Comparative study between Image Processing and Similar Techniques used in Adaptive Traffic light System

1Mustafa Hassan, 2Dr. Amin Babikir, 3Dr. Salah Talha and 4Attika Malik

1Future University, Faculty of Engineering, Computer Engineering Department, Box.1055, Khartoum, Sudan.
2Amin University, Faculty of Engineering, Telecommunication Department, Box. 12707, Khartoum, Sudan
3Taif University, Faculty of Computer and IT, Computer Engineering Department, Box. 888, Taif, Saudi Arabia Kingdom
4Future University, Faculty of Engineering, Computer Engineering Department, Box.1055, Khartoum, Sudan

ARTICLE INFO
Article history:
Received 12 March 2015
Accepted 28 June 2015
Available online 22 July 2015

Keywords:
Adaptive traffic light, Image processing, Wireless sensor, Ultrasonic sensor, IR sensor, Weight sensor.

ABSTRACT
As known the population of cities and number of cars are increasing day by day. Due to that increasing and bad traffic management, a lot of man-hours are being wasted. Regarding of this problem, a self adaptive traffic system using different techniques is developed. The technique role is to detect a condition of roads and then feed the traffic light controller. The accuracy of detecting condition of the roads depends on the technique type used. Image processing one of the modern and real-time technique used in adaptive traffic system. The paper study several techniques followed by explanations and discussions. Then the paper concluded with the comparison between advantages and disadvantages of image processing and similar techniques. The study shows that image processing has brightness future in terms of it is better traffic management and performance.

INTRODUCTION

Traffic control and management is a major problem in many cities, especially in growing and big cities. Traffic signals solve the problem of traffic conflict on intersection by time division multiplexing. One of the effective systems of the traffic signal is adaptive systems. It provides clearly-observable and significant benefits over traditional operation (fixed system operation), even during congested peak periods and incidents (Kevin Fehon et al., 2010). Signal controller controls phases, sequence and timing of the traffic signals. Optimization of traffic signal timing and sequence is a critical factor when addressing traffic congestion. So for trying to solve the problem of traffic congestion different technologies have been used in adaptive traffic light control system. These technologies made the process of timing of the traffic signal continuously adjusted based on the changing arrival patterns of vehicles at an intersection, usually with the goal of optimizing a given measure of effectiveness. Hence, the collecting real-time traffic data is a very important issue to inform the microcontroller about the situation of the roads at an intersection. Conventional methods of traffic data collection have limitations such as weight sensor, IR sensor and ultrasonic sensor. Those include limited coverage due to a sensor’s fixed-location installations and the cable-based communication methods used to transmit the detected traffic information, which increases the costs of implementation and maintenance (Binbin Zhou and et al., 2013)

With the continuing development of real-time technologies the possibility of overcoming these drawbacks of conventional methods is increased. Because of flexibility in deployment and various functions and numerous potential applications. These typically include environmental monitoring, tracking and controlling. Under the guarantee of that all of the traffic data can be measured using smart sensors (cameras) or other real-time sensors can overcome the shortcoming mentioned above.

Overview of the techniques used in adaptive traffic system:

1. Image processing:
   An image: is defined as an array, or a matrix, of square pixels (elements of picture) arranged in rows and columns. Image processing is defined by (Jay Acharya and et al., 2013) as it refers to digital image processing. The producing the input image in the place is referred to...
as imaging. It is also refers to optical and analog image processing.

Digital Image Processing (DIP): is multidisciplinary science that makes employ the principles from various fields such as optics, computer science, mathematics, surface physics and visual psychophysics. Some of the important applications of image processing in computer vision include, remote sensing, feature extraction, face detection, finger-print detection, optical sorting, argument reality, microscope imaging, lane departure warning system, Non-photorealistic representation, medical image processing, and morphological imaging (Basavaprasad B and Ravi M, 2014). An image contains sub-images often referred as regions or regions-of-interest. Images regularly contain groups of objects each of which is the basis for a region. Most generally, image processing requires the images to be available in digitized form. For digitization process, the input image is sampled on a separate lattice and every sample or pixel is quantized by a fixed number of bits. The process is the digitized image. To show a digital image, first it is converted into an analog signal that is scanned onto an output. Image processing is very closely related to computer vision and computer graphics. The goals of image processing are divided into five groups:

1. Hallucination (monitor the objects that are not visible.)
2. Image restoration and sharpening (for creating better image.)
3. Image repossession (search for the image of interest.)
4. Measurement of pattern (measures a range of objects in an image.)
5. Image acknowledgment (differentiate the objects in an image)

**Image segmentation:**

Image segmentation is a process of partitioning a digital image into multiple segments, that means a set of pixels, pixels in a region are similar depending on some homogeneity criteria like color, intensity or texture, in order to place and match objects and boundaries in an image.

Image segmentation is generally defined as the basic image processing that subdivides a digital image $f(x, y)$ into its continuous, disconnect and nonempty subset functions from first function to $n$ function, which provides appropriateness to extraction of feature. Practically application of image segmentation including filtering of noisy images, medical applications (Locate tumors and other pathologies, Measure tissue volumes, Computer guided surgery, Diagnosis, Treatment planning, study of anatomical structure), Locate objects in satellite images (roads, forests, and so on.), Face Recognition, Finger print Recognition, and so on. There are many segmentation methods have been proposed in the literature, which is provides options for deciding segmentation technique selected over another depending on characteristics of the problem being considered.

Image segmentation approaches divided into two parts based on the properties of the image:

**Detecting Discontinuities:**

Is to partition an image based on sudden changes in intensity, which is includes image segmentation algorithms such as edge detection.

**Detecting Similarities:**

Is to partition an image into regions that are similar depending on a set of predefined criterion; which is includes image segmentation algorithms such as thresholding, region growing, region splitting and merging.

**Classifications of image segmentation methods:**

*The main categories of image segmentation are:*

**Edge base segmentation:**

Edge segmentation is algorithm aim to identify points in digital image at which there is a sudden change in image brightness or where is a jump in density from one pixel to the next one. It includes sub classes such as grey histogram techniques and gradient based which is involves differential coefficient technique, laplacian of a Gaussian and canny techniques global.

**Region based segmentation:**

Region based on segments partitions of an image into regions that are similar depending on a set of predefined criteria. The main example of this techniques are thresholding (thresholding and local thresholding), region operation (region growing, region splitting and merging).

**Theory based segmentation:**

Different image segmentation algorithms were derivative from different scopes, which are very significant for segmentation approaches like neural network-based, clustering based and fuzzy-based technique.

**Model-based segmentation:**

It can be applicable if the shape of the object is exactly known (Mustafa.H. and et al., 2015).

The proposed system for controlling the traffic light by image processing depends on the concept above. So all the systems proposed are shared on one point which is to detect vehicles through an image instead of using electronic sensors embedded in the pavement. Table below shows the history of using image processing in adaptive traffic light:

In (Muzhir Shaban Al-Ani and Khattab Alheeti, 2011) the authors presented a flexible adaptive traffic light system and offers many advantages such as: minimizing the traveling time for vehicles and
passengers that minimizing pollution, minimizing the traffic congestion as possible that save energy and reduction in emergency response time. The (Vikramaditya Dangi and et al., 2012) used edge detection method which also is used by (P.Srinivas and et al., 2013) with different technique and both giving a better technique for controlling jam traffic. The better thing is that (P.Srinivas and et al., 2013) used algorithm to remove extra hardware. Also (Ruheena Hashmi, 2014) showed that image processing is the better technique to control traffic jam and it is also more consistent in detecting vehicle presence because it uses actual traffic frames.

### Table 1: The using of image processing in adaptive traffic light for several researchers.

<table>
<thead>
<tr>
<th>Year</th>
<th>Image processing method</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Vehicles area Calculation</td>
<td>(Muzhir Shaban Al-Ani and Khattab Alheeti, 2011)</td>
</tr>
<tr>
<td>2012</td>
<td>Edge detection (recognized on the basis of a predefined threshold)</td>
<td>(Vikramaditya Dangi and et al., 2012)</td>
</tr>
<tr>
<td>2012</td>
<td>Image enhancement (Gamma correction)</td>
<td>(Pejman Niksaz., 2012)</td>
</tr>
<tr>
<td>2013</td>
<td>Region of interest (Area of queue)</td>
<td>(Arif A. Bookseller and Rupali R bJagtap, 2013)</td>
</tr>
<tr>
<td>2013</td>
<td>Partitioned profile (road) into sub-profiles</td>
<td>(Prof. Uma Nagaraj and et al., 2013)</td>
</tr>
<tr>
<td>2013</td>
<td>Edge detection (Canny edge detector)</td>
<td>(P.Srinivas and et al., 2013)</td>
</tr>
<tr>
<td>2014</td>
<td>Object detection and account.</td>
<td>(Ruheena Hashmi., 2014)</td>
</tr>
</tbody>
</table>

### Table 2: Evaluation of different technologies of load sensors.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitive</td>
<td>Conductive elastomers</td>
<td>Good sensitivity; Moderate hysteresis; Wide dynamic range; Linear response robust.</td>
<td>Complex circuitry; Susceptible to noise; Limited Spatial Resolution; Some dielectric are temperature sensitive</td>
</tr>
<tr>
<td></td>
<td>Carbon felt and Carbon fiber</td>
<td>Shapable; Good gripping surface; withstand very high temperature; withstand high overloads</td>
<td>Sensor noise at low loads; Not suited for miniature sensors</td>
</tr>
<tr>
<td>Piezoresistive</td>
<td></td>
<td>Wide dynamic range; Durability; Good mechanical material properties</td>
<td>Frailty of electrical junctions; Inherently dynamic; Good solutions are complex; Difficulty of separating; Pyroelectric/piezoelectric effects.</td>
</tr>
<tr>
<td>Piezoelectric</td>
<td></td>
<td>Wide dynamic range; Durability; Good mechanical material properties</td>
<td>Inherently dynamic; Good solutions are complex; Difficulty of separating; Pyroelectric/piezoelectric effects.</td>
</tr>
<tr>
<td>Pyroelectric</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Weight sensor:**

Weight sensor (load cell) is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force (weight) being measured. It is used to measure the traffic density by counting the number of vehicles in each lane and their weight by sensing the weight and sends signal to microcontroller, programmable language control (PLC) and microprocessor of Traffic light.

### 2.1. Principle and operation:

Load sensor can be made by different technologies such as resistive, capacitive, inductive, piezoresistive, piezoelectric, pyroelectric and others. Most commonly available load cells are based on the principle of change of resistance in response to an applied load. (Prof. Roland Siegwart, 2010) has evaluated the different technology as in the table below:

### 3. **Infrared Sensor (IR):**

An infrared sensor is an electronic instrument which is used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation. Infrared sensors are also capable of measuring the heat being emitted by an object and detecting motion.

### 3.1. Principle and operation:

The principle of an IR sensor working as an Object Detection Sensor can be explained using the following (figure 1). An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo – Coupler or Onto – Coupler.
When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined. It has been implemented in traffic control by (A. Ms Promila Sinhmar, 2012) to optimize the better traffic control in a city. (Berna Saracoglu, 2009) is described the limitations of IR sensor in performance that has poor tolerance to light reflections such as ambient light or bright object colors. (Table 3) summarizes the advantages and disadvantages of IR sensor.

**Table 3: Advantages and disadvantages of IR sensor.**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low power consumption with low lost</td>
<td>Dead zone between 0 - 4cm No object recognition any closer than 4 cm.</td>
</tr>
<tr>
<td>Low dissipation current at OFF-state</td>
<td>No accurate detection results with transparent or bright colored materials.</td>
</tr>
<tr>
<td>External control circuit unnecessary</td>
<td>IR distance detection sensor for solid-state and gas are two different units.</td>
</tr>
<tr>
<td>Good low-light sensitivity with high resolution</td>
<td>Detection accuracy loss with increasing reflection distance.</td>
</tr>
<tr>
<td>Strong human recognition and identification</td>
<td>Change in detection results due to the differences in weather conditions.</td>
</tr>
<tr>
<td>Easy set-up and wiring procedure</td>
<td>Decreased the sensing reliability with moisture and humidity.</td>
</tr>
<tr>
<td>Microcontroller connection against the ambient light reflection sensitivity</td>
<td>Heavy processor to convert the non-linearity of analog output voltage vs. reflective object distance curve</td>
</tr>
</tbody>
</table>

4. **Ultrasonic sensors:**

Ultrasonic sensors use sound waves rather than light, making them ideal for stable detection of uneven surfaces, liquids, clear objects, and objects in dirty environments. These sensors work well for applications that require precise measurements between stationary and moving objects.

4.1. **Principle and operation:**

Ultrasonic sensors transmit ultrasonic waves from its sensor head and again receive the ultrasonic waves reflected from an object as in (figure 2). By measuring the length of time from the transmission to reception of the sonic wave, it detects the position of the object.

**Fig. 2: Ultrasonic operation.**

4.2. **Advantages and disadvantages:**

The main advantages of ultrasonic sensors are due to the continuous interrogation of the quantities of interest by a wave field and the immaterial sensing principle (Valentin Magori, 1994). These are:

- Excellent long term stability
- Low power consumption and low cost realization.
- In particular, the advantages of ultrasonic distance sensors are:
  - Directional sensitivity
  - High structural resolution due to large bandwidth
  - Remote measurement, low interference with objects to be detected, sensitivity to virtually all kinds of objects
  - Imperviousness to wetness, contamination or wear.

Ultrasound has the property, that its velocity is strongly affected by the flow velocity of the fluids in which it propagates. This drift effect is the basis for high resolution flow sensors. Deficiencies of ultrasound systems are often associated with properties that are advantageous at other times, such as the effect of temperature and material composition on the speed of sound. The effect that ultrasound attenuation increases with frequency, limits the measurement distance compared with optical or microwave based sensors. However, in these cases lower frequencies can be selected, at the expense of reduced structural resolution, and higher sensitivity to acoustic interference noise.

5. **Wireless sensor networks (WSN):**

A wireless sensor network is a group of specialized transducers with a communications infrastructure that uses radio to monitor and record physical or environmental conditions.

5.1. **Principle and operation:**

A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer,
transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from a battery.

Advantages and disadvantages of (WSN):
In (Debnath Bhattacharyya et al., 2010) has describe the advantages and disadvantages of implementing (WSN). It summarized as:

Advantages:
• Network setups can be done without fixed infrastructure.
• Ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests.
• Flexible if there is ad hoc situation when additional workstation is required.
• Implementation cost is cheap.

Disadvantages:
• Less secure because hackers can enter the access point and get all the information.
• Lower speed compared to a wired network.
• More complex to configure than a wired network.
• Easily affected by surroundings (walls, microwave, large distances due to signal attenuation, etc.).

Comparative analysis:
Usually the choice of techniques depends on required measurement needs for the traffic control system such as accuracy, performance and cost. One of the important technique that is used recently is image processing. As mentioned above image processing in (table 1). It showed better results in terms of performance, flexibility and accuracy, because of the high technique and speed of smart camera and computer system for processing image. The other techniques used have shown some limitations such as limited coverage due to sensors fixed locations. Also the circuit elements and design of sensors have some kinds of drawbacks as in (table 2). The table represents the advantages and disadvantages of load sensor. It showed that the load sensor is affected by temperature. That means it doesn’t work perfectly. Table 3 represents the advantages and disadvantages of IR sensor. It showed that the lacks of IR sensor in detecting objects due the difference weather conditions. Then the other one is the ultrasonic sensor. From the study of the advantages and disadvantages properties it has limitations in distance measurement and attenuation of ultrasound by increasing frequencies, which are cause problems in detecting objects. The last study of technique is wireless sensor networks. It is proves that it is easy affected by surroundings, causing signal attenuation.

Conclusion:
The study showed that image processing is a better technique comparing to other techniques to control the state change of the traffic light. It is more consistent in detecting vehicle presence because it uses actual traffic images. It visualizes the reality so it functions much better than those systems that rely on the detection of the vehicles’ metal content. Image processing in general promising brightness future and it has becomes the focus of modern research in traffic light control system.

REFERENCES
Binbin Zhou, Jiannong Cao and Jingjing Li, 2013. An adaptive Traffic Light Control Scheme and Its Implementation WSN-Based ITS. International Journal on Smart Sensing and Intelligent System.
Mustafa Hassan, Dr. Amin Babikir, Dr. Khalid
Abraham and Attika Malik, 2015. Adaptive Traffic
Light Control System: A Review. Australian Journal

Muzhir Shaban Al-Ani and Khattab Alheeti,
2011. Intelligent Traffic Light Control System Based

Srinivas, P., Y.L. Malathilatha and Dr. M.V.N.K
Prasad, 2013. Image Processing Edge Detection
Technique used for Traffic Control Problem.
International Journal of Computer Science and

Estimation Using Image Processing. International
Journal of Signal Processing, Image Processing and
Pattern Recognition.

Roland Siegwart, 2010. Force Sensing
Technologies. Swiss Federal Institute of Technology
Zurich.

Ruheena Hashmi, 2014. Traffic Alert System
through SMS Using Image Processing. Excel Journal
of Engineering Technology and Management
Science.

Yousef, K.M., J.N. Al-Karaki and A.M.
Shatnawi, 2010. Intelligent traffic light flow control
system using wireless sensors networks, Journal of
information science and engineering, 753-768.

Uma Nagaraj, Jinendra Rathod, Prachi Patil,
Sayali Thakur and Utsav Sharma, 2013. Traffic Jam
Detection Using Image Processing. International
Journal of Engineering Research and Applications
3(2): 1087-1091.

Valentin Magori, 1994. Ultrasonic Sensors in
Air. IEEE Ultrasonics Ferroelectrics, and Frequency
Control Society.