Video-Based Intelligent Traffic Control System

Zahari Taha, Said Amir Azan, Taufiq Abdul Gani, Nazaruddin
Centre for Product Design and Manufacturing
University of Malaya

Abstract - This paper presents our experience in developing a video-based and intelligent urban transportation system. The paper focuses on two aspects which are a video-based approach for detecting traffic speed and volume and a fuzzy-logic-based expert system for controlling traffic signal at an intersection. Both are developed using MATLAB Toolboxes for image acquisition, image processing and fuzzy logic. The results show that fuzzy logic is a viable approach for an intelligent traffic control system.

KEYWORDS: Urban Transportation System

1. INTRODUCTION

There has been a growing interest on intelligent transportation systems (ITS) in the last few years. The expertise involved is not only from traffic engineering, but is also from diverse and multidisciplinary such as image processing, control, and communication. There are many problems in ITS. One of the fundamental issues that will be discussed in this paper is how to automatically collect or capture traffic data. In the past, the current sensors (inductive loops and axle sensors etc.) have been used. However these sensors can not collect all the data that are of interest to traffic engineers. Most important of all, if the data is to be collected at a different location, the installation of these equipments, which needs to be buried beneath the road, creates serious traffic disturbances. In order to overcome the above problems, many researchers have used image processing-based. It can give time-variant and spatial information about a scene and can be recorded easily for further analysis. Ease of installation on present road, flexibility, and maintenance issues are among other advantages, which encourage researchers to concentrate on this type of data collection (Siyal, 2004).

In addition to automatic traffic data capturing, another recent research interest in ITS is the application of artificial intelligence techniques such as expert systems, fuzzy logic, neural networks and genetic algorithms for intersection signal control. There are two types of traffic signal control namely off-line and on-line control. The optimal signal-timing for off-line control are planned by previously surveyed traffic data. The signal timing can not be changed in response to the real-time fluctuation in traffic demand. In contrast, on-line controls are mostly adaptive controllers that have the ability to make real-time adjustments to signal settings in response to both observed and/or predicted real-time traffic demands. Because of its flexibility, applicability and optimality, adaptive and online signal control tends to be the mainstream of signal controls nowadays (Yu-Chiu Chiou and, L. W. Lan, 2004). This paper presents our experience in developing an intelligent traffic control system, which is able to capture traffic data automatically and apply an intelligent control strategy that will improve the traffic flow at intersection efficiently.

2. IMAGE ACQUISITION AND PROCESSING IN TRAFFIC APPLICATION

The first image processing algorithm required to extract traffic parameters, is an image detection technique in which a given image is subtracted from its background. However this method is not effective since it depends mostly on the accuracy of the background updating technique and the selection of a suitable threshold value. An alternative technique is the edge detection technique. Edge-based image detection is generally more effective than background subtractions. The edge
information of the objects remains significant despite the variation of ambient lighting. The conventional gradient-based edge detection operations have found wide acceptance in image processing applications. However, morphological edge detectors have shown better performance than conventional edge detectors while having a lower computational cost (Fathy and Siyal, 1995; Siyal, 2004)

3. FUZZY-LOGIC BASED EXPERT SYSTEM FOR TRAFFIC SIGNAL AT INTERSECTION

In the early studies of transportation system, deterministic and/or stochastic approaches have been used to solve complex traffic and transportation engineering problems. However, it is difficult to incorporate linguistic information representing subjective knowledge that is often encountered, because such information is frequently hard to quantify using 'classical' mathematical techniques. Obviously, a wide range of traffic and transportation engineering parameters are characterized by uncertainty, subjectivity, imprecision and ambiguity. Human operators, dispatchers, drivers and passengers use this subjective knowledge or linguistic information on a daily basis when making decisions (Teodorovic, 1999).

Both of objective and subjective knowledge should be considered. The existence of linguistic information can not be and should not be simply ignored. Fuzzy logic, first introduced by Zadeh (1973), is an extremely suitable concept with which to combine subjective knowledge and objective knowledge. Fuzzy logic is based on mathematical representation of human knowledge and experiences. Fuzzy logic controllers have been successfully implemented in many systems that have inherent uncertainties. As far as we know, the fuzzy logic controller for traffic intersection is firstly published by Pappis and Mamdani (1977). They considered the control of an isolated traffic intersection with simple one-way east-west/north-south traffic control with random vehicle arrivals and no turning movements. Fuzzy rules were developed for evaluating the suitability of extending the existing green phase.

4. DEVELOPMENT OF A VIDEO-BASED SYSTEM TO CAPTURE TRAFFIC DATA

In this section the development of a video-based system to capture traffic data using image acquisition and image processing toolboxes in MATLAB is presented. Those tool boxes are collections of functions that extend the capability of the MATLAB numeric computing environment. The Image Acquisition tool box supports a wide range of image acquisition operations, including acquiring images through many types of image acquisition devices, from professional grade frame grabbers to USB-based Webcams. The Image Processing Toolbox supports a wide range of image processing operations, including spatial image transformations, morphological operations, neighborhood and block operations, linear filtering and filter design, transforms, image analysis and enhancement, image registration, deburring, and region of interest operations.

The process flow chart of the system is as follows:

![Flow Chart](image)
1. A snapshot of an RGB-typed image is taken.

2. The RGB image is converted to gray-scaled image.

3. The process continues by performing some image processing operations such as filtering, threshold, edge detection, and morphology.

4. Finally the process for a single image is finished by labeling all the objects found.

Once the objects, in this case vehicles are found, the coordinate points of center of mass can be determined. The speed of the vehicles is calculated by taking the difference between the current position, its center mass and the previous position and dividing the result into time interval. A snapshot of the captured image and the results after processing is shown in Figure 2.

![Figure 1 Result](image)

5. DEVELOPMENT OF A FUZZY LOGIC TRAFFIC CONTROLLER AT AN INTERSECTION

This section presents the design of a fuzzy logic traffic controller (FLTC) at an intersection. A FLTC model introduced by Favilla, Machion, and Gomide (1999) is implemented using MATLAB. The Fuzzy Traffic Controller controls the traffic flow at an urban intersection. Basically it compares the incoming traffic of the approach that has the green phase with the vehicle queue formed in the other approaches. On the basis of this information, it decides to extend or not the current green time. If the decision is no extension of the current green time, the traffic light state will change to another state, allowing the traffic of another approach to flow. The proposed Fuzzy Traffic Controller has the following inputs: Arrival of vehicles in the approach that has the green phase and Queue of the vehicles in the approaches that has the red light. The controller output provides the Extension of the current green phase, which can be extended until a maximum previously defined value is reached. This condition also makes the state of the controller change. The Fuzzy Traffic Controller has the following inputs (state variables) and their associated linguistic values:

- Arrival (almost-none, few, many, too-many)
- Queue (very-small, small, medium, long)

The output of the controller and its associated linguistic value is:

- Extension (very-short, short, medium, long)
The rules for the controller are defined as follows:

Table 1. The rules

<table>
<thead>
<tr>
<th>Q U E U E</th>
<th>Arrival</th>
<th>almost</th>
<th>none</th>
<th>few</th>
<th>many</th>
<th>too many</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>very small</strong></td>
<td>Very short</td>
<td>Short</td>
<td>medium</td>
<td>long</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>small</strong></td>
<td>Very short</td>
<td>Very short</td>
<td>medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>medium</strong></td>
<td>Very short</td>
<td>Very short</td>
<td>Very short</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>long</strong></td>
<td>Very short</td>
<td>Very short</td>
<td>Very short</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A snapshot of the MATLAB FIS editor is presented in Figure 3. The input boxes (Arrival and Queue) are on the left, the output box (Extension) is on the right while the rule box is in the middle.

The membership functions of the input variables (Arrival and Queue) are presented in Figure 4 and 5 respectively.
The membership function of the output variable (Extension) is presented in Figure 6.

![Figure 1 Membership Function of Extension](image1)

The rule viewer is presented in Figure 7. We can change the inputs interactively by moving the red and horizontal lines on the input or keying-in manually at the prompt. The output will be displayed on the output part.

![Figure 2. The Rule Viewer](image2)

6. CONCLUSION AND FUTURE WORKS

Image acquisition and processing has been shown as a more feasible approach in traffic control. A system developed in MATLAB has successfully captured and collected data traffic in real time. A fuzzy-ruled based system has been developed in MATLAB to make decisions on the extension of the green phase at a signalized intersection. It can be concluded that video-based system should be considered as an appropriate approach due to its effectiveness in collecting traffic data. Last but not least, the development can be accomplished timely and efficiently since the availability of many supporting tools (third parties) in image processing and intelligent control. In the future, more intensive and extensive studies on other problems in traffic control have to be carried out in order to produce a complete and robust traffic controller. There are some other intelligent methods that should be considered to be incorporated in the existing system such as neural network, genetic algorithm and etc.

REFERENCES


