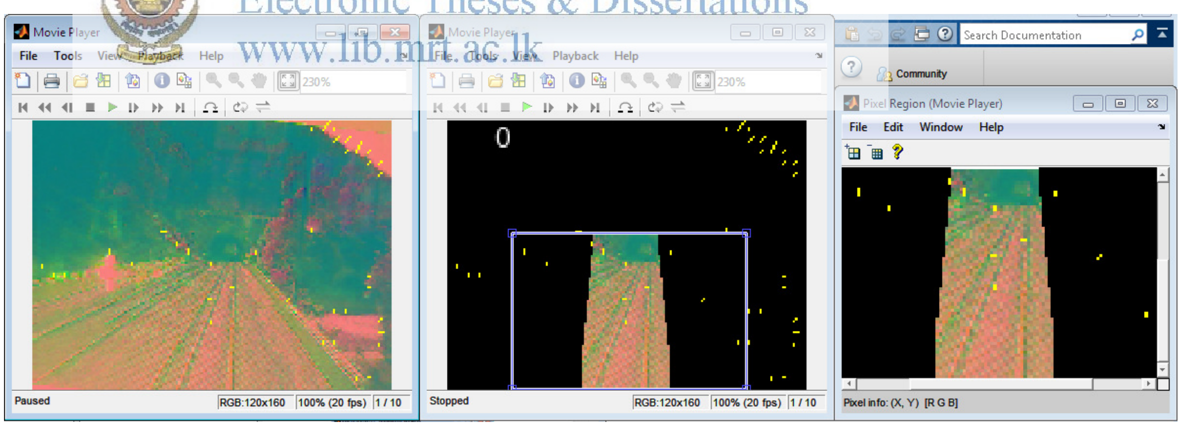



**Fig 3.15: Pixel Values of the Cursor Point**

**Last ten frames of video are as follows;**

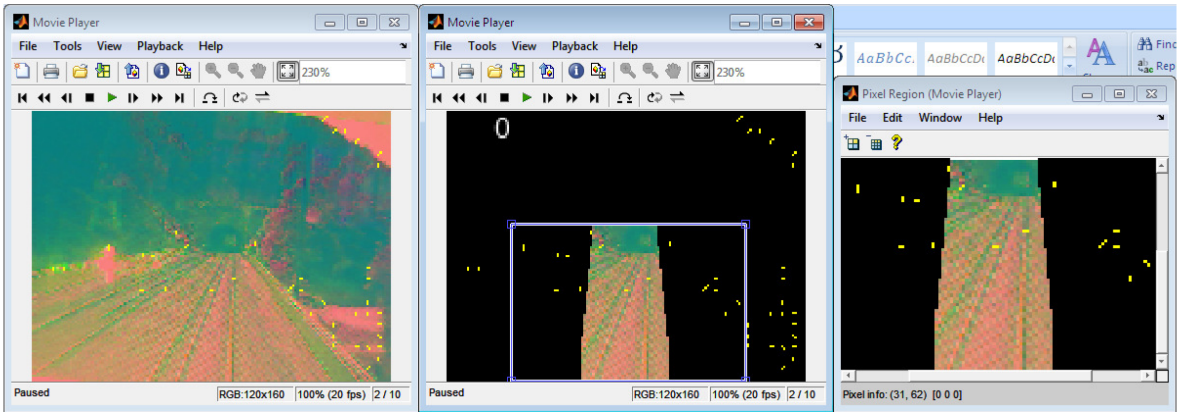
**Frame 01**





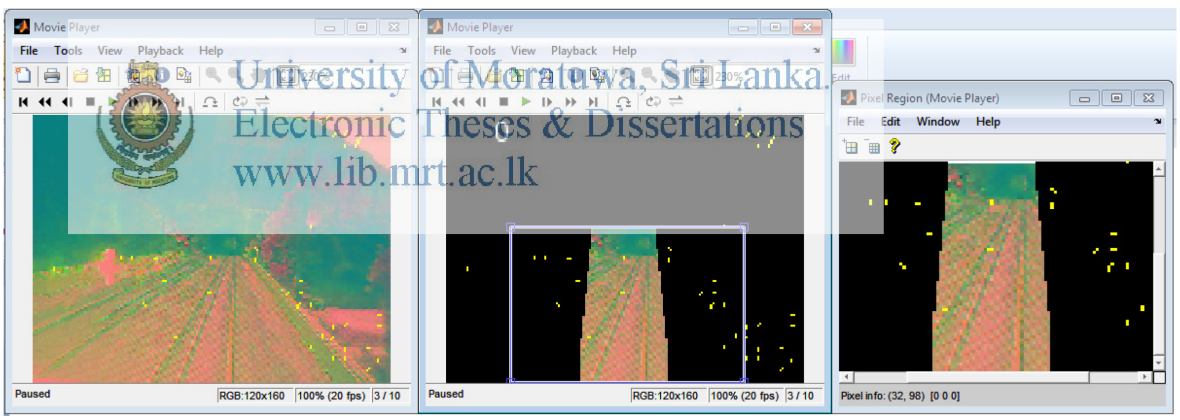

**Yellow Pixels inside DANGER Zone (8)**

**Frame 02**




**Yellow Pixels inside DANGER Zone (6)**

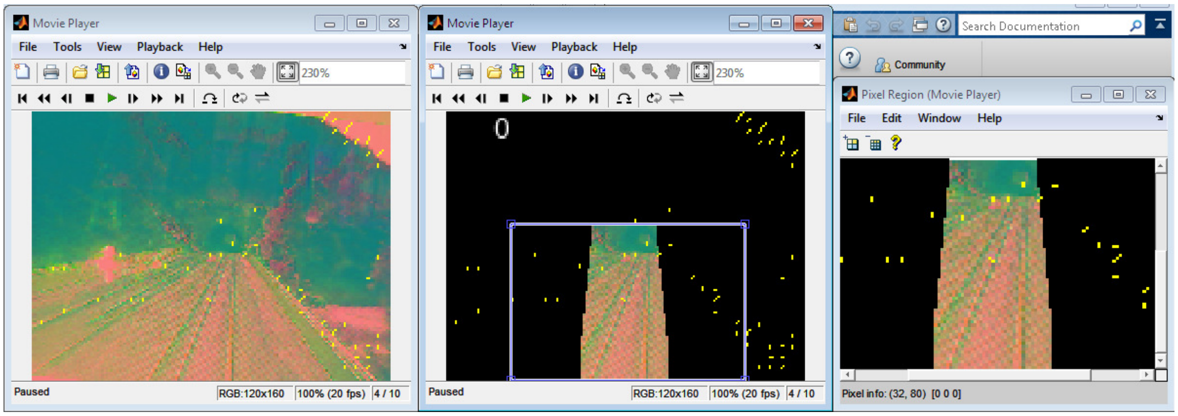
**Frame 03**





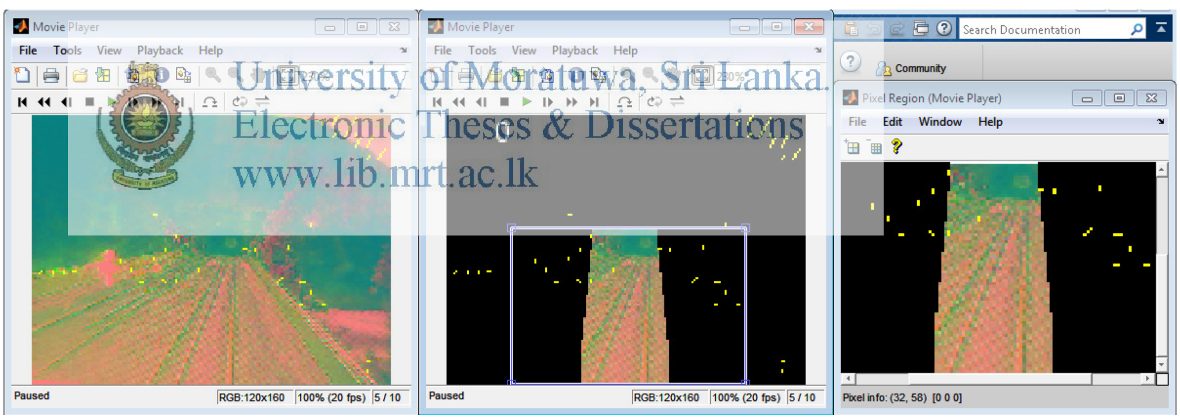

**Yellow Pixels inside DANGER Zone (6)**

**Frame 04**




**Yellow Pixels inside DANGER Zone (11)**

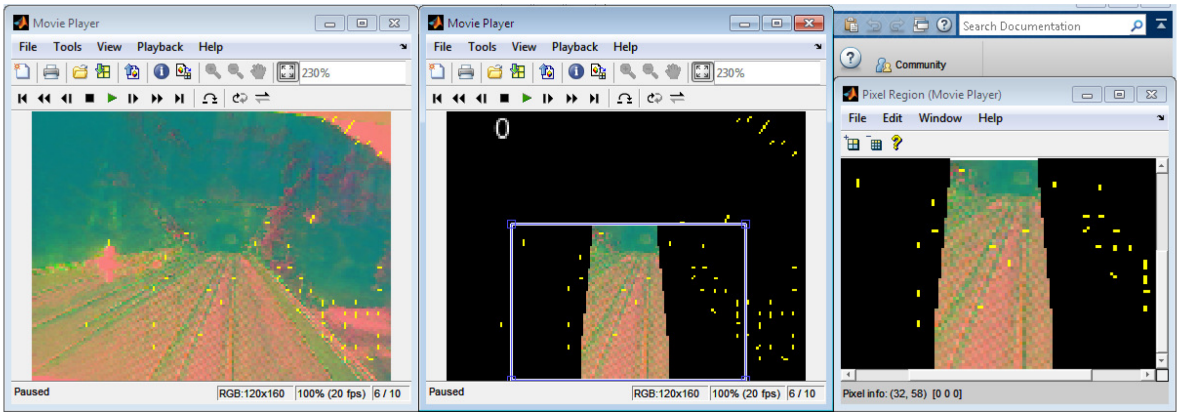
**Frame 05**





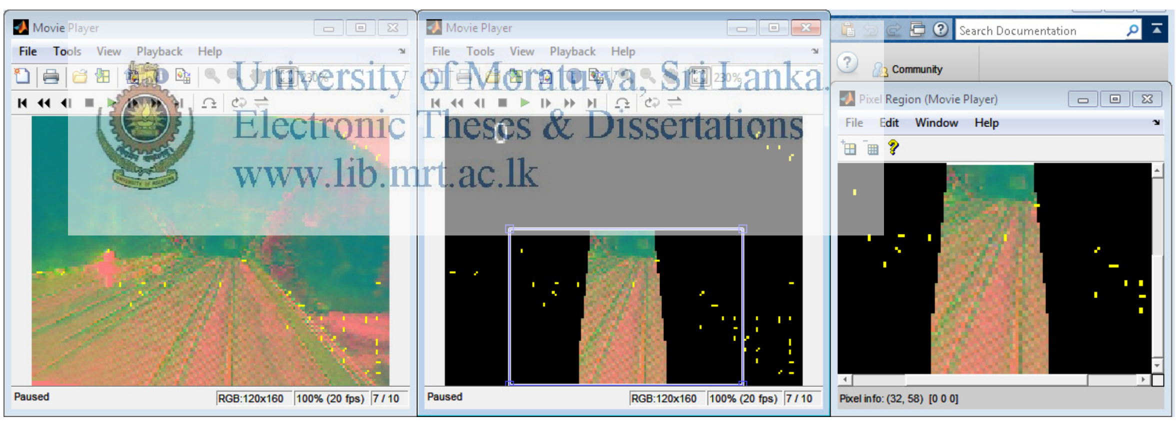

**Yellow Pixels inside DANGER Zone (4)**

**Frame 06**




**Yellow Pixels inside DANGER Zone (10)**

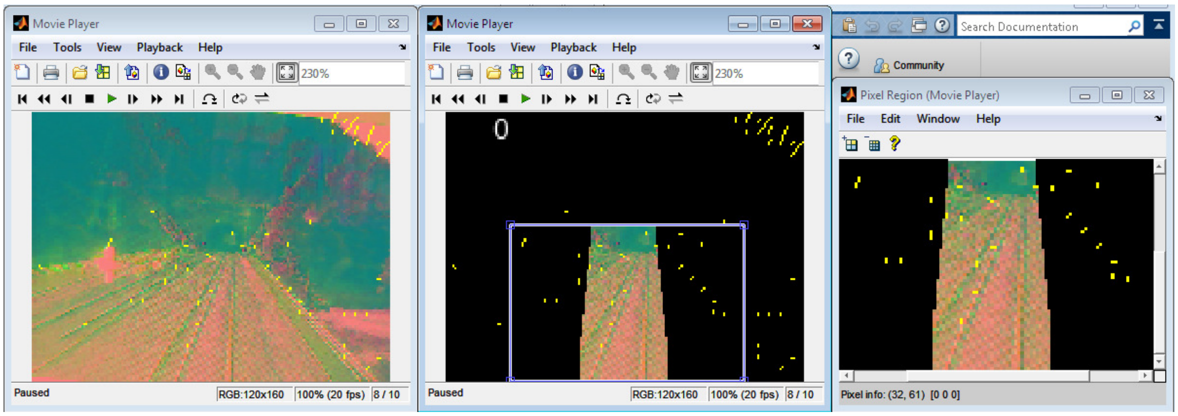
**Frame 07**






**Yellow Pixels inside DANGER Zone (3)**

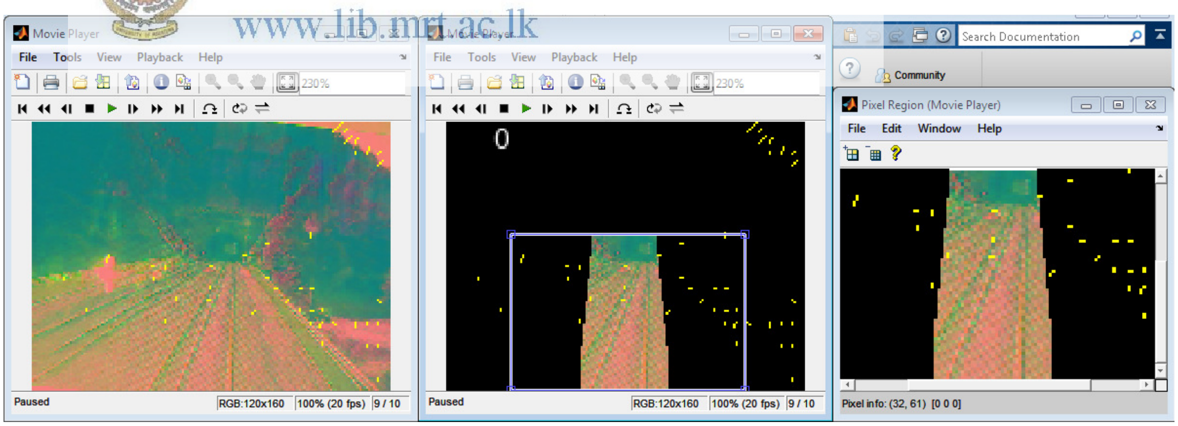
**Frame 08**




**Yellow Pixels inside DANGER Zone (20)**

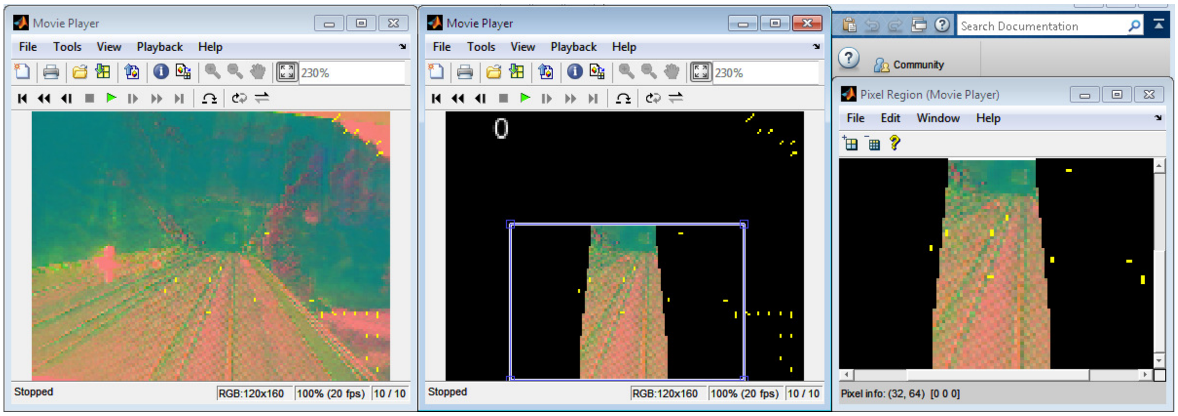
**Frame 09**






**Yellow Pixels inside DANGER Zone (8)**

**Frame 10**




**Yellow Pixels inside DANGER Zone (8)**

**Case 02: Collision of Two Locomotive Engines**

A collision of two locomotive engines has been considered. Again ten consecutive video frames have been analyzed for motion segmentation and found areas with more than 300 pixels which are higher than the minimum no. of pixels for blob analysis resulting as obstacles in danger zone.

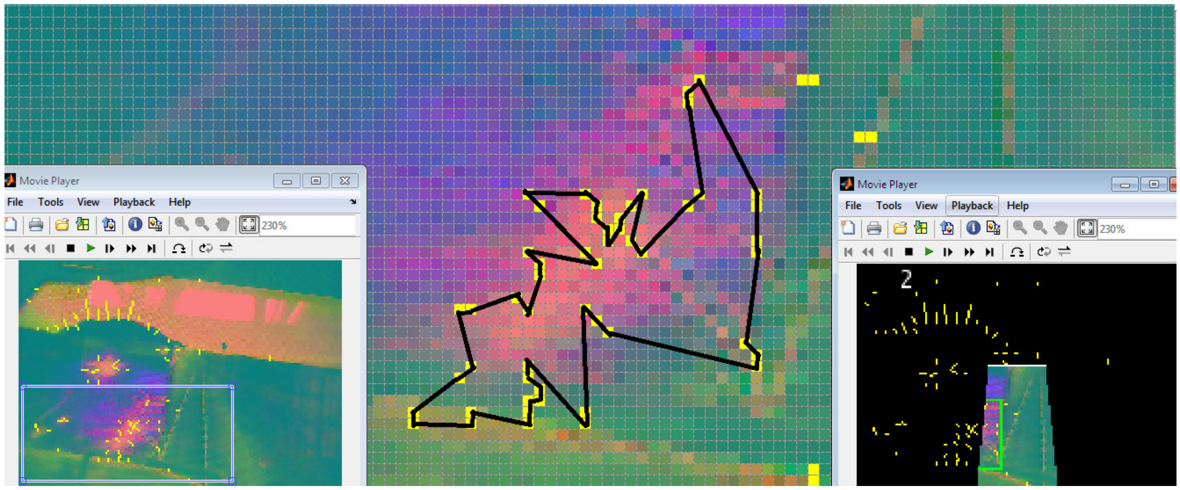


**Video Clip:** Train Collision Compilation!


**Fig 3.16: Collision of locomotives**

Ten adjacent frames of the video have been considered.

**Frame 01**

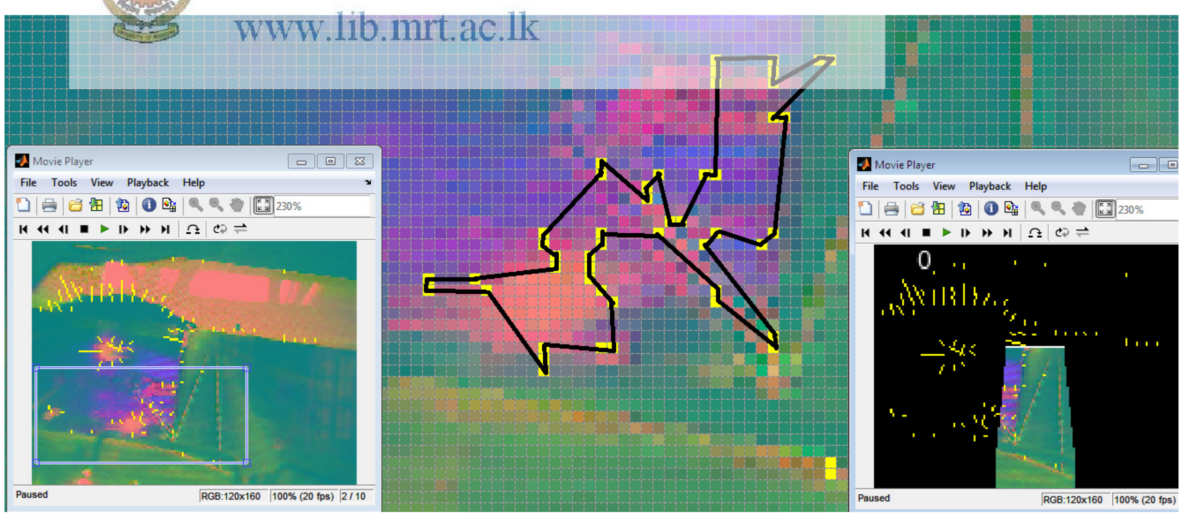



No. pixels bounded by yellow pixels > no. of minimum pixels for blob analysis (300)

**Error. Should be 01No. of blobs.**

**Frame 02**

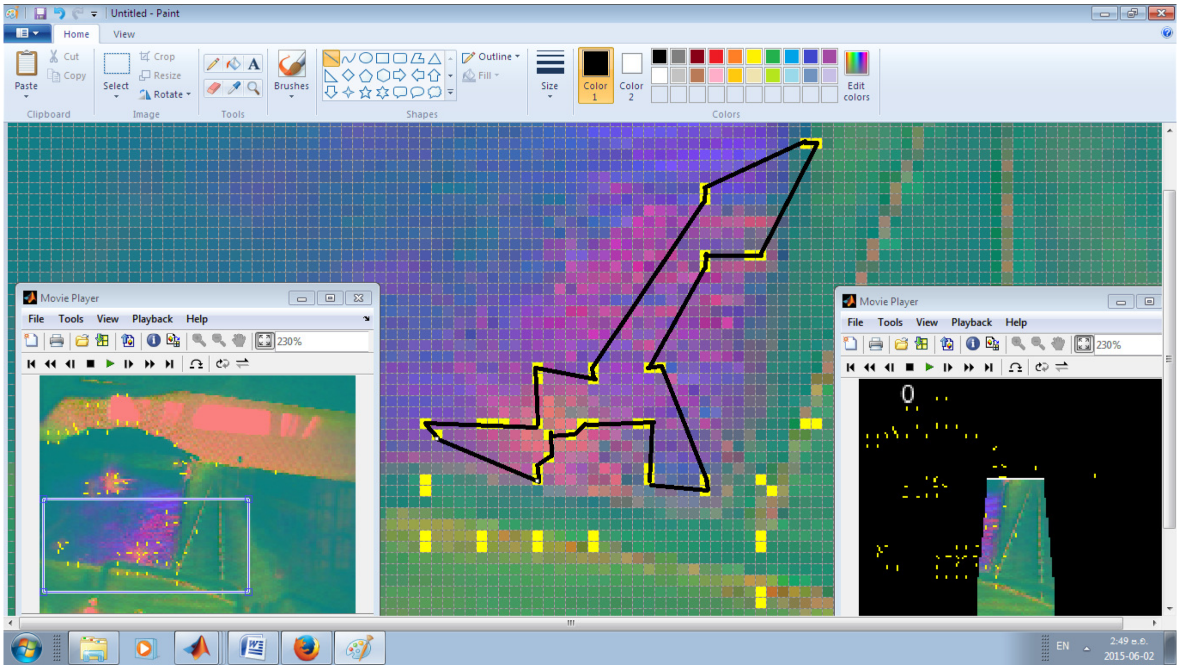





No. pixels bounded by yellow pixels (290) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 03**

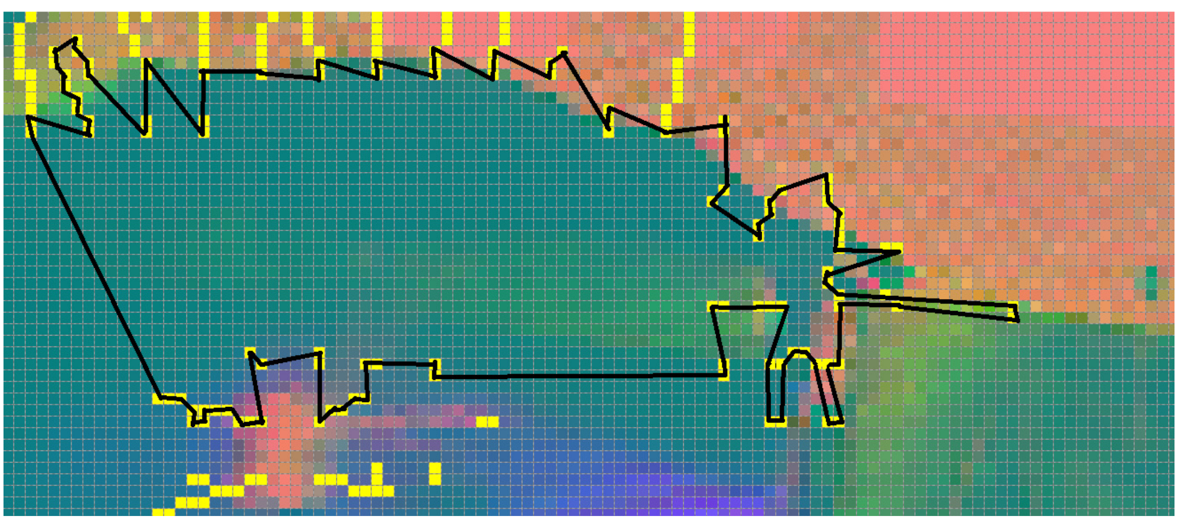


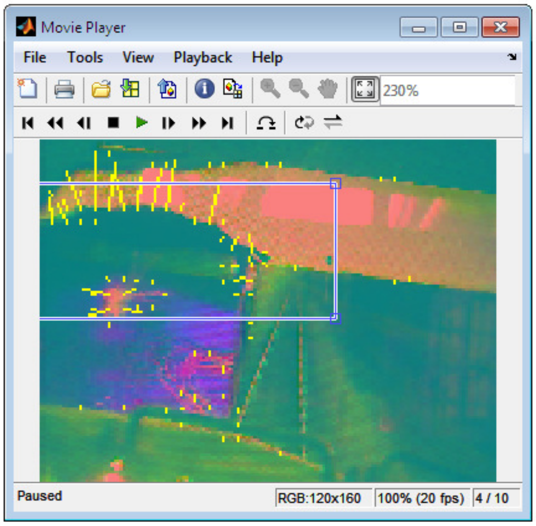

No. pixels bounded by yellow pixels (261) < no. of minimum pixels for blob analysis (300)

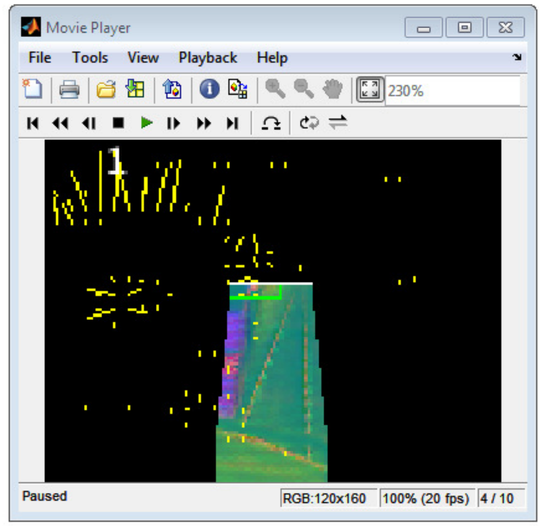


**Therefore, 0 Nos. of blobs identified.**

**Frame 04**





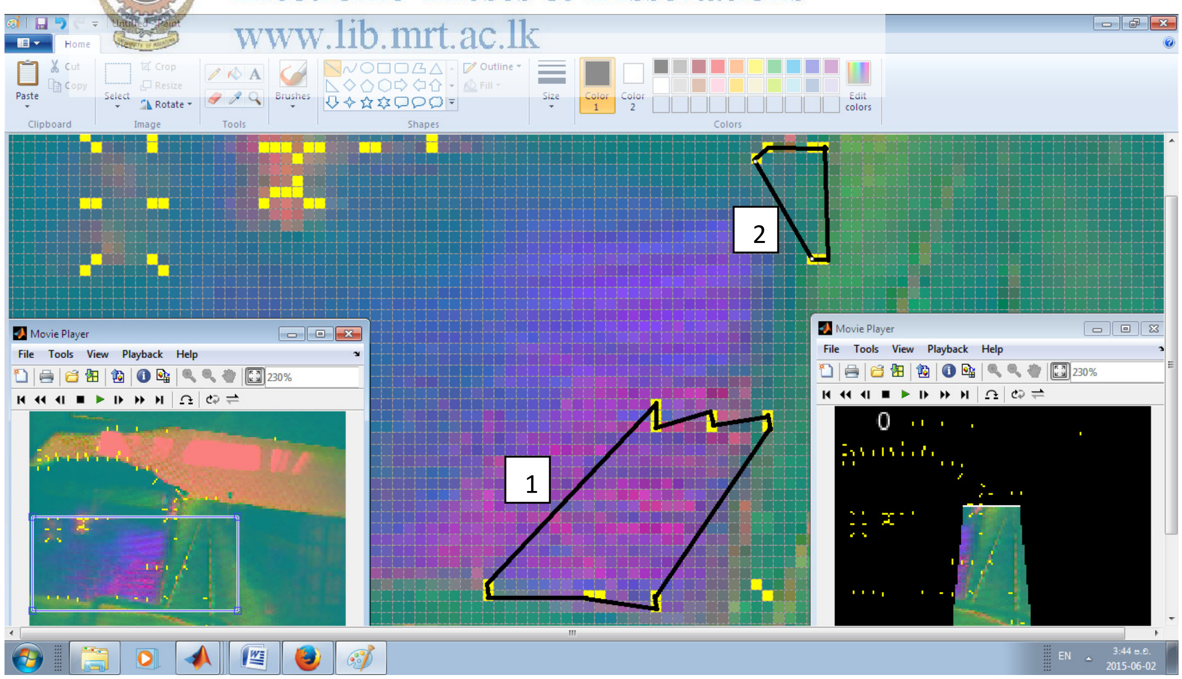




No. pixels bounded by yellow pixels > no. of minimum pixels for blob analysis (300)

**Therefore, 01 No. of blobs identified.**

**Frame 05**





Motion Segmentation 01

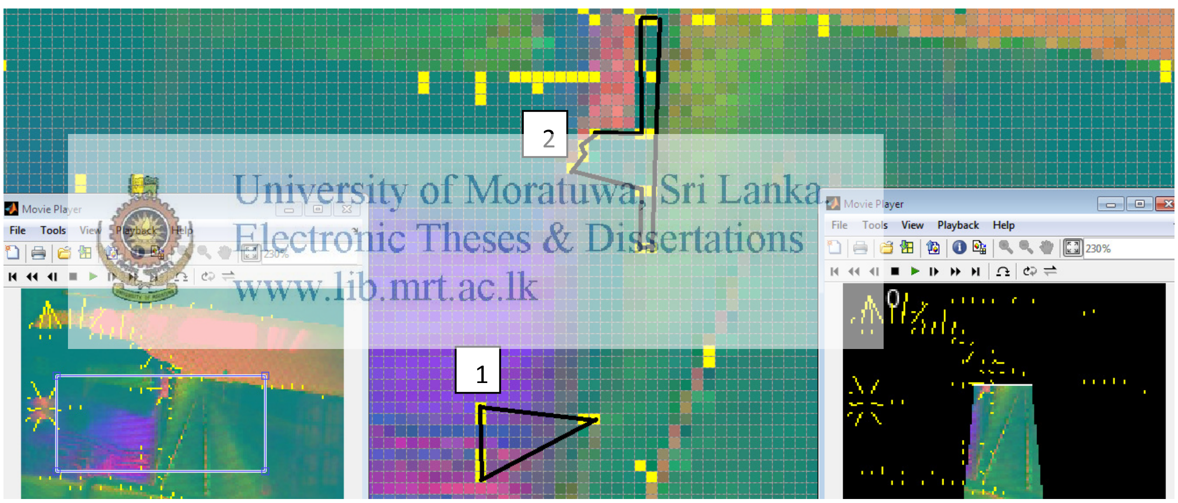
No. pixels bounded by yellow pixels (252) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (54) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 06**






Motion Segmentation 01

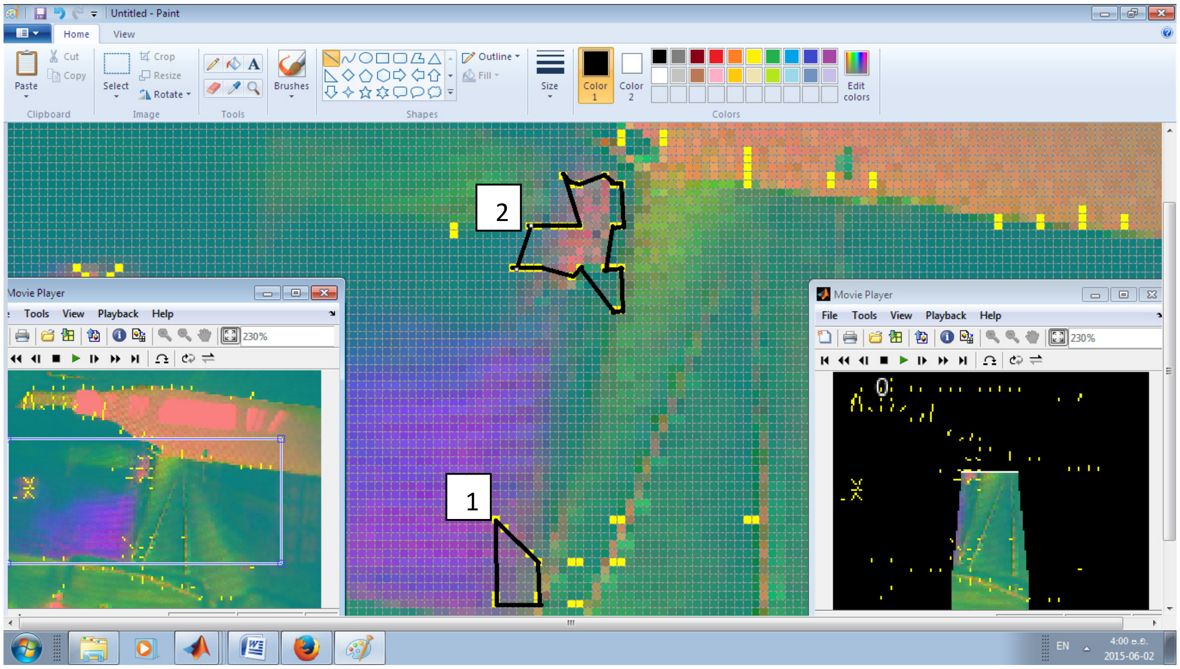
No. pixels bounded by yellow pixels (39) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (65) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 07**




Motion Segmentation 01



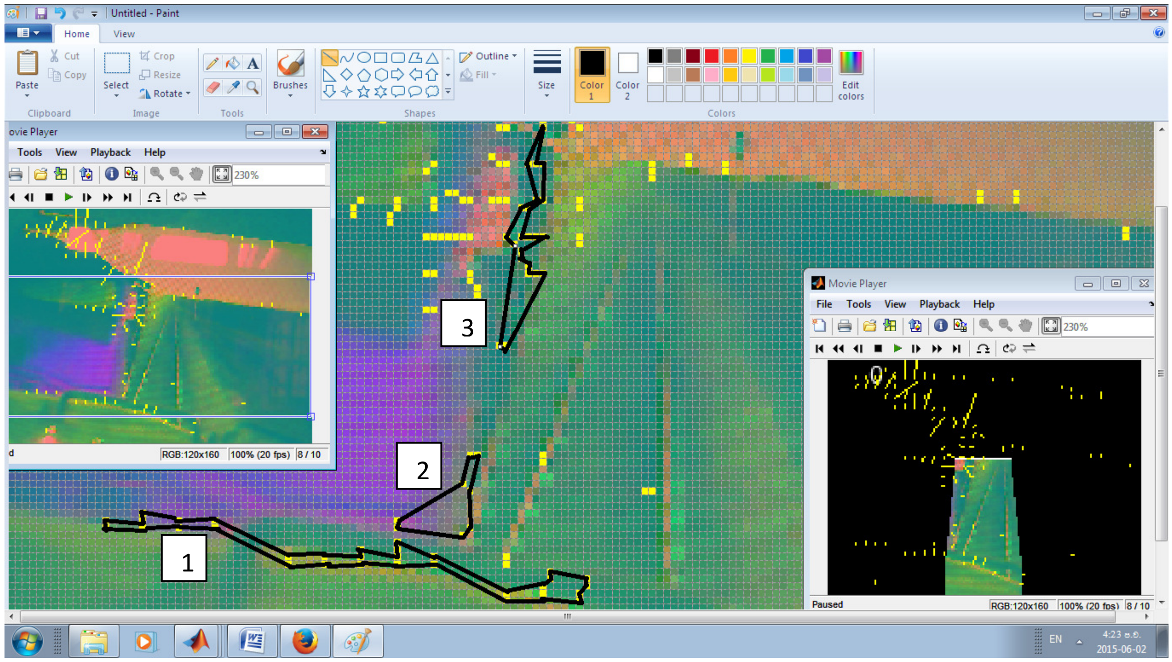
No. pixels bounded by yellow pixels (51) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (146) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 08**




Motion Segmentation 01

No. pixels bounded by yellow pixels (162) < no. of minimum pixels for blob analysis (300)



Motion Segmentation 02

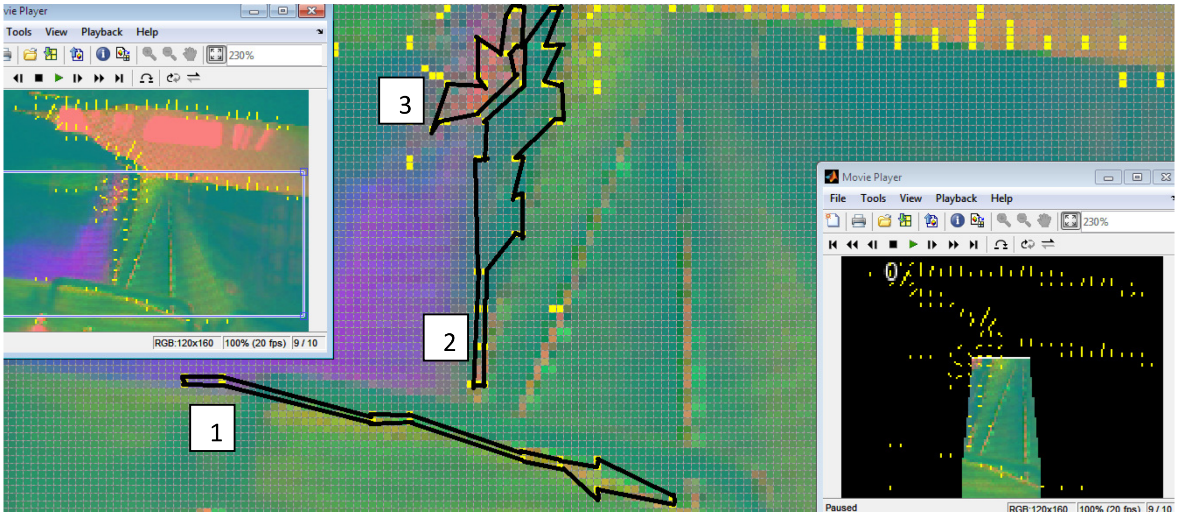
No. pixels bounded by yellow pixels (69) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 03

No. pixels bounded by yellow pixels (103) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 09**




Motion Segmentation 01

No. pixels bounded by yellow pixels (161) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (242) < no. of minimum pixels for blob analysis (300)

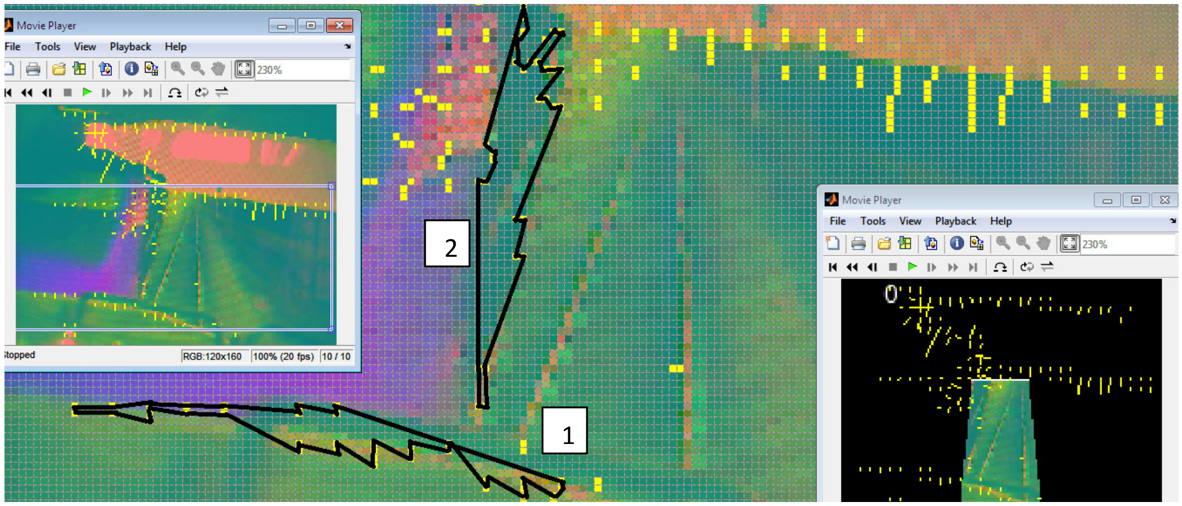


Motion Segmentation 03

No. pixels bounded by yellow pixels (86) < no. of minimum pixels for blob analysis (300)

**Therefore, 0 Nos. of blobs identified.**

**Frame 10**




Motion Segmentation 01

No. pixels bounded by yellow pixels (241) < no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (293) < no. of minimum pixels for blob analysis (300)



**Therefore, 0 Nos. of blobs identified.**

**Case 03: Collisions with Road Vehicles**

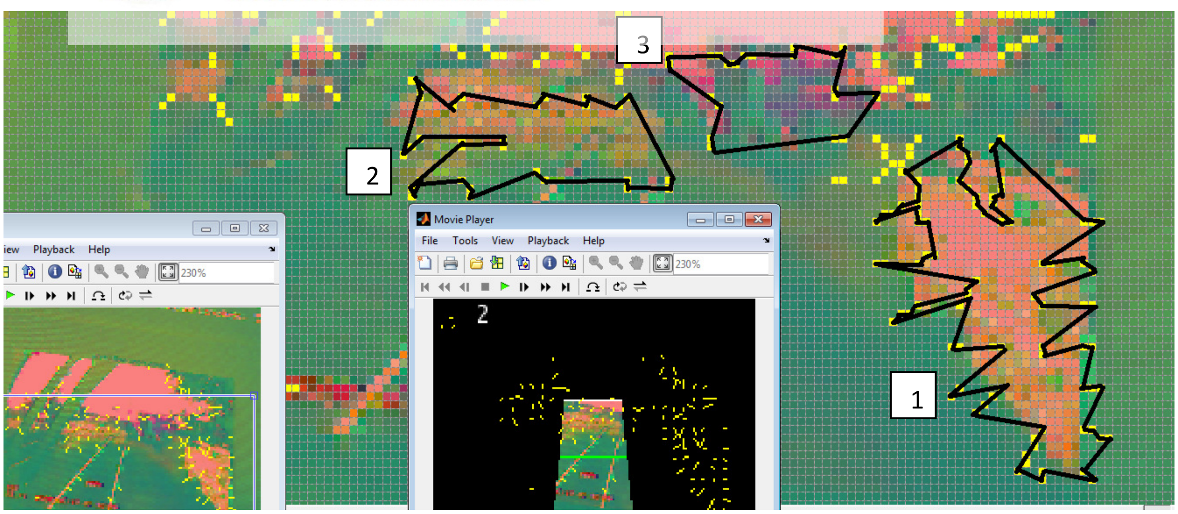
Three vehicles crossing the railway have been subjected to collision with a locomotive engine. Ten video frames have been considered below for their motion segmentation. However, three consecutive video frames show the areas covering more than 300 pixels which are greater than the minimum no. of pixels for blob analysis resulting as obstacles in danger zone.

**Video Clip:** Train Collision Compilation!


**Fig 3.17: Locomotive engine collision with road vehicles**



**Frame 01**




Motion Segmentation 01

No. pixels bounded by yellow pixels > no. of minimum pixels for blob analysis (300) (out of the DANGER Zone)

Motion Segmentation 02

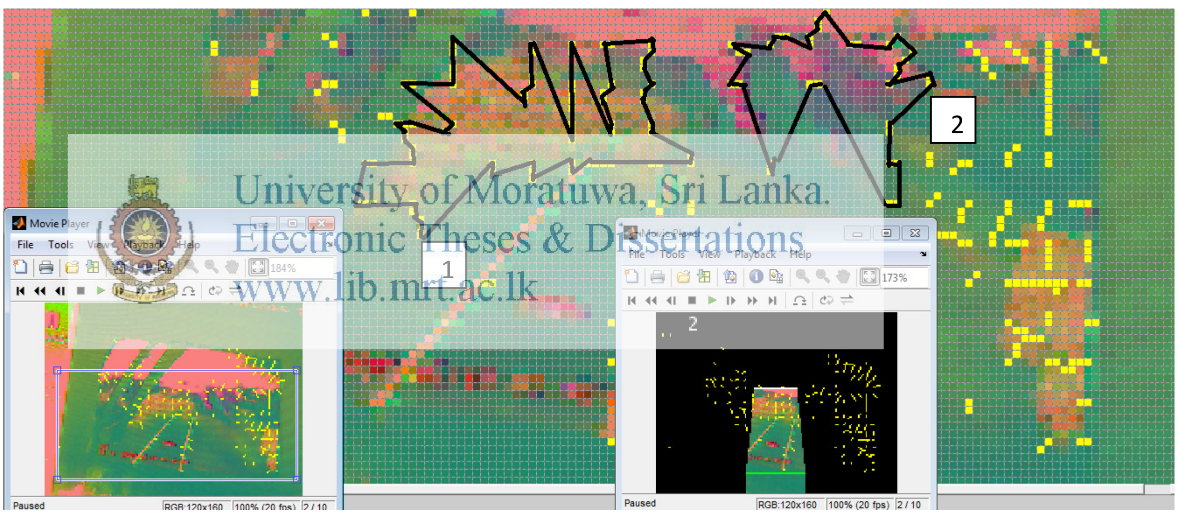
No. pixels bounded by yellow pixels (378) > no. of minimum pixels for blob analysis (300)

Motion Segmentation 03

No. pixels bounded by yellow pixels (336) > no. of minimum pixels for blob analysis (300)

**Therefore, 02 Nos. of blobs identified.**

**Frame 02**





Motion Segmentation 01

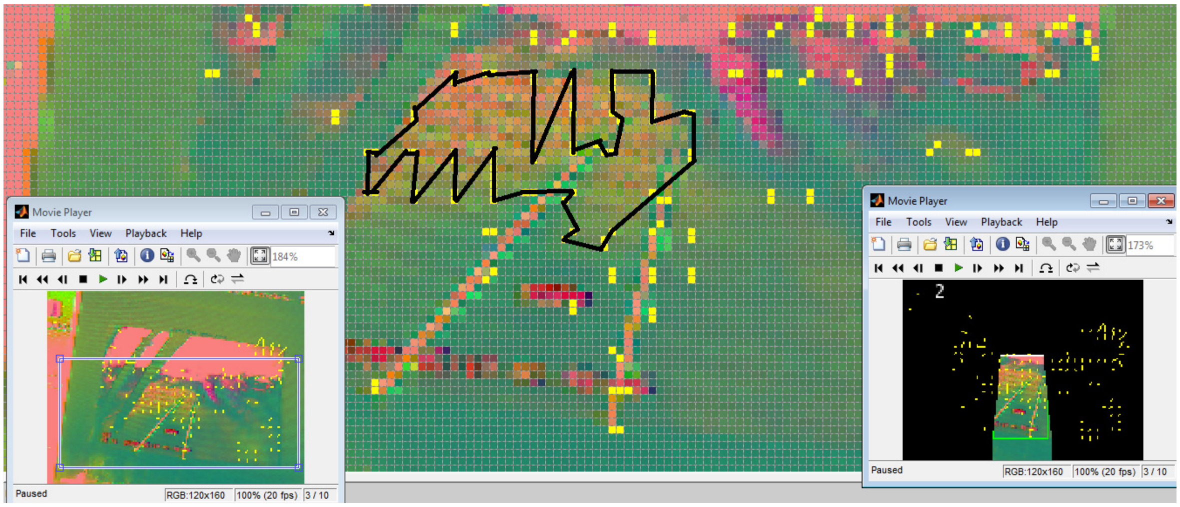
No. pixels bounded by yellow pixels (648) > no. of minimum pixels for blob analysis (300)

Motion Segmentation 02

No. pixels bounded by yellow pixels (355) > no. of minimum pixels for blob analysis (300)

**Therefore, 02 Nos. of blobs identified.**

**Frame 03**




No. pixels bounded by yellow pixels (526) > no. of minimum pixels for blob analysis (300)

**Error. Should be 01No. of blobs.**

From Frame 04 to 10, due to collision of the locomotive engine with the vehicles, vibrational effect on front camera leads to erroneous readings.



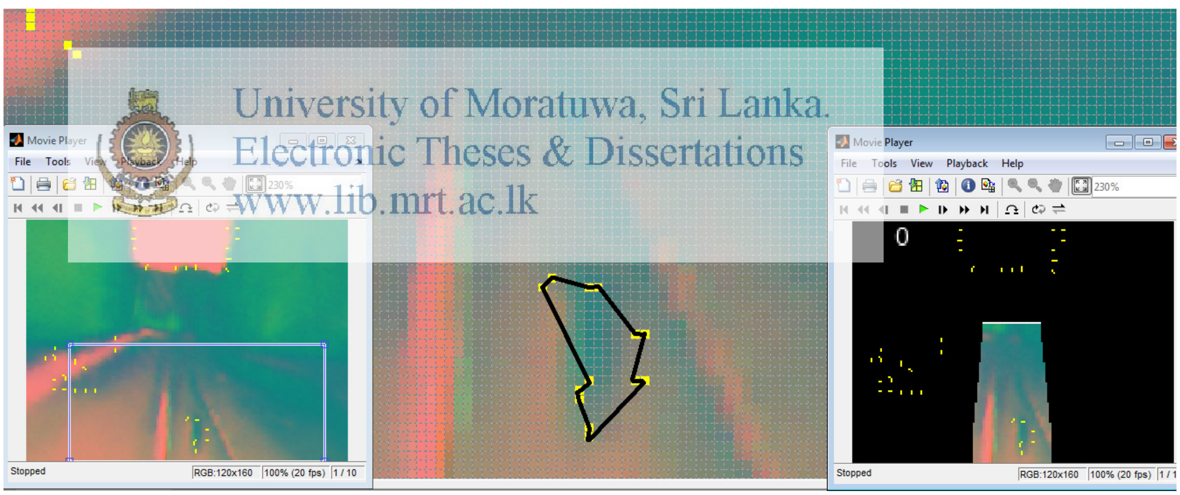
**Case 04A: A locomotive hits a dog**

A locomotive hits a dog which sits on the railway has been considered. Since the minimum number of pixels for blob analysis has been set to 300, the dog has not been identified as a obstacle since the number of pixels bounded by yellow pixels is less than 300.

**Video Clip:** https://www.youtube.com/watch?v=YZG8VyVYQX4&spfreload=10


**Fig 3.18: Dog was hit by a locomotive**

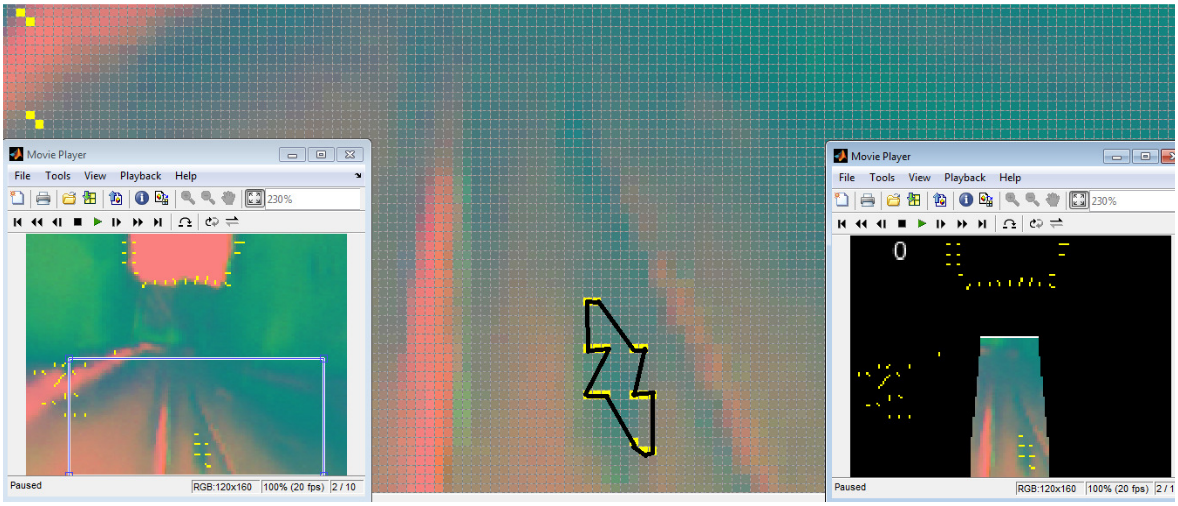
**Frame 01**





No. pixels bounded by yellow pixels (116) < no. of minimum pixels for blob analysis (300)

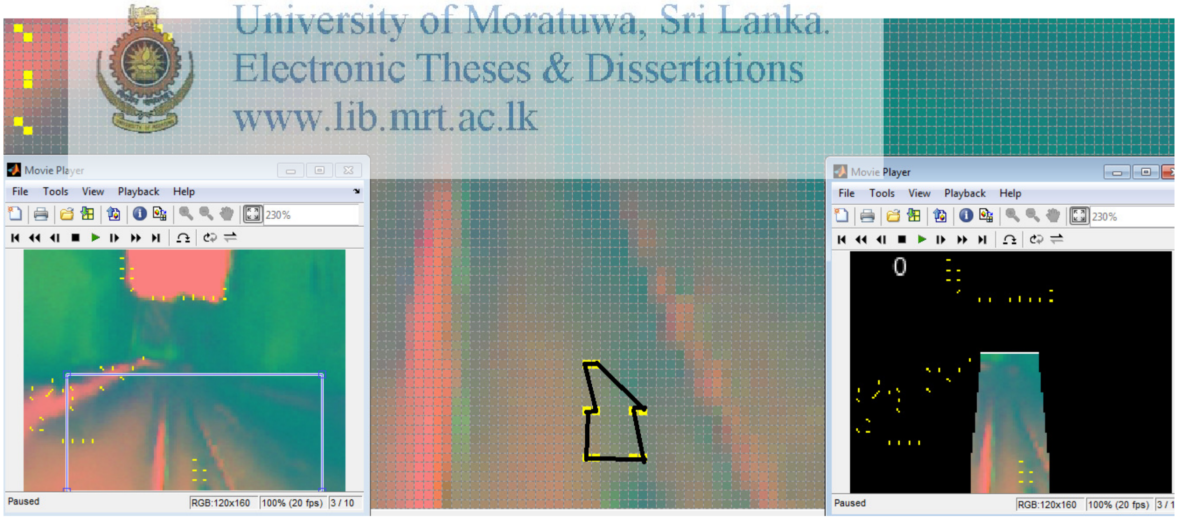
**Frame 02**




No. pixels bounded by yellow pixels (84) < no. of minimum pixels for blob analysis (300)

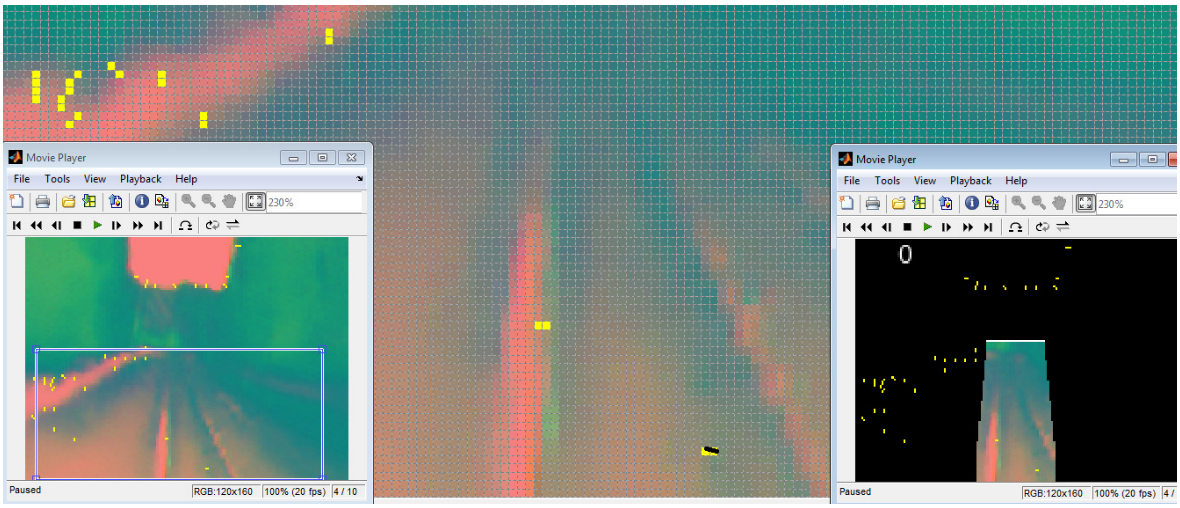
**Frame 03**






No. pixels bounded by yellow pixels (84) < no. of minimum pixels for blob analysis (300)

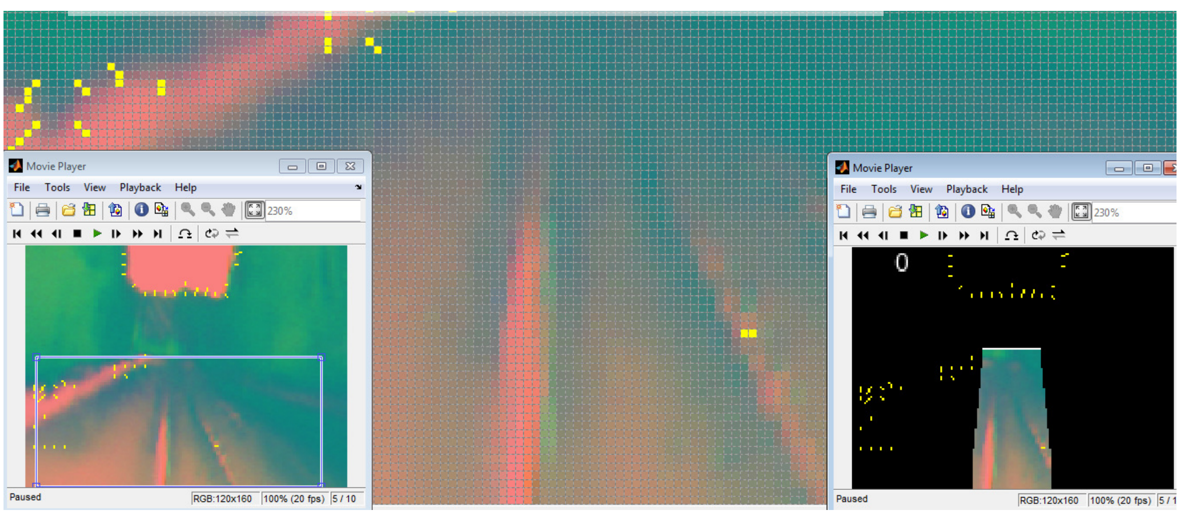
**Frame 04**




No. pixels bounded by yellow pixels (2) < no. of minimum pixels for blob analysis (300)

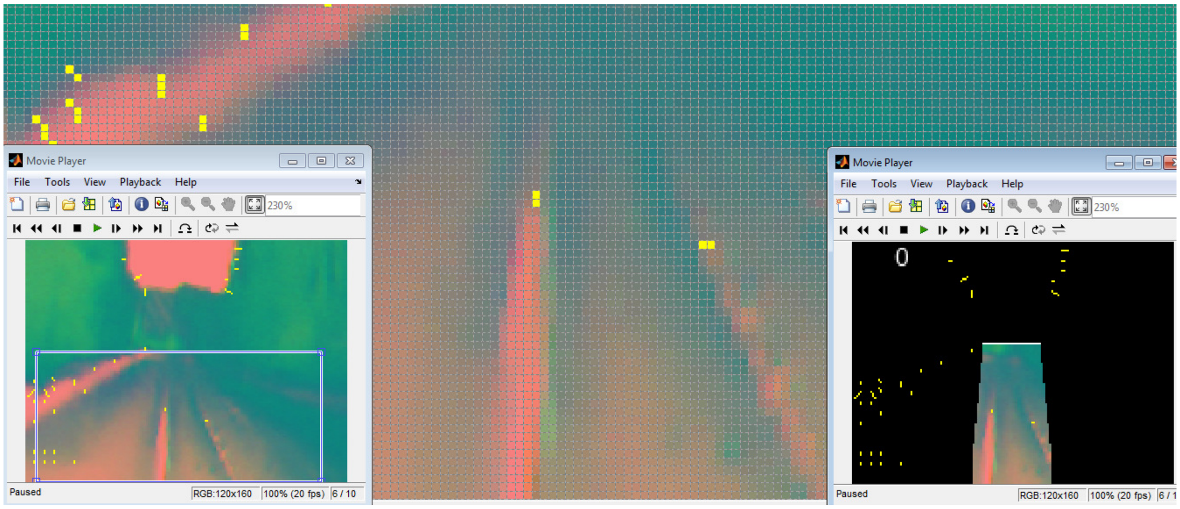


**Frame 05**




No. pixels bounded by yellow pixels (0) < no. of minimum pixels for blob analysis (300)

**Frame 06**




No. pixels bounded by yellow pixels (0) < no. of minimum pixels for blob analysis (300)

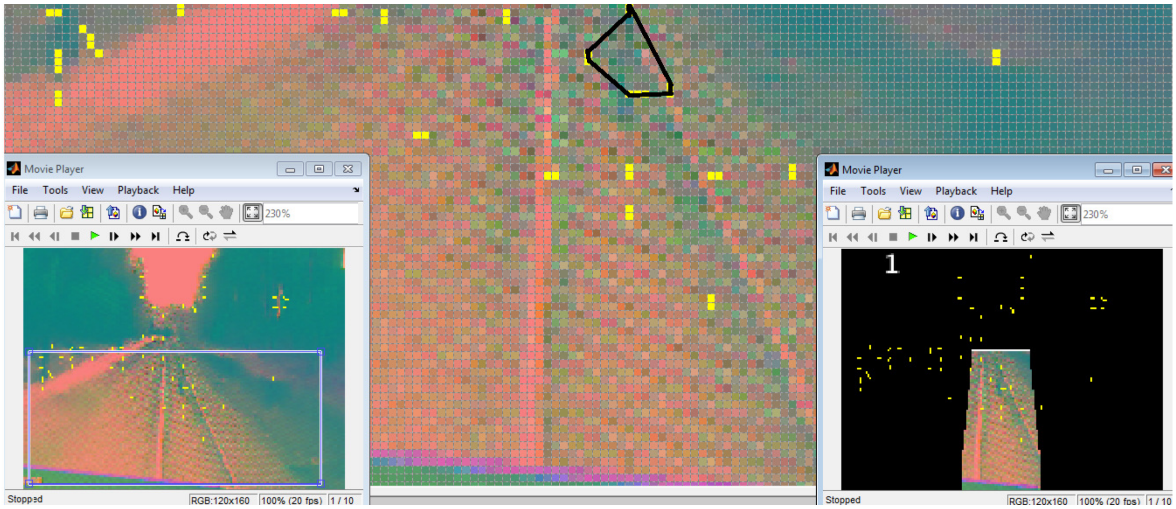


**Case 04B: A locomotive hits a dog (Minimum Blob Area Pixels reduced to 50)**

A locomotive hits a dog which sits on the railway has been considered. Since the minimum number of pixels for blob analysis has been set to 50, the dog has been identified as a obstacle. Further, some dark areas of the railway also counted as obstacles due to minimum blob area pixels reduced to 50.

**Video Clip:** https://www.youtube.com/watch?v=YZG8VyVYQX4&spfreload=10

**Frame 01**

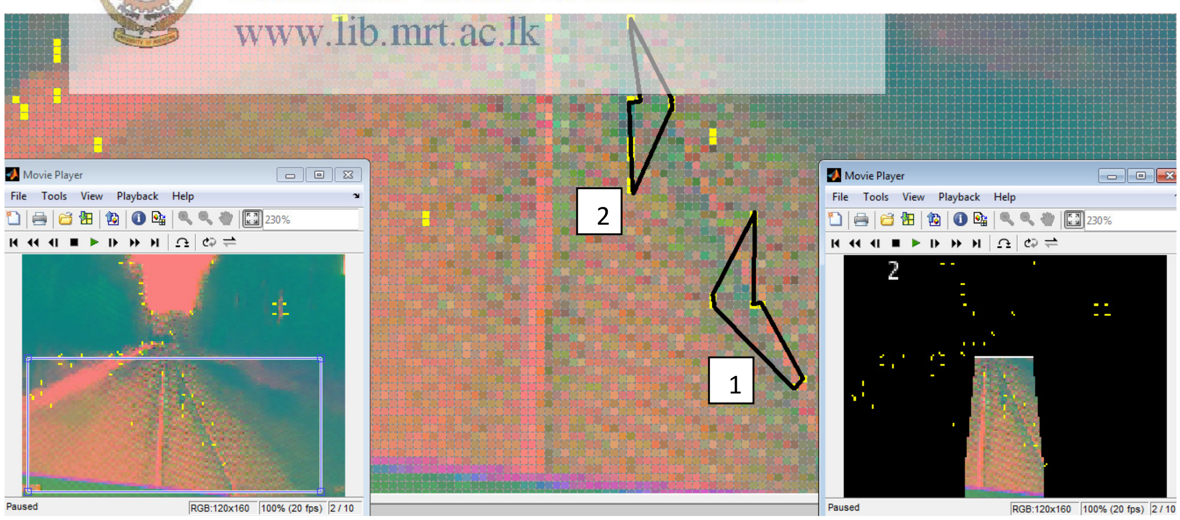



No. pixels bounded by yellow pixels (78) > no. of minimum pixels for blob analysis (50)

Therefore, one obstacle had been counted.

**Frame 02**






Motion Segmentation 01 (Dark Area)

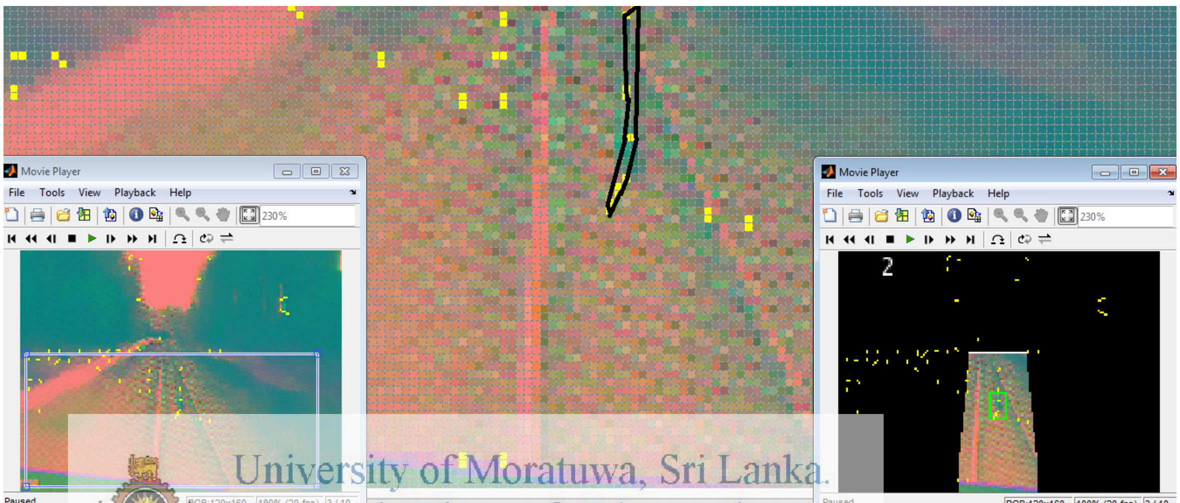
No. pixels bounded by yellow pixels (96) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dog)

No. pixels bounded by yellow pixels (67) > no. of minimum pixels for blob analysis (50)

Therefore, as in the counter, two obstacles had been counted.

**Frame 03**

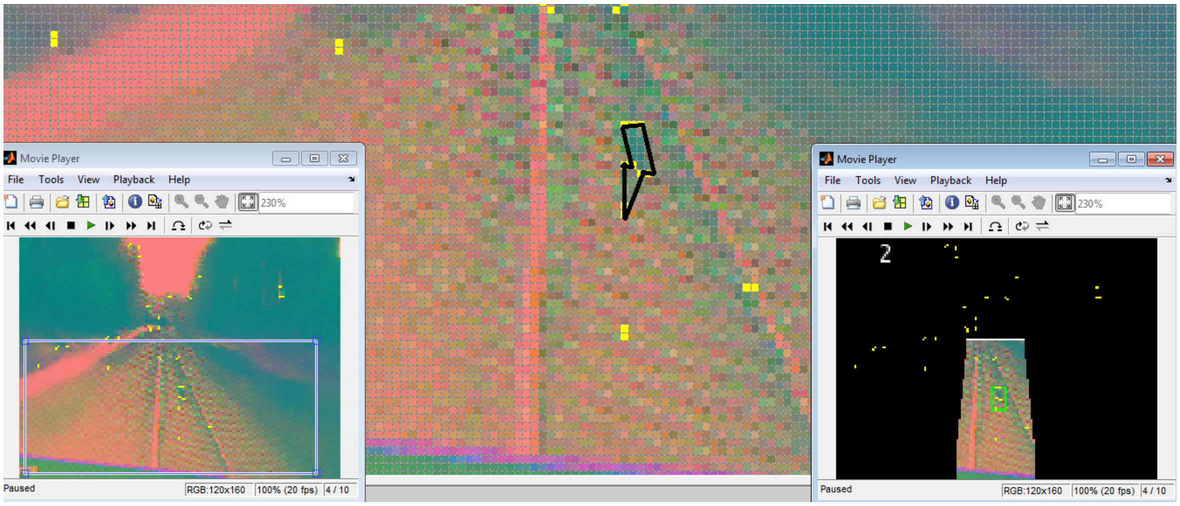





No. pixels bounded by yellow pixels (53) > no. of minimum pixels for blob analysis (50)

Therefore, one obstacle had been counted. However, counter shows 2 but one obstacle had been bounded by green color (left).

**Frame 04**

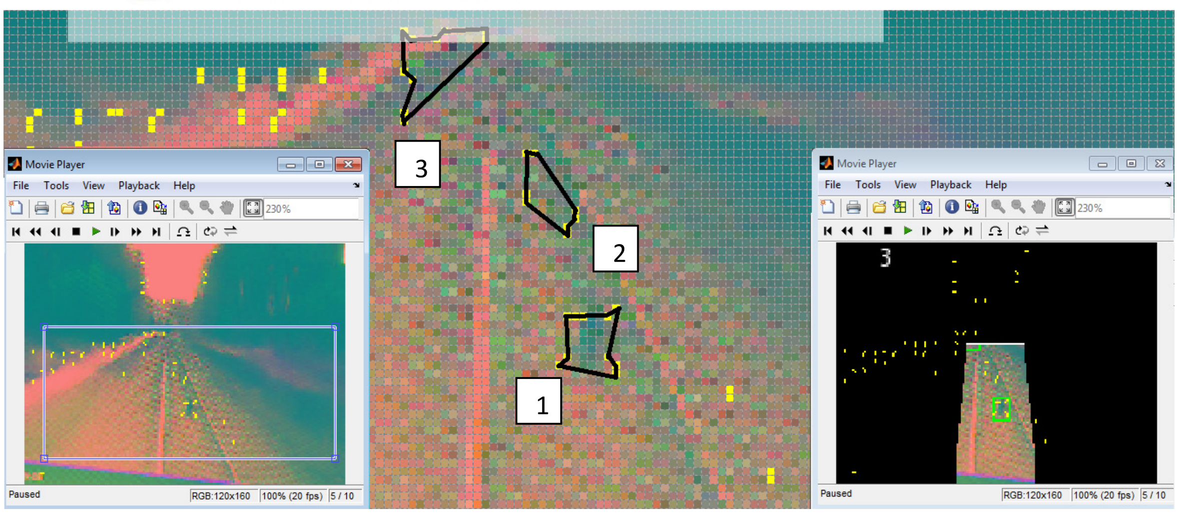



No. pixels bounded by yellow pixels (51) > no. of minimum pixels for blob analysis (50)

Therefore, one obstacle had been counted. However, counter shows 2 but one obstacle had been bounded by green color (left).



**Frame 05**




Motion Segmentation 01 (Dog)

No. pixels bounded by yellow pixels (56) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dark Area)

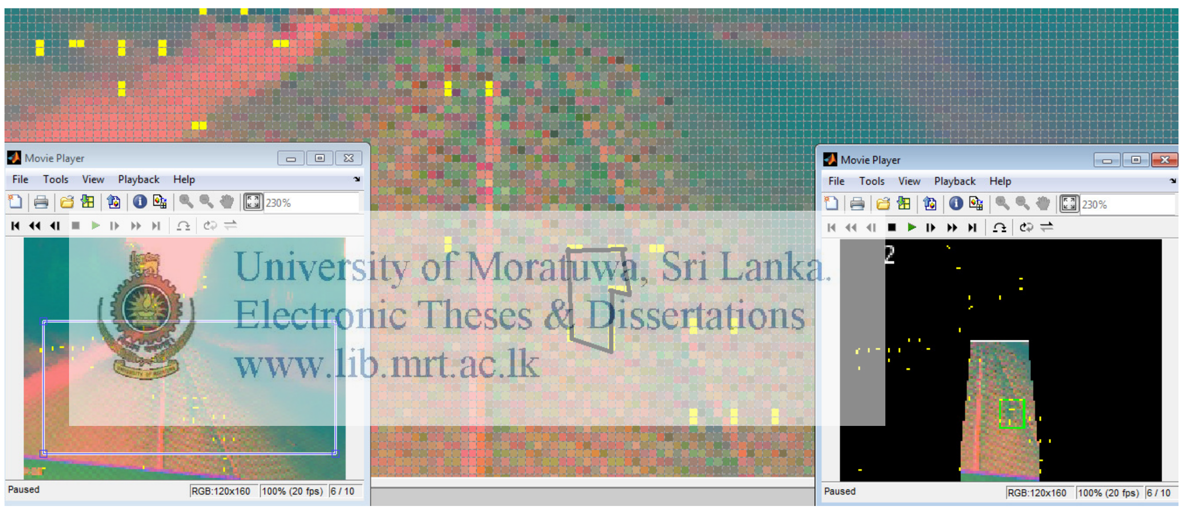
No. pixels bounded by yellow pixels (51) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 03 (Dark Area)

No. pixels bounded by yellow pixels (78) > no. of minimum pixels for blob analysis (50)

Therefore, as in the counter, three obstacles had been counted.

**Frame 06**

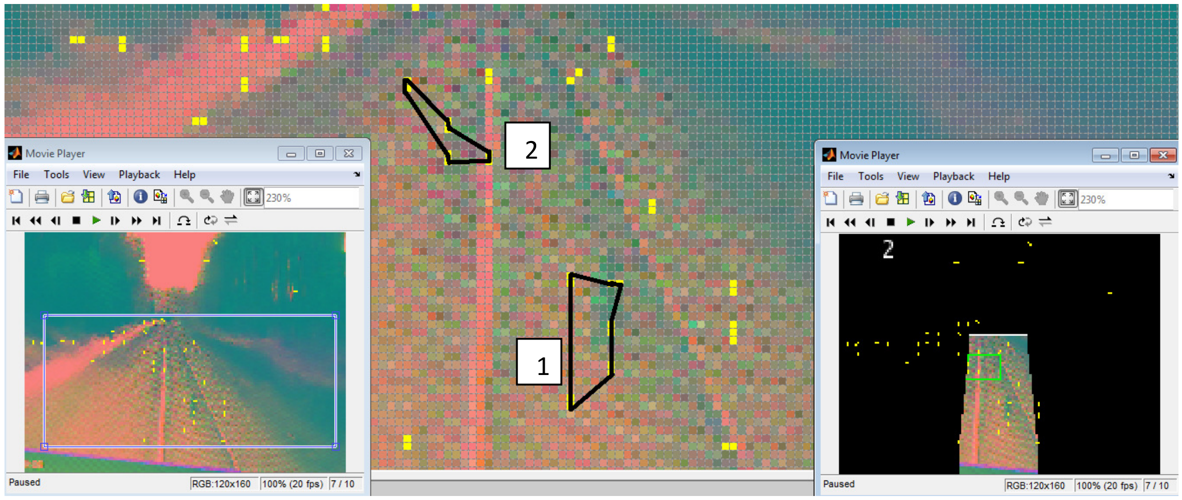




No. pixels bounded by yellow pixels (83) > no. of minimum pixels for blob analysis (50)

Therefore, one obstacle had been counted. However, counter shows 2 but one obstacle had been bounded by green color (left).

**Frame 07**




Motion Segmentation 01 (Dog)

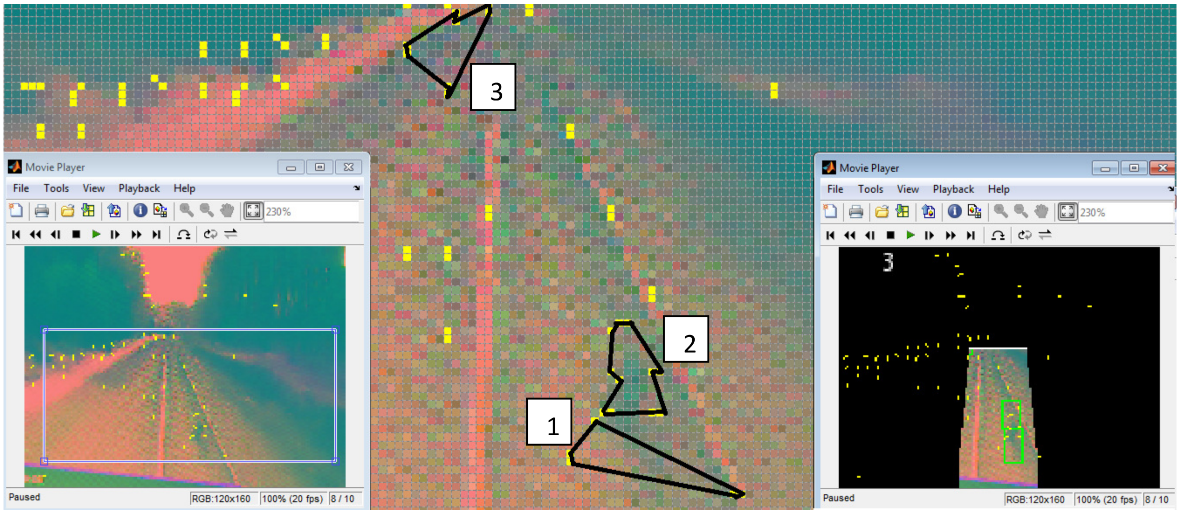
No. pixels bounded by yellow pixels (82) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dark Area)

No. pixels bounded by yellow pixels (51) > no. of minimum pixels for blob analysis (50)

Therefore, as in the counter, two obstacles had been counted.

**Frame 08**




Motion Segmentation 01 (Dog)

No. pixels bounded by yellow pixels (71) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dog)



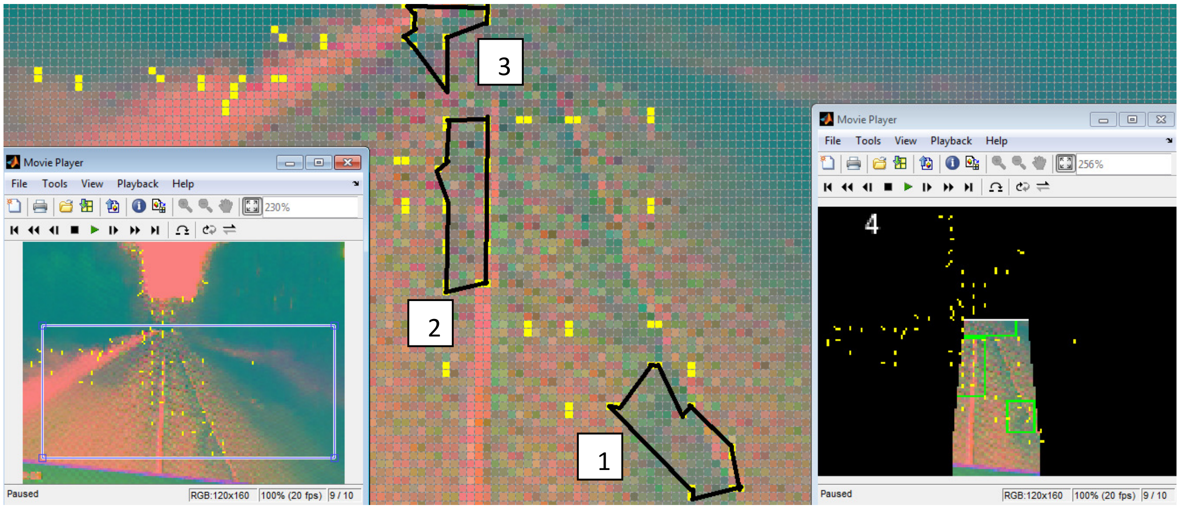
No. pixels bounded by yellow pixels (73) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 03 (Dark Area)

No. pixels bounded by yellow pixels (56) > no. of minimum pixels for blob analysis (50)

Therefore, as in the counter, three obstacles had been counted.

**Frame 09**




Motion Segmentation 01 (Dog)

No. pixels bounded by yellow pixels (110) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dark Area)



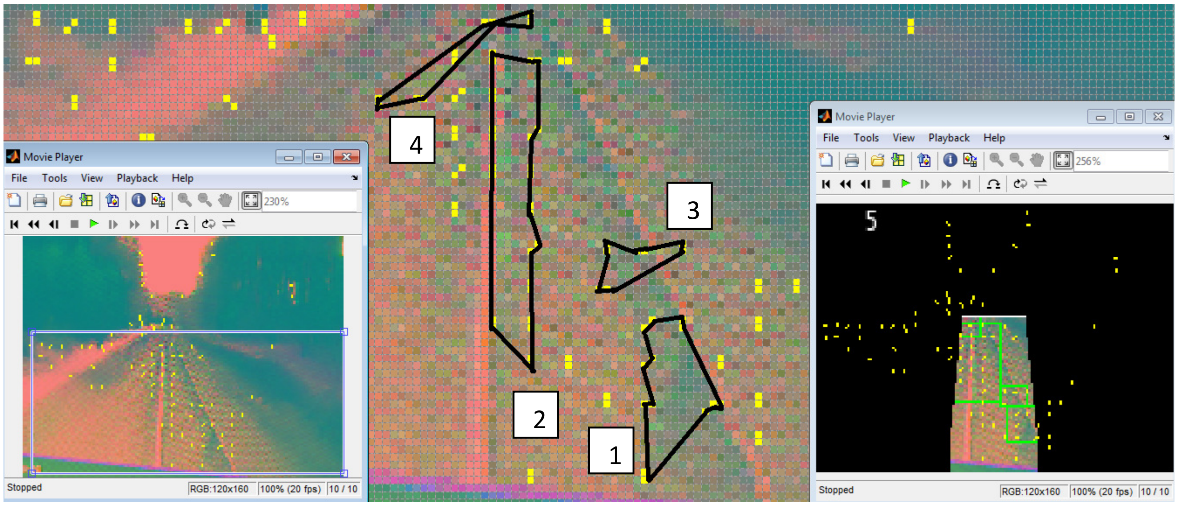
No. pixels bounded by yellow pixels (101) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 03 (Dark Area)

No. pixels bounded by yellow pixels (53) > no. of minimum pixels for blob analysis (50)

Therefore, three obstacles had been counted. However, counter shows 4 but three obstacles had been bounded by green color (left).

**Frame 10**




Motion Segmentation 01 (Dog)

No. pixels bounded by yellow pixels (131) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 02 (Dark Area)



No. pixels bounded by yellow pixels (218) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 03 (Dark Area)

No. pixels bounded by yellow pixels (51) > no. of minimum pixels for blob analysis (50)

Motion Segmentation 03 (Dark Area)

No. pixels bounded by yellow pixels (58) > no. of minimum pixels for blob analysis (50)

Therefore, four obstacles had been counted. However, counter shows 5 but four obstacles had been bounded by green color (left).

# 4.CONCLUSIONS & RECOMMENDATIONS

This thesis proposes a portable system which can be adapted not only for image based obstacle detection in locomotive engines but also for the other vehicles as well.

The main conclusions of the research are given below;

1. A front camera mounted on a wooden base placed on locomotive engine front section programmed with MATLAB simulations and blob analysis can be used as an obstacle detection system for railways.

   When front camera moves on engine speed, objects moving on other speeds and other directions in front of front camera and propagation of idling obstacles of front camera far ahead with time can be detected from blob analysis inside the danger zone.

2. Finding distances of locomotive engine stoppage for decelerations during braking programmed with MATLAB simulations and optical flow analysis of side camera images and interfacing with front camera yaw variation can be adopted to prevent accidents.



As the recommendations;

The image processing based obstacle detection system implemented for the railway locomotive engines is still in experimental level. Much improvements can be done by researching the model further.

The system implemented can be used for following applications as well,

1.) Heavy vehicles such as tipping trucks, backhoes and containers to detect obstacles. MATLAB Simulation 01 can be used.

2.) A security system of an office building at night can be used. Obstacle detection system can be used to track movement of thieves. MATLAB Simulation 01 can be used.

# REFERENCE LIST


[1] Rossi Passarella, Bambang Tutuko & Aditya P.P. Prasetyo, Design Concept of Train Obstacle Detection System in Indonesia, 2011, PP 455- 456

[2] H. Ben Brown, Jr., Gregg Podnar, Mel Siegel, Rail- Scout, A Concept for Reducing Railway Accidents , 2005, PP 1- 4

[3] B.K.P. Horn and B.G. Schunck, "Determining Optical Flow", Artificial Intelligence, 1981, Vol 17, PP 185- 203

[4] Lanka Udawatta and Buddhika Jayasekara, "Image Processing Based Application", Computer Aided Simulations, 2009, PP 227- 236

[5] Future Electronics Egypt Ltd. (Arduino Egypt), Servo Motor Control & Arduino, 2014, PP 1- 6

[6] MATLAB Central, Articles on usage of Arduino Simulink Blocks, MATLAB 2014b, 2014

[7] Math Works, Blob Analysis, MATLAB 2014b, 2014

[8] Paul Merrell, Dah- Jye Lee, Randal Beard, Statistical analysis of multiple optical flow values for estimation of unmanned aerial vehicle height above ground, 2004

[9] Ying Wu, Optical Flow and Motion Analysis, EECS432- Advanced Computer Vision Notes Series 6, 2001

[10] Didi Sazbon, Hector Rotstein, Ehud Rivlin, Finding the focus of expansion and estimating range using optical flow images and a matched filter, Machine Vision and Applications, 2004, PP 234 – 236

[11] http://cs.stanford.edu/people/eroberts/courses/soco/projects/1997-98/computer-vision/motion.html, 2006

[12] Shahriar Negahdaripour, Berthhold K. P. Horn, A Direct Method for Locating the Focus of Expansion, Computer Vision, Graphics and Image Processing 46, 1989, Page 320

[13] Wikipedia, Closed - Circuit Television Camera, 2014

[14] Thomas Brox, Jitendra Malik, Object Segmentation by Long Term Analysis of Point Trajectories, 2011, Page 282 – 294

[15] Ce Liu, Beyond Pixels; Exploring New Representations and Applications for Motion Analysis, 2009, Page 81- 85

[16] Yong- Ren pu, Li Wei Chen, Su- Hsing Lee, Study of Moving Obstacle Detection at Railway Crossing by Machine Vision, 2014, Page 2611 – 2612

[17] Anjali Jain, Dr. Neeraj Tiyagi, Collision Detection and Avoidance in Railways using WiMAX, 2012, Page 789- 794

[18] Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, 2000, Page 1- 43

**Appendix- A  Letter of Request**

Towns North of Colombo Water Supply Project,

Kandana,

$20^{th}$ September 2011.

Through Addl. General Manager,

Through Project Director,

AGM,

Training Center,

Thelawala,

Dear Sir,



<u>MSc/ PG Diploma Course in Industrial Automation Intake 2009</u>

I need to carryout some part of my research work with CGR. Please kindly issue a permission letter addressing to Chief Mechanical Engineer, Sri Lanka Railway, Ratmalana for granting permission for said work.

Yours truly,

A.L.S. Sriwardene

## Appendix- B Letter of Obtaining Statistics from Railway

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தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை
**National Water Supply & Drainage Board**

Chairman } Tel : [illegible] Fax : [illegible]
Vice Chairman } Tel : [illegible] Fax : [illegible]
Head Office } Tel : [illegible]
P.O. Box } 14, Mt. Lavinia
General Manager } [illegible]
Working Director } Tel : [illegible] Fax : [illegible]
Hunting No : [illegible]
Fax : [illegible]
E-mail : [illegible]
Galle Road, Ratmalana, Sri Lanka.

My No. } MDTD/IA/UOM/2009
Your No. }
Date } 2014.04.08

ManPower Development &
Training Division. NWSDB,
Thelawala Road, Ratmalana.

Manager,
OPS Section,
Sri Lanka Railways.

Dear Sir,

***Request for Obtaining Statistics***

Mr. A.L.S. Siriwardena, Senior Engineer of National Water Supply & Drainage Board is following [illegible] Programme conducted by the University of Moratuwa.

As a part of this programme to prepare his thesis he needs some statistics from Sri Lanka Railways. If you are in a position to allow this request kindly issue these requested data to Mr. A.L.S. Siriwardena.

Thanking You,
Your Faithfully,

W.G.M.P. Kulasiri
Manager (Training)

W.G.M Parakrama Kulasiri
Manager (Training)
Manpower Development & Training Division
National Water Supply & Drainage Board

MINISTRY OF WATER SUPPLY & DRAINAGE
"Water - Every Drop is Precious"

**Appendix- C Letter of Requesting to Test Prototype**

**Department of Electrical Engineering**
University of Moratuwa, Sri Lanka
Katubedda, Moratuwa, Sri Lanka

Tel: +94-112-640404 Fax: +94-112-650625

Dr. AGBP Jayasekara Email: buddhika@elect.mrt.ac.lk

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10 April 2014

To General Manager
Sri Lanka Railways,

Sir,

**Request to Test a Prototype of Obstacle Detection System for Trains.**

Mr. ALS Siriwardene is developing an obstacle avoidance system for trains as a driver assisting device in his research project leading to a degree of Master of Science in the Department of Electrical Engineering under my supervision.

I will greatly appreciate [illegible] His details are given [illegible]

Name: ALS Siriwardene
NIC No: [illegible]31432210
Index No. (MSc. Course): 09/8718

TF/F22

Pl arrange

Thank you,

9/04/2014

Dr. AGBP Jayasekara
BSc Eng, MSc, PhD, MIEEE, AMIE(SL)
Department of Electrical Engineering
University of Moratuwa
Moratuwa 10400
Sri Lanka
Email: buddhika@ieee.org
Phone: +94 11 2640404
Fax: +94 11 2650622

MELP
Pl speak
11/04

**Appendix- D Financial Expenditure for preparing Prototype Model**

The financial expenditure for a prototype model with high accuracies will be much reasonable as follows;

**Table D Financial Expenditure for preparing Prototype Model**

| Item No. | Description | QTY | Rate ($) | Amount ($) |
|---|---|---|---|---|
| 01 | CCTV Cameras | 02 | 250 | 500 |
| 02 | Personal Computer (Core i5) | 01 | 1000 | 1000 |
| 03 | Arduino (UNO) Hardware | 01 | 30 | 30 |
| 04 | Servo Motor | 01 | 20 | 20 |
| 05 | MAT LAB Software | 01 | 300 | 300 |
| 06 | Accessories (wiring, bases, connectors, etc.) | 01 | 10 | 10 |
| | Total | | | 1860 |