**Title**

**Application of Image Processing in Gap Acceptance Determination**

**Abstract**

Gap acceptance models are applicable in determination of capacity of unsignalized intersections. The capacity of roundabouts as one case of unsignalized intersection, involves determination of accepted and rejected gaps, follow-up times and circulating flow traffic as parameters for determination of roundabouts’ capacity. A well-known technique involves manually recording the time events from videos recorded at intersection for determination of the said parameters. However, this process is time consuming and is asscociated with human errors during the process. This paper presents a tool for determination of the accepted and rejected gaps using image processing techniques which includes foreground detection, morphological operations ande developing region of interest for the headways determination. The techniques have been programmed and implemented through the use of Matlab software. The performance of the method in determination of the headways goes to …. Percent accuracy when compared with manual approach.

**Introduction:**

Capacity analysis of roundabouts utilizes the gap acceptance theory. In roundabout’s capacity determination, determination of accepted gaps, rejected gaps, follow-up times and circulating traffic forms a core role. Gaps refers to time difference between successive vehicles in the circulating lanes. A gap in the circulating stream is said to be accepted if an approaching vehicle enters the intersection in the before expiration of such gap. On the other hand, a gap is rejected when the approaching vehicle doesn’t enter the intersection using the available gap.

Collection of the mentioned time events have been manually through video observation and hence record of the said events. Another option, has been to semi-automate the process by creating a program which records timestamps of certain events in the video for the purpose of determining the gap acceptance parameters.

The processes mentioned, since they involve human decisions upon the event, are not free from human errors in correctly recording the time events. In addition, the process is time consuming since a single video has to be played more than one times if an anticipated accuracy is to be expected.

This paper aims at utilizing the image processing methods in determination of gap acceptance parameters at roundabouts. Since the process runs solely depending upon computer vision, it involves reduced human errors and expedited extraction process. The paper is organized

The existing knowledge of image processing has been applied in many areas of traffic engineering especially in traffic count, vehicle classification and determination of headway along the travelled way.

**Related Works**

An attempt to use image processing in study of traffic flow operations and vehicle detection has been applied as substitute to human vision in much of literature. The studies range from incorporating feature detection methods from still images to foreground detection methods in video imaging.

(Kembhavi, et al., 2011) developed a vehicles detector from aerial images by incorporating rich set of image descriptors which includes color probability maps. Their tool involved image properties like Color Probability Maps, Histograms of Oriented gradients and Pairs of Pixels (PoP) methods. The vehicles features were then extracted through the use of Partial Least Squares classification after training the images.

(Tourani, et al., 2015) developed an image detection algorithm to detect and eventually count vehicles in the road using a combination of both frame differentiation and edge detection algorithms. By using Kalman filter, the position of the image was estimated and tracked. The filter also helped in classification of vehicles such that the counting was done in specified groups. He found that the counting was inaccurate by 4% and that classification was inaccurate by 5%.

(Rad, et al., 2010) Developed an algorithm that uses the digital video, image processing and computer vision to automatically the vehicle speed in an accurate manner. The algorithm involved camera calibration, background generation and vehicle detection methods which led to speed measurement. The speed of the vehicle was calculated using the position of the vehicle in each frame. To obtain a good foreground, the authors generated a background based on two modes in the HSV model; one with advantage of saturation and the other based on value. With this diversity, based upon value, the object with the white and bright color is recognized explicitly. On the other hand, since the vehicles with dark colors could not be well recognized by this attribute, the authors used Saturation attribute in HSV model to classify the dark colored objects. The detected speeds were found to differ from the actual vehicle speeds by the range of 0.4kph to 4.7kph.

.. Altay et al(2013) used LIDAR sensors to determine time to headway parameter in vehicles (Altay, et al., 2013)

This study extends such good efforts into determination of acceptance and rejection of gaps.

**Methodology**

An algorithm was developed determine the headways as well as gap acceptance parameters. The initial step in this process is to do effective foreground detection. Then the headways are determined from the process. After that, the acceptance and rejection parameters are then determined from the fact that there is no any

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The approach carried out by this study involves the following algorithm

1. Background modeling
2. Foreground detection
3. Morphological operations
4. Determination of region of interest
5. Headways determination

**Background Modeling**

Background modeling involves creating a reference image that defines all the static features of the image like parking vehicles, road surface, building conditions together with climatic conditions or illuminations. This is an important component in the motion analysis. Several methods to obtain the background have been developed [2,6,7,8,10]. (Marzouk, 2010) classifies techniques into two major categories, recursive techniques and non-recursive techniques. Recursive techniques need no formation of buffer of several frames for modeling foreground (Hassanpour, et al., 2011). Non-recursive techniques involve creating a buffer of frames and then estimates a background image based upon the temporal variation of each pixel within a buffer (Marzouk, 2010). A mathematical operation is then applied to the buffer to form a background frame. The mathematical approaches applied to that background range from average filter, median filter and linear predictive filter. Median filter determines the median value of all the cell values in the background.

In this paper, a median filter mechanism was applied to model the background. Background subtraction is determined by finding the median value of the given pixel numbers. a number of frames are selected from the video and median value for each pixel is determined. For this method, considering a video with n frames, where we have to pick k frames for background, the video was divided into n/k parts and from each portion 1 frame chosen as a representative. The median value for such frame was chosen. a value of k was chosen depending upon the quality of the foreground obtained. Figures below indicate the influence of the value of k to achieve different qualities of foreground

Fig. Different K-values for

**Foreground Detection**

Foreground detection is done by comparing the background generated with the original frames. A threshold of the difference between the frames is chosen that will filter the background and retain the foreground. According to .... a good foreground is obtained if the values are normalized, that is: the pixel difference is divided by the original frame values. A threshold is also chosen such that, it will remove the noise of the background in the foreground without affecting the quality of the foreground

**Morphological Operations**

Morphological operations are applied to the foreground detected for the purpose of removing noise.

Several morphological operations are done to the foreground to remove the unwanted noise. The existing morphological operations are such as disk, open and closed operations are done. Considering the foreground obtained, the suitable operation was closed operation. This modified the foreground to fill in the voids in the foreground.

**Filtering Mechanism**

Filtering of the foreground is one of the important step in getting a clear foreground for further processing. In this paper a closing morphological filter the image was done following creation of a disc structural element that is used as a reference for filtering the background

**Headways Determination**

Determination of the headways involves recording frame numbers related to the events in the respective

From the region of interest determined, the change in pixels in the foreground at the same address is traced. Since the background is in binary condition, the change in pixels from zero to threshold value is noted. If the change increases above given threshold, then the frame number is picked. A vector with frame numbers which correspond to regions of interest filled above given threshold is formed.

Or

Through tracing the change in pixel values, a given threshold is determined.

**Acceptance rejection of gap determination**

For each gap, the decisions of acceptance and rejection have to be determined. the arrival of the vehicles at the conflict region, and their orientation have to be identified. Orientation of the approaching vehicles is determined for the purpose of separating approaching vehicles from circulating vehicles.

A frame number corresponding to the presence of image in the conflict region + with orientation from approaching direction is determined. Then, for each gap, a number of vehicles that entered the region within a given gap is determined. T

Results

The results obtained from this involves the number of gaps corresponding to each gap accepted or rejected.

Masked Images

Through the use of image processing methods, the masked images can be used in determination of headways

**Headway determination**

A region of interest is chosen that reflects the point of entrance to the conflict region. A change in pixel values of the masked binary image at the region of interest will reflect the presence or absence of the vehicle of interest. Graphically, the filled area variations can be plotted against frame number which will then detect the gap in frame numbers between the vehicles. Figure 3 shows pixel distribution having peaks implying variations between fully occupied cells(peaks) and empty cells. A threshold value of the area is chosen and all cells. To trace a change in pixel values, a sliding window of six successive frames is chosen to determine the value of slope between the points. Plotting a slope curve, indicates, the regions with maximum positive slope (or positive slope above a given threshold) will indicate the point of entry of vehicles at the region of interest while that of minimum negative (or below given minimum threshold) slope as point of exit.

The frame number associated with each maximum slope above a given threshold value is determined. The timestamp can be determined through dividing frame number by the frame rate. The timestamp difference between successive vehicles gives the headway values.

**Results**

Table xxx summarizes frame numbers as well as timestamps of circulating vehicles’ arrival events. The difference is between the timestamps is headway values.

Table of results:

**Validation**

Manual process of recording of the headways was done to determine accuracy of using the proposed method. The headway distribution of the values is as seen below:

Table: Headway distribution

The comparison reveals that the correlation between the manual headway and the calculated headway reach up to … percent. This implies that the proposed method is has an accuracy of …. Percent compared with manual record of events.

Graph: Relationship between IP Vs Manual

The discrepancy resulted at some points is attributed to two things. One is the overlap of vehicle images and blockage of region of interest by turning vehicles. Due to lower orientation angle of the camera, the vehicles may appear overlapping causing headway detection difficult to determine. Different from the straight portion of the roadway, the vehicle trajectory involves turning maneuver, which may also block the region of interest and hence appear as an intersection. Understand

The solution to this problem would be increasing the height for recording especially use of aerial graphics from drones or high rise points.