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Integrate Mobile Robotic Imaging System For Real Time Under Vehicle Inspection

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***Abstract*—This paper is concerned with the hardware and software design to control three-wheeled non holonomic mobile robot in real time under-vehicle inspection system (UVIS). The system has intelligent autonomous or semi-autonomous scanning capability to explore any defect, breakage and strange objects. UVIS could follow different types of the black paths with good accuracy using image segmentation for the capturing data.**

***Keywords*— under-vehicle inspection, mobile robot, real time, Image segmentation**

I. Introduction

The exploration of under vehicle video system with an autonomous mobile robot requires much programming effort. Additionally the robot possesses the infrared/ultrasonic sensors and cameras, which constitute the perception function. Full parallel projection approaches, multi- perspective mosaics, and panoramic stereo mosaic is the more important approaches applied to ground robot applications. The range of the roadside scenes to that on the robot camera is from tens of feet indoor to hundreds of feet outdoor [1]. The roadside parallel-perspective stereo mosaics and multi- perspective mosaics used in the inspection.

Cheng Qian et al [2], presented a mobile scanning system in real time under-vehicle inspection architecture. The inspection system decomposed into bricks of three kinds: sensing, mobility, and computing. These bricks are physically and logically independent and communicate with one another by wireless communication. Each brick is mainly comprised of five modules: data acquisition, data processing, data transmission, power, and self-management. David L. Et al [3], 3D range scans are collected under vehicle carriages to focus specific problem. These scan requires, appropriate segmentation and representation algorithms to simplify the process of vehicle inspection, to enhance security and surveillance missions and discussed a super quadrate based representation.

Balaji Ramadoss [4], developed hardware and software requirements of a robot like image system for real time under vehicle inspection.

The integrated hardware designed for the robot like imaging system consists of infrared, near infrared and high-resolution video sensors, which used to visualize the real-time data from the vehicle from a handheld computer such as Tablet-PC. The robot is capable of capturing the real-time data under the vehicle structure and transmits to a remote computer by using TCP/IP protocols. The system has networked controls with electronic control devices that can manipulate the illumination constraints, power controls and channel selections. Nicholas S. Et al [5], address the small omnidirectional inspection system (ODIS), man-portable mobile robotic system that can used for autonomous or semi-autonomous inspection under vehicles in a parking area. The robot features three ‘‘smart wheels’’ in which both the speeds and directions of the wheel can be independently controlled and a vehicle electronic capability that includes multiple processors and a sensor array with a laser, sonar and IR sensors, and a video camera. ODIS employs a novel guidelines command language for an intelligent behaviour generation. R. Sukumar et al [6], presented a 3-D sensing to an under-vehicle inspection robot. It provides flexibility with ambient lighting and illumination beside to the ease of visualization, mobility, and increased confidence toward inspection. Laser-based range-imaging techniques leveraged to reconstruct the scene of interest and address various design challenges in the scene-modelling pipeline. Matthew et al [7], presented a simple robot localization technique by using the wireless visual serving technique involved in an autonomous ground vehicle ODIS (omnidirectional inspection system) for under-car inspection tasks in a standard parking lot environment. Seung Yu et al [8], presented a system for inspecting and measuring cracks in concrete structures to provide objective crack data to be used in evaluating safety. The system consists of a mobile robot system and a crack detection system. The mobile robot system controlled to maintain a constant distance from the walls while acquiring image data with a Charged Couple Device (CCD) camera. Hitoshi Miyata et al [9], present fuzzy control theory for controlling an autonomous mobile robot for the parallel parking; the fuzzy rules can derived from modelling the driving action of the conventional car.

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Localization of the robot for the parking drawn through the computer simulation. Scott and Keith Doty [10], described a vision system based on combining a mobile autonomous robot with wireless links to a host PC running MATLAB™. The TJ Pro-Avr™ consists of a mobile robot platform. A mosaic of the under vehicle video is desired to simplify the process of inspection. Andreas et al [11], developed, tested, and deployed sensing and imaging systems. Describing efforts made to build multi-perspective mosaics of infrared and colour video data for under vehicle inspection. It desired to create a large, high-resolution mosaic that visualizes the entire scene shot by a camera making a single pass underneath the vehicle. Several constraints placed on the video data to ease the assumption that the entire scene in the sequence exists on a single plane. Therefore, a single mosaic used to represent a single video sequence. The method uses phase correlation to perform registration and is capable of building mosaics from video sequences captured using infrared and Visible-spectrum modalities. Mel Siegel [12], described a computer vision methods and algorithms for detection of reprocessing corrosion, and subsurface corrosion. Cracks and surface corrosion are both detected by algorithms that pipeline preprocessing / enhancement, multi-resolution / wavelet based, feature extraction, and neural net based, feature vector classification ; subsurface corrosion was detected by a structured laser light surface profiling technique for the pillowing that subsurface corrosion causes. Functionality illustrated by application to current data.

This studied, describe the design, implementation, and building a three-wheeled UVIS based on mobility, sensory, and image navigation system for inspection applications.

II. WHEEL MOBILE ROBOT DESIGNS (WMR)

UVIS designed to explore any defect/breakage by integrating a mobile robot motion with the image and video processing software and hardware system. The hardware includes versatile wheel mobile robot to ensure better mobility and stability regarding vibrations during the process of data acquisition. The system equipped with inspection high-resolution wireless cameras figure (1), which can operate in the infrared, visible spectrum and near infrared. The designed software includes, features comprise the data collected by the robot with the stored data. The system designed to inspect automatically every part of the bottom of the vehicle and identify the required information. Online image segmentation/enhancement, colour mapping, video mosaic as in [13], edge detection, morphology, colour mapping, spatial and frequency filtering are included in the software, figure (2).

A typical model of a non-holonomic WMR consists of a vehicle (25 x 20 x 5cm), with two driving wheels on the same axis and a free caster wheel at the end of the mobile robot. The two wheels allow the mobile robot to navigate forward, backward, right, and left at the same velocity. The motion and orientation achieved by independent actuators, two DC (60-RPM) motors providing the necessary torques for driving wheels. The wheels are designed to have an ability to follow or trace the black line on a white background in a closed/open loop depending on the task in a smooth or rough environment (without obstacles). The mobile robot has free navigation under a car or specified environment with a velocity 5 cm/s to 15 cm/s, which allow accurate path spatially when steering to left, and right in 90-degree angle. Three 9V-7A/h recharging batteries mounted on the robot.

UVIS interaction with its environment is essential to its autonomy and adaptability. The platform allows passing illumination to three IR (infrared) sensors to detect the black lines. The sensors provide the operator with the actual working position of the robot.

Figure1. Wireless camera and its receiver

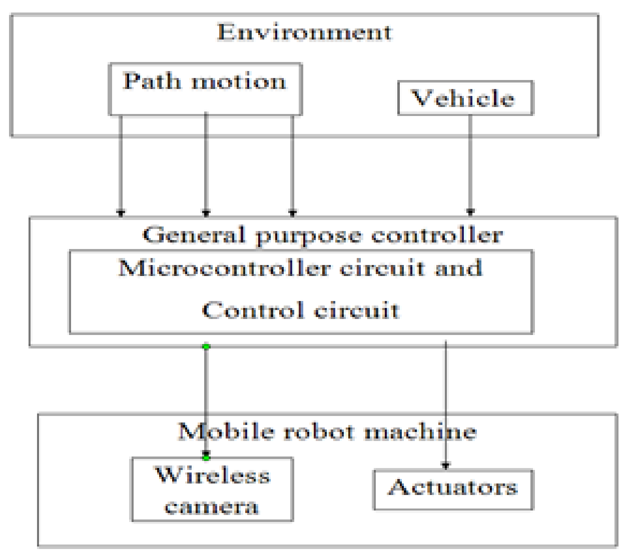

Figure 2. Blocking of Inspection Robot

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III. Hardware And Software Architecture

A micro controller (PIC16F84A) with 18 pins 8 bits used to control the DC motor's drivers and cameras figure. 3. A PWM timing circuit, switch, reset circuit and oscillator circuit. Four OPB608A IR sensors used in object detection, through a light or ultrasonic signal with a specific frequency, which transmitted from a source, reflected back by the object and detected by the receiver. Three light sensors used to detect the black line path on the white background and one used as distance sensor to detect the vehicle when it passes through inspection area. Infrared light sensors compare two IR LED's modulated about 40 KHz with a light beam and one IR receiver. On capturing a target in the left range , the left LED connected to the relevant IR LED will illuminate, when a target is captured in right range, the right LED, will illuminate and when a target is captured in the left+ right range, both LED's will illuminate. The rays reflected from the target to the IR receiver, which has a phototransistor that provides analog output, a figure (4). The positions of three IR sensors, figure (5), are perpendicular to a path to follow. A robot provided high illumination light to detect the navigation black line on white background and get a good video quality.

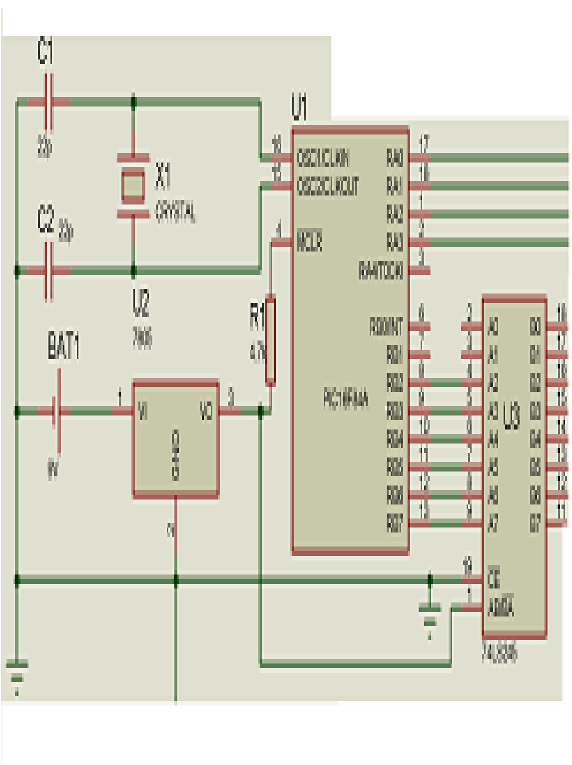

Figure 3a Operating microcontroller circuit

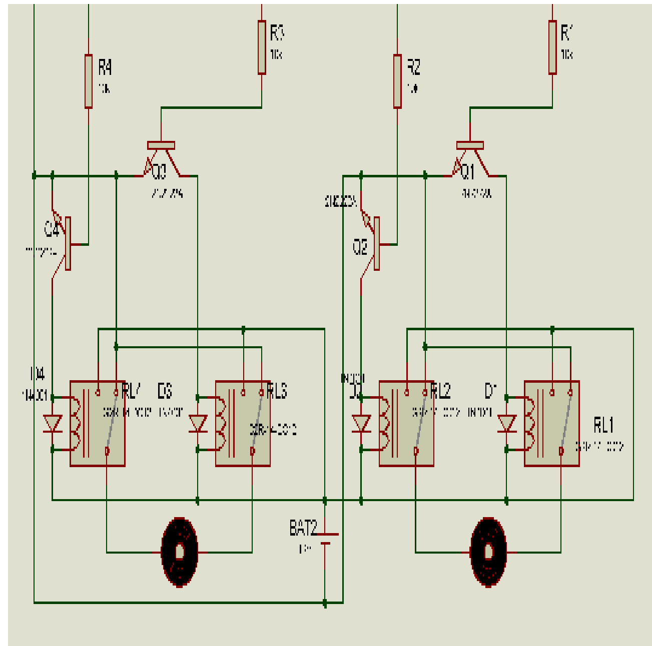

Figure 3b. The actuator control circuit

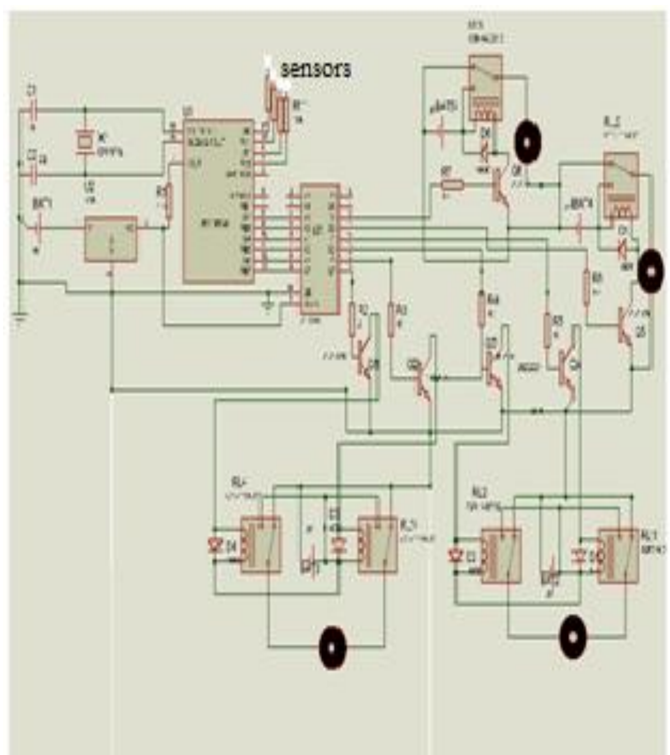

Figure 3c Operation and Control Circuit

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Infrared and ultrasonic sensors used in object-detection. Different types of sensor used as distance sensor time (GP2Y0A02YK) and light sensor other times (OPB125A).

Control and processing image software are to support the overall modularity concept. Programming the micro controller programmed with PICPBASIC language and compiling to a hexagonal numbering system with a PIC simulator IDE simulator

Figure 4. Infrared light sensor

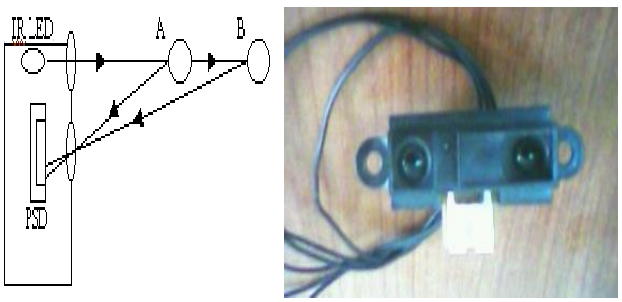

Figure 5. Iinfrared-ranging sensor

PIC16F84A microcontroller with +5V input at pin 14 use sensors signals through port A to control the two DC motor and wireless cameras. Clock frequency using 4MHZ crystal at pin 15 and 16 with two parallel capacitors (22pf) to provide clock pulse for the internal circuit of the integrated circuit. The input pins is, connect to four 10k ohm to reduce or remove noises from infrared sensor current (> 25mA) that will make the integrated circuit in saturated, state. Pin 5 connected to 0Vand buffer circuits within output signal of the microcontroller PIC to avoid the damage when the two actuators and cameras started.

Pin 4 of the microcontroller is connected to +5V using 470 Ohm to clear and reset circuit by connecting switch to 0V .The output signals from the microcontroller as digital 1 (1.5V to 5V) and logic 0 (0V to 1.4V) control the wireless camera and the two DC motor.

The two DC motors controlled by using four relay (+9V and 0V) through pin (1, 2) and pin (3, 5) according to the voltage at pin 4 (0V to 1.5V: the motor work otherwise stopped). To implement signals of pin 4, a collector of 2N222 (NPN), transistor is connected to pin 4 of the relay, so it can used as switch when the output signal of the microcontroller,(RB4, RB5, RB6, and RB7) , passes through it , connecting to the base of the transistor and connect the emitter to the 0V (the earth of the circuit) . Ten kilo-ohm resistor connected between the buffer and the base of the transistor to bias the base of the transistor to prevent excessive current to avoide overheat and to protect the transistor. Other output signals of the microcontroller (RB2, and RB3) are used to operate the two wireless camera with 9VDC using two relays supplied with +9V and 0V and provide 9VDC to pin 3 to out 9V to operating camera. The two circuits connect to diode (1N4001) between pin 1 and pin 4 to prevent the current from supply to the transistor.

Mobile robot direction controls use a single pole relay as on/off with two DPDT relay in series. A digital signal for the pole relays, logic 0 (low) turns the relay off and logic 1 turns it on (high) and can operated from any gate. The first DPDT relay is used to control the forward and backward motion, the second relay are used for left/right orientation and that may cause damage to transistor at transient time when convert pole position of the relay dependent on two logic outputs from microcontroller. The difference between the current of the DC motor (1 to 2 Ampere) and microcontroller output pin current (25 MA) will cause a drooping and damaging in the microcontroller. To avoid this problem a buffer integrated, circuit (74LS245) connected to the microcontroller output pin (the output signal from pic16f84a involves the port B pin only), figure 6.

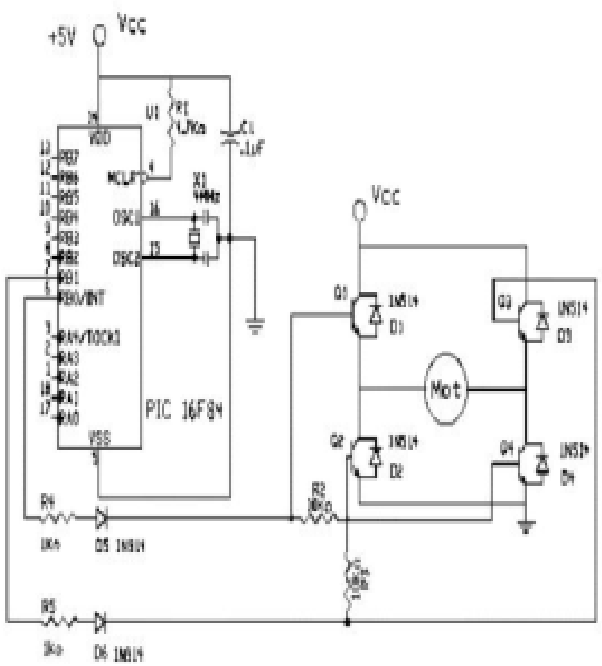

Figure 6. The operating circuit for Pic16f8 4a

Table (1), shows the inputs data (V1 and V2) that denote the wheels velocities (the motor rotation), robot velocity and direction of the motion for the path of motion.

TABLE I.
The velocities results and motion

NO.	Actuators' state	Left wheel	Right wheel	Vx m/sec	Vy m/sec	V m/sec	Θ/ degree
1	1ON & 1 OFF	0	1	0.05	0	0.05	0-360⁰
2		1	0	0.05	0	0.05	0-360⁰
3		0	-1	0.05	0	0.05	0-360⁰
4		-1	0	0.05	0	0.05	0-360⁰
5	2 ON	1	1	0.05	0	0.05	0
6	2 ON	-1	1	0	0	0	360⁰
7	2 ON	-1	-1	0.05	0	0.05	0
8	2 ON	1	-1	0	0	0	360⁰

When one wheel is on and the other is off, the robot will have the same value of V with different inputs. For example in case (5) all the wheels are on (1, 1), rotated in the same direction to make the robot move in forward path. For case (7), all the wheels are on (-1,-1), in opposite direction to case (5), causes robot to move backwardbut. For cases (6 &8) all the wheels are o each wheel rotate in opposite direction to other, cause robot to rotate on the center of mass (rotation).

IV. Kinematic Model Of The WMR

The analysis of the kinematics for the wheeled mobile robot (WMR) is given under the non-holonomic mobile robot constraint of pure rolling, and non-slipping differentials drive robot as shown in figure.7 as given in [14,15&16].

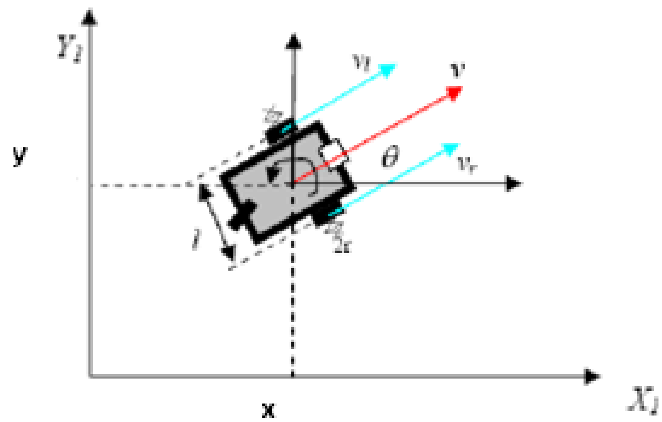

Figure. 7 Velocities for WMR

$$\dot{x} = v\cos\theta \qquad (1)$$

$$\dot{y} = v\sin\theta \qquad (2)$$

$$\dot{\theta} = \omega \qquad (3)$$

$$\dot{q}_I = J(q)v, \begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\theta}\end{bmatrix} = \begin{bmatrix}\cos\theta & 0\\ \sin\theta & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}v\\ \omega\end{bmatrix} \qquad (4)$$

Where q is the vector of position and J (q) is the Jacobin matrices. A mobile robot called non-holonomic if its model contains at least one non-holonomic constraint that described by more than three coordinates that could obtain from the kinematic model. Three values needed to describe the location and orientation of the robot, while others needed to describe the internal geometry and have two or three degree of freedom with singularities.

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\theta}\end{bmatrix} = \begin{bmatrix}\frac{R}{2}\cos\theta & \frac{R}{2}\cos\theta\\ \frac{R}{2}\sin\theta & \frac{R}{2}\sin\theta\\ \frac{R}{L} & -\frac{R}{L}\end{bmatrix}\begin{bmatrix}\omega_r\\ \omega_l\end{bmatrix} \qquad (5)$$

WhereIt is defining the linear velocity of point COM (center of motion) of the WMR and $\omega(t)\ \epsilon R$defining the angular velocity of point COM of the WMR. The vehicle motions controlled by its linear velocity $v(t)$ and rotational velocity$\omega(t)$, is timing, so that the bounded velocities of the WMR considered as the inputs to the mobile robot.

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V. IMAGE ANALYSIS

Video was obtained under-side and under vehicles for threat detection, using both standard videos and modalities. The multi-perspective video mosaic of the detected object generated after the noise reduction.

Digital image processing encompasses a broad range of hardware, software, and theoretical underpinning. Figure (8) shows the overall objectives to produce a result from a problem domain by image processing.

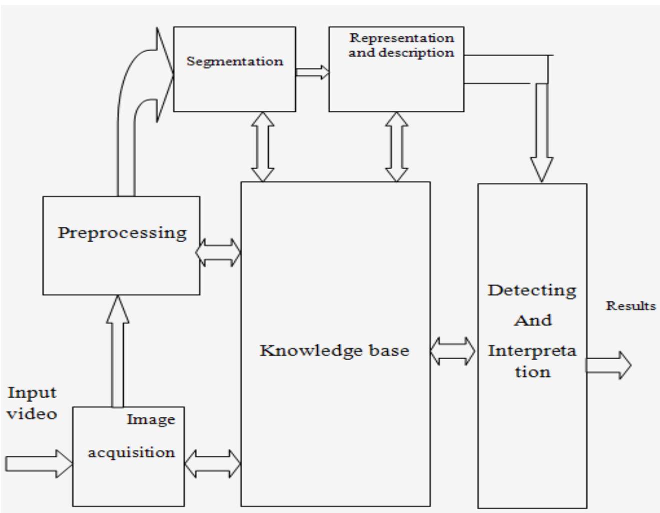

Figure 8. Operation of Image Processing

The illumination affects the capability of the light infra-red sensors responsible for detection path of motion, inspection time, resolution, intensity, and other factor of the object for acquiring image at any time (in night and daytime) as shown in Figure 9&10.

Figure 9. Objects in Daytime without Illumination

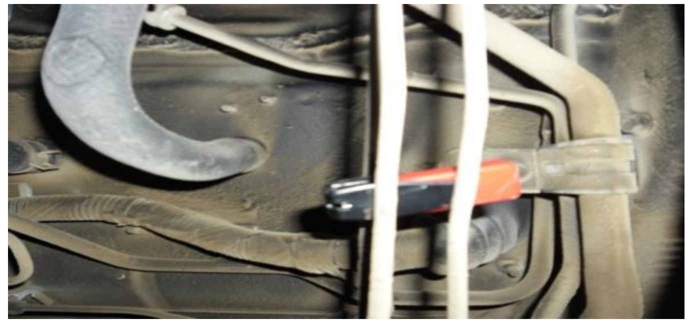

Figure10. Objects in Night with Illumination

Inspections affected with field of view, depth of field, range inspection, temperature and frame rate. The image sizes is controlled through reducing it from 90 to (45 or 60) degree of angle. A 120 or 135 angle with Y-axis will reduce the dead zone of the inspecting area, avoid the match approach that required between cameras when using more than one camera, and reduce a complexion in the process of inspection more than using one camera as shown in figure 11. Several cameras will be uses as many video sequences will be required. Neighboring images share the same partial viewpoint and overlap slightly to ease their merger.

Figure 11. Image 60^0 Field of View

VI. RESULTS AND DISCUSSION

The camera will start acquisition image at the beginning of the robot motion. Low illuminations produce non-smooth motion figure .12, with longer time, figure13&14.

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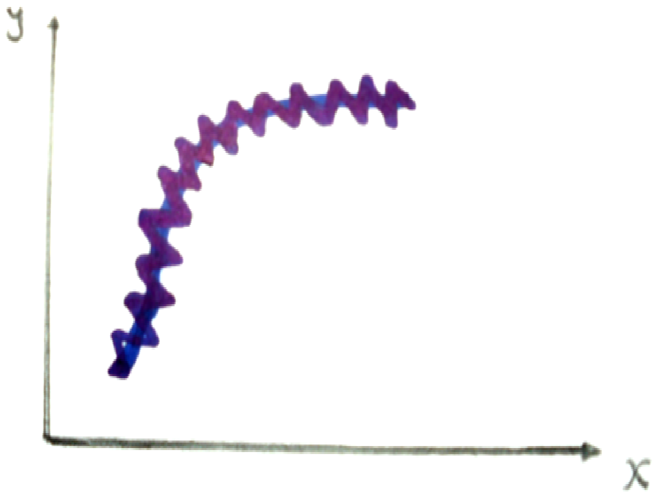

Figure. 12. The none smooths Motion

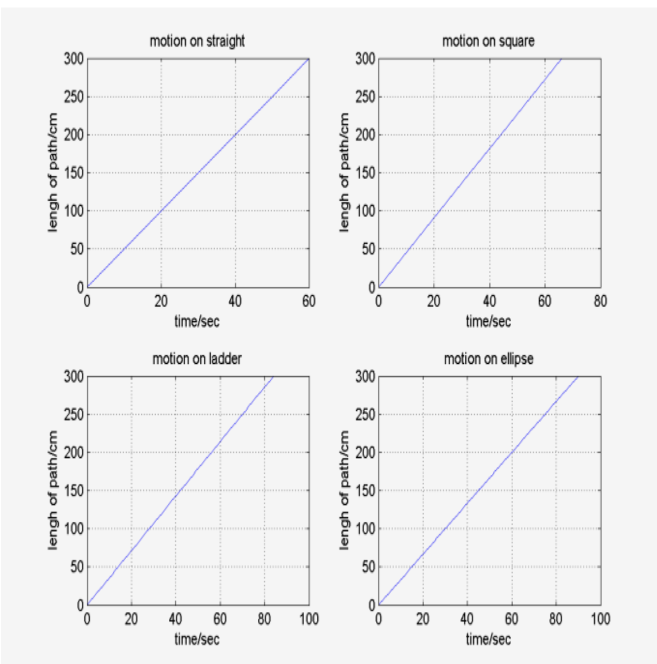

Figure 13. Time with correct illumination

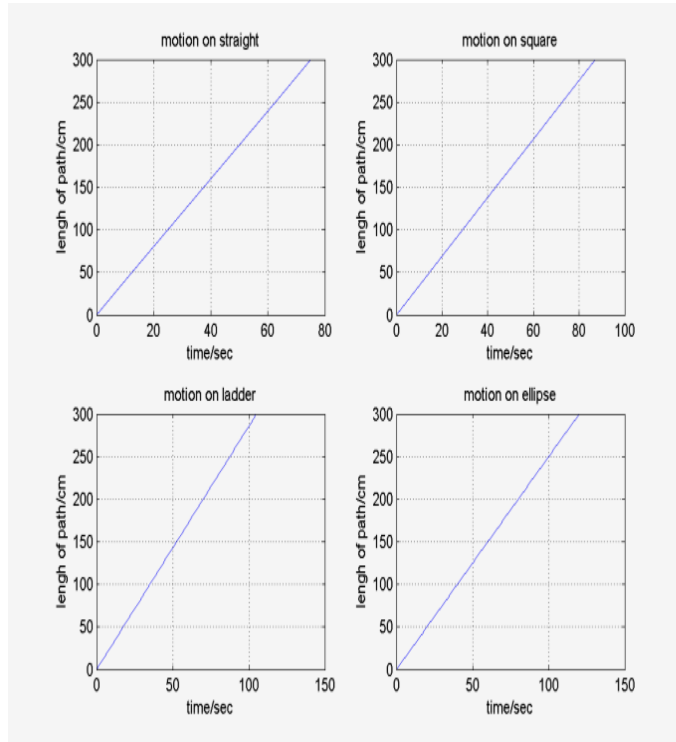

Figure. 14. Time with Low Illumination

Different paths of motion (straight, square, ellipse, ladder) are investigated with an inspection device (number of cameras, field of view, distance between camera), inspecting an area of the vehicle, and the time of inspection figure. 15.

Figure15. Inspect and Non-Inspected Area

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The video frame's sequence for the detected object analyzed with a MATLAB image acquisition figure 11. The goal of segmentation is to locate the position and the shape of an object or objects of interest, which may depict in the original image .Using histogram or watershed technique obtained this information. Segmentation could therefore look as a computer vision problem. In this study, different approach of segmentation is used such as edge based, morphological, K-mean cluster to obtain the important object of image segmented, and their comparable answer figures (16, 17,18 & 19) respectively .After a process of segmentation, the morphological operation used to estimate the objects and use it as input to other steps of an image process.

Different type of morphology operation used to implement a good image by reducing the image noise.

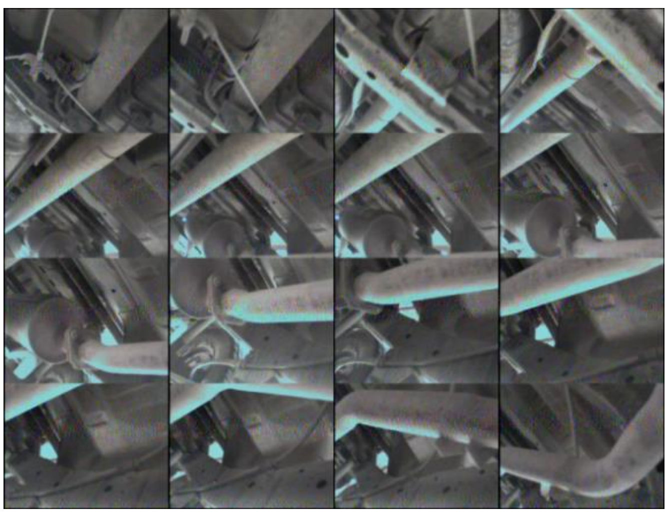

Figure16. Acquire from Straight Motion

Figure 17a

Figure 17b

Figure 17. (a) Original Image (b) Edge and Morphological Segmentation

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Figure 18. 1st & 2nd Clustering Segmented Image

Figure 19 .Clustering-Morphology Operation

VII. CONCLUSIONS

The main conclusions are:

a) The mobile robot system designed is simple and easy to program with acceptable results.

b) The WMR move with high stability, smooth motion and without noisy images with increasing the activation of infrared lighting sensor.

c) The multi-perspective mosaic is more useful than the video display to preview all the objects of the vehicle, easy to process with more places to preview the object to the operator.

d) K-mean clustering is used to preview objects at one separating coloured image without applying histogram equalization that was used by other techniques (edge and morphological).

e) Image enhancement, morphological and special transformation could be used after K-mean clustering with a good result compared with other segmentation techniques.

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