



Title	Application of Image Processing to the Analysis of Congested Traffic
Authors(s)	Micu, Alexandra, O'Brien, Eugene J., Sevillano, Enrique
Publication date	2016-08-30
Publication information	Micu, Alexandra, Eugene J. O'Brien, and Enrique Sevillano. "Application of Image Processing to the Analysis of Congested Traffic." Civil Engineering Research Association of Ireland, August 30, 2016.
Conference details	Civil Engineering Research in Ireland 2016, Galway, Ireland, 29-30 August, 2016
Publisher	Civil Engineering Research Association of Ireland
Item record/more information	http://hdl.handle.net/10197/9228

Downloaded 2026-04-30 01:11:30

The UCD community has made this article openly available. Please share how this access benefits you. Your story matters! (@ucd_oa)



© Some rights reserved. For more information

Application of Image Processing to the Analysis of Congested Traffic

E. Alexandra Micu¹, Eugene J. O'Brien¹, Enrique Sevillano¹

¹School of Civil, University College Dublin, Newstead Building, Dublin 4, Ireland

email: alexandra.micu@ucdconnect.ie, eugene.obrien@ucd.ie, enrique.sevillanobravo@ucd.ie

ABSTRACT: Traffic congestion has become a significant problem in all developed countries. This is mainly due to the increasing number of vehicles but also to the fact that the infrastructures are usually not designed to take over all this traffic. As a result of this increasing number of vehicles on the roads, bridges are becoming serious strangulation points in the transport system. This issue is more important because most of bridges are either approaching or have surpassed their expected design life and traffic data traditionally collected with inductive loops detectors do not provide information about congested traffic situation. Due to this drawback, it needs a better solution for traffic monitoring. The aim of this paper is to explore the capabilities of using images for applications on transport, especially for traffic monitoring, to extract information about traffic such as gaps between cars, cars and trucks, or trucks. In that sense, a high resolution camera will be used in this work in order to capture aerial images of congested traffic. These images will be processed to distinguish all vehicles as different objects on the road, to identify the type of vehicles (regular cars or trucks) and to measure the length for each vehicle. In order to achieve that result, an algorithm able to detect and count the vehicles on the road as separated objects will be firstly applied, enclosing each object within a rectangle.

KEY WORDS: Congested traffic; High resolution camera; Image processing; Traffic monitoring.

1 INTRODUCTION

In recent years, traffic congestion has become a significant problem in daily life in all developed countries. This is mainly due to the increasing number of cars but also to the rising number of heavy vehicles. Furthermore, many of the infrastructures were not designed for such a high demand of traffic, and thus they cannot take over all of it. It is known that the bridges are an important component in the network of roads. As a result of the increasing number of vehicles, bridges are becoming serious strangulation points in the transportation system. Usually, a bridge is designed for the worst combination of trucks that can be reasonably expected to cross it in its lifetime, but designers assume long convoys of trucks blocked on the bridge with no cars in between, which is not realistic. In addition, having an approximately 50 years design life, most of bridges are either approaching or have surpassed their expected design life [1], which makes this issue even more important.

Nowadays, Weigh-In-Motion (WIM) systems are used to collect vast amounts of truck weight and traffic data that can be used to obtain site-specific and state specific live load models for bridge design and load capacity evaluation [2]. However, Weigh-In-Motion data is collected in free - flowing conditions because many WIM technologies do not work well at low speeds [3], which makes impossible to have information about congested traffic. Furthermore, even although WIM data often only includes truck data, the gaps between vehicles mean that the presence of cars is implicitly accounted for in free-flowing conditions. However, headways obtained from WIM data collected at high speed cannot be used to calibrate a congestion model because of the different gaps and driving behaviours implicated [4]. All traditional

methods for gathering traffic information capture data through measuring stations based on induction loops [5]. Although, inductions loops cannot be used to gather data about traffic congestion on long span bridges since speeds are not constants and there is no information about gaps between cars, or cars and trucks, or trucks. This is a drawback for congested traffic situations and this work proposes to use a camera based monitoring system that can overcome all those inconveniences.

The aim of this paper is therefore to analyse traffic congestion. In that sense, image analysis is used as a monitoring method. Image analysis can provide a means to extract and quantify objects and patterns in image data, as well as answers about heavy trucks or the frequency of long platoons of trucks on the bridge. Thus, a high resolution camera is used in this work with the purpose to capture aerial images of congested traffic. These images will be processed to distinguish all vehicles as different objects on the road, to identify the type of vehicles (regular cars or trucks) and to measure the length for each vehicle. In order to achieve that result, there have been processed colour images taken by helicopter from 300m altitude.

2 IMAGE PROCESSING

In image science, image processing is transforming of pictures using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video; the output of image processing may be either an image or a set of characteristics or parameters related to the image [6].

An image as input data can be defined as a two-dimensional function $f(x,y)$, where x and y are spatial coordinates, and the

amplitude of at any pair of coordinates is called the intensity of the image at that point [7].

A digital image can be considered as a large array of discrete dots, each of which has a brightness associated with it. These dots are called picture elements, or more simply pixels.

$$f(x, y) = \begin{bmatrix} f(1,1) & \cdots & f(1,N) \\ \vdots & \ddots & \vdots \\ f(M,1) & \cdots & f(M,N) \end{bmatrix} \quad (1)$$

Before continuing, it is necessary an introduction about how computers represent colours as numbers. Therefore, in this paper can be identified: colour images, gray-scale images and binary images.

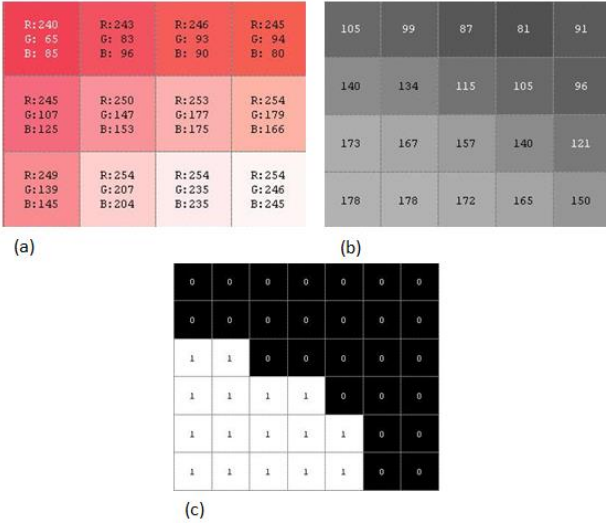


Figure 1: (a) RGB (colour) image; (b) Gray-scale image; (c) Binary image

A colour image consists of three individual monochrome images, referred to as the red (R), green (G) and blue (B), as can be seen in figure 1.a. On the other hand, a gray-scale image, represented in figure 1.b., is an image in which the value of each pixel is a single sample and represents shades of grey, fluctuating from 0 (black) at the lowest intensity to 255 (white) at the biggest. Finally, the two colours used for a binary image are black and white where the white colour is used for the foreground (or objects) while the rest of the image is the background. Figure 1.c. is an example for images of this sort.

Whereas the images are considered matrices and are processed using mathematical operations, these will be handled using Matlab because this software has an enormous number of functions for generating and manipulating matrices. As a consequence of using this software, any image processing operation, such as to investigate aspects of images, transforms the grey values of the pixels and also the entire image is processed as a single large block. This may be illustrated by the flow chart from figure 2.

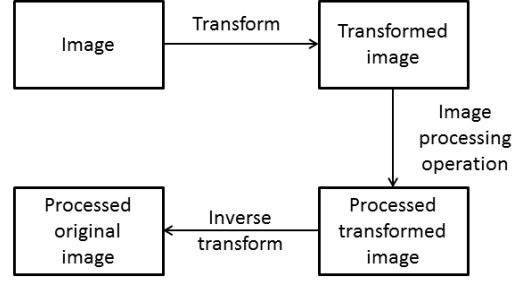


Figure 2. Steps of processing [8].

This research utilizes two main approaches of image processing: first one is thresholding which is the simplest method of image segmentation, and the second one is morphological reconstruction.

Image thresholding is a simple method of separation an image into foreground and background. This technique divides objects by transforming gray-scale image into binary image, using Otsu' method.

The pixels of a given image are represented in L gray level of pixels, $[1, 2, \dots, L]$. The number of pixels at level i is noted by n_i and the total number of pixels is $N = n_1 + n_2 + \dots + n_L$. The gray-level intensity is normalized as a probability distribution:

$$p_i = n_i/N, p_i \geq 0, \sum_{i=1}^L p_i = 1 \quad (2)$$

The pixels are separated into two classes C_0 and C_1 (background and objects) by a threshold at level k ; where C_0 represents pixels with levels $[1, \dots, k]$, and C_1 represents pixels with levels $[k+1, \dots, L]$. Then the probabilities of class existence and the class average levels are given by:

$$\omega_0 = \Pr(C_0) = \sum_{i=1}^k p_i = \omega(k) \quad (3)$$

$$\omega_1 = \Pr(C_1) = \sum_{i=k+1}^L p_i = 1 - \omega(k) \quad (4)$$

And

$$\mu_0 = \sum_{i=1}^k i \Pr(i|C_0) = \sum_{i=1}^k ip_i / \omega_0 = \mu(k) / \omega(k) \quad (5)$$

$$\mu_1 = \sum_{i=k+1}^L i \Pr(i|C_1) = \sum_{i=k+1}^L ip_i / \omega_1 = \frac{\mu_T - \mu(k)}{1 - \omega(k)} \quad (6)$$

Where

$$\omega(k) = \sum_{i=1}^k p_i \quad (7)$$

$$\mu(k) = \sum_{i=1}^k ip_i \quad (8)$$

are the cumulative moments of the histogram up to the k th level, and

$$\mu_T = \mu(L) = \sum_{i=1}^L ip_i \quad (9)$$

is the total mean level of the original image [9].

Morphology is a wide range of operations that processes images based on shapes. Morphological operations apply a structuring element to an image to label all the components in that image, generating an output image of the same size. The basic morphological operations are dilation and erosion. Dilation attaches pixels to the edges of objects in an image, while erosion clears pixels on object edges. The shape and the size of the structuring element used to process the image

influences the number of pixels attached or cleared from the objects.

3 APPLICATIONS OF IMAGE PROCESSING FOR TRAFFIC MONITORING

Therefore, the process begins by reading the image, checking the image intensity and converting the image into a gray-scale image as shown in figure 3.



Figure 3. Gray - scale image.

Due to this, image from figure 3 undergoes an adjustment to the intensity values of the image by means of a function that has an optional parameter of particular interest, the gamma value, which describes the shape of the function. If gamma is equal to 1, a linear calibrating is used. Otherwise, values less than one produce an image with brighter output values, and values greater than one produce an image with darker output values. The figure 4 shows the result for a gamma value of 0.5.



Figure 4. Adjustment with gamma = 0.5.

The next step is to turn the image from figure 4 into a binary image and that can be performed by thresholding (figure 5).



Figure 5. Binary image.

At the same time, thresholding is useful to remove unnecessary detail from an image, such as marking lines, to concentrate on essentials, such as vehicles.

Another stage assumes removal of the small objects and smoothing the connected components. This is done by means of the analysis of the area of each connected objects where the area is in fact the actual number of pixel in the region (figure 6). Whenever the analysed area is equal or greater than a given value (this value represents a reduced amount of vehicle's area), that area is meant to be kept. Otherwise, the object is removed from the image [10].



Figure 6. Binary image with small objects removed.

Furthermore, another function based on morphological reconstruction was applied [11]. This function labels all the components in the binary image and returns the number of components it finds in the image [12] such in figure 7 where 5 object were found.



Figure 7. Final objects.

The last step of this processing is to check the shape for each object in original input image. Thus, for the objects in the figure 7, it is calculated the perimeter for each area and then the perimeter is drawn on the original image to compare the obtained shape with the original shape of the objects as shown in figure 8.

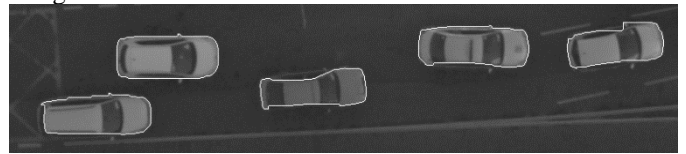


Figure 8. Original image with perimeter.

Finally, the figure 9 presents the original image with the framed objects into an imaginary rectangle that completely encloses the given object and its sides are always parallel to the axes. The area of the bounding box is an important parameter because these rectangles provide information about objects, such as length, and they will be used to classify the objects in different types [13].

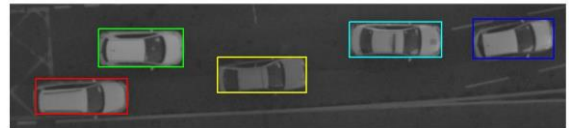


Figure 9. Framing each object into a rectangle.

The graphic from figure 10 and the table 1 present the cars' lengths obtained through two methods: first one is represented on X-axis and it shows the true lengths measured manually, and the second one, pictured on Y-axis, it displays the length of each rectangle which framing each car.

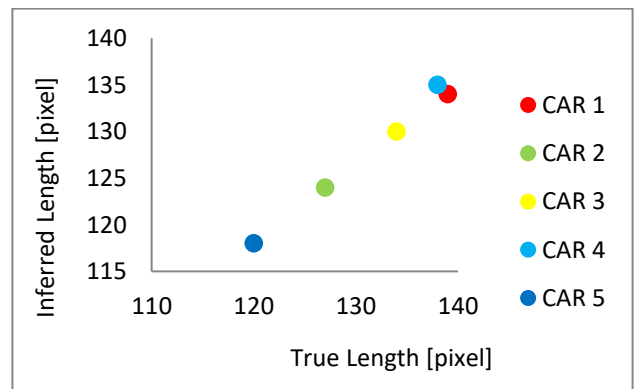


Figure 10. Information obtained from the image.

Table 1. Lengths [pixel].

Car	Inferred length	Measured length
Car 1	134	139
Car 2	124	127
Car 3	130	134
Car 4	135	138
Car 5	118	120

4 CONCLUSIONS

This paper has examined the traffic on the road with image processing method applying an algorithm able to detect and count the vehicles on the road. The first result achieved is the number of cars. After counting, the shape was analysed and the figure 8 shows that the shape of the obtained object after processing is similar to the real shape of the objects. Afterwards each object was identified and framed into an imaginary rectangle. Hence each rectangle provides information about car's length and the area of rectangle can be used to classify the objects in different types. The results of this research indicate that good quality images can provide quality information about traffic such as vehicle class, length, and inter-vehicle gaps. One of the more significant findings to emerge from this study is that image processing allows analysing traffic condition. The future goal is that this algorithm to be further improved and then applied to analyse traffic congestion on a long – span bridge.

ACKNOWLEDGMENTS

The authors would like to thank Science Foundation Ireland for their support of this research.

REFERENCES

- [1] F. Catbas, M. Gul, J. Burkett, Damage assessment using flexibility and flexibility-based curvature for structural health monitoring, *Smart materials and structures* 17(1) (2007) 015024.
- [2] F. Moses, Weigh-in-motion system using instrumented bridges, *Journal of Transportation Engineering* 105(3) (1979).
- [3] E.J. O'Brien, A. Lipari, C.C. Caprani, Micro-simulation of single-lane traffic to identify critical loading conditions for long-span bridges, *Engineering Structures* 94 (2015) 137-148.
- [4] E.J. O'Brien, C.C. Caprani, Headway modelling for traffic load assessment of short to medium span bridges, (2005).
- [5] E. O'Brien, A. Lipari, C. Caprani, Estimation of density and gaps in congested traffic, *Proceedings of the ITRN2011* (2011).
- [6] R.C. Gonzalez, R.E. Woods, S.L. Eddins, *Digital image processing using MATLAB*, (2009).
- [7] R.C. Gonzales, R.E. Woods, S.L. Eddins, *Digital image processing using MATLAB*, Pearson Prentice Hall 2004.
- [8] A. McAndrew, An introduction to digital image processing with matlab notes for scm2511 image processing, School of Computer Science and Mathematics, Victoria University of Technology (2004) 1-264.
- [9] N. Otsu, A threshold selection method from gray-level histograms, *Automatica* 11(285-296) (1975) 23-27.
- [10] G. Shapiro, *Computer and Robot Vision*, Volume I, Addison-Wesley, 1992.
- [11] P. Soille, *Morphological image analysis: principles and applications*, Springer Science & Business Media 2013.
- [12] C.M. Thompson, L. Shure, *Image processing toolbox [for use with Matlab]*, (1995).
- [13] S. Rege, R. Memane, M. Phatak, P. Agarwal, 2D Geometric shape and color recognition using digital image processing, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 2(6) (2013) 2479-2487.