ISSN 2229-5518

Thermal Imaging system for Precise Traffic Control and Surveillance

Akash Kannegulla, A. Salivahana Reddy, K V R Sai Sudhir, Sakshi Singh

Abstract— Thermal imaging is a concurrent technology used in many applications like power line maintenance, surveillance and intelligent transportation systems. This paper focuses on traffic control and surveillance using thermal imaging cameras. With the combination of two powerful technologies- thermal imaging and image processing, a very accurate measure of traffic density has been achieved, unhindered by any environmental factors like low visibility due to fog or darkness, or other stray objects like animals or humans. The simulations of the gray scale thermal images captured are performed in Matlab, using which the exact count of vehicles on the road is obtained. This paper not only presents a novel method for speeding up traffic flow, but also overcomes the limitations of existing techniques like implementation costs and precision in determination of traffic density. Future research in the same direction consists of fire alarm and detection of accidents and explosives.

Index Terms— Gray scale images, Image Processing, Matlab, Surveillance, Thermal imaging, Traffic control, Traffic density

———————————— ◆ ————————————

1 Introduction

TRAFFIC has become one of the main concerns in every city with the rapidly increasing number of vehicles on road. Traffic jams and sluggish traffic movement not only cause inconvenience to the general public, but also hinder the movement of emergency vehicles like ambulances, which may lead to detrimental consequences. In this paper, we make an attempt to solve this problem by employing thermal imaging to precisely determine the amount of traffic on each road and develop an algorithm to facilitate its free and faster movement.

In a city, there are several ways of reaching the destination from the initial position as shown in figure 1. But the driver of a vehicle on the road may not be able to choose the path with minimum traffic. Due to this plain reason sometimes, some paths get jammed with excess traffic while the others might remain relatively deserted. To eliminate this problem, we have proposed a system of dynamic traffic lights, where traffic signal timings are varied in accordance with the amount of traffic on each road. Besides, we have also developed a mechanism to simultaneously display the count of vehicles present on roads on LED boards placed at every junction. This allows the driver to choose the quickest path and thus maintain constant traffic flow in the entire city.

Several attempts have been made in the past to improvise traffic control systems. Some of the reported techniques have used ant algorithms [1] and sensor systems [2]. However, these techniques are inept for dynamic traffic signaling and traffic density indications on LED boards and suffer from a lot of limitations of cost, accuracy and efficiency. To rectify these problems, we have used here, the powerful tool of thermal imaging. Thermal imaging cameras installed on each road capture snaps of the traffic present and the thermal images obtained, on processing, are capable of generating much more accurate traffic estimates (exact count of vehicles present). This whole setup is very affordable compared to other existing methods and can be used not only for traffic control, but also for surveillance.

This paper presents the physics behind thermal imaging, discusses image processing of the thermal images obtained, and utilizes the traffic information produced after processing, for traffic control and surveillance.

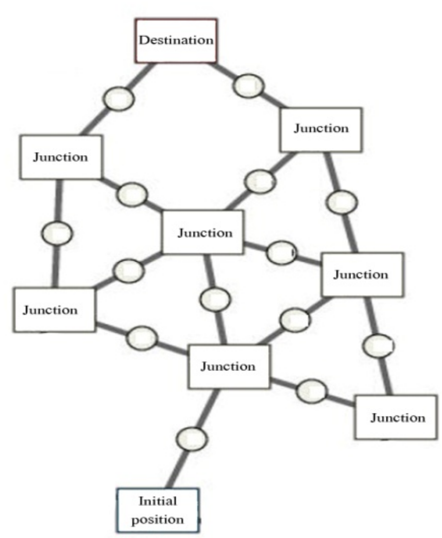


Figure. 1. Multiple paths for reaching destination from the initial position.

- *Akash Kannegulla is currently pursuing his Bachelors degree program in Electronics and Instrumentation engineering in Amrita University, Bangalore, India. E-mail: akash.kann@gmail.com*
- *A. Salivahana Reddy is currently pursuing his Bachelors degree program in Electronics and Communication engineering in Amrita University, Bangalore, India. E-mail: salivahana.3@gmail.com*
- *K.V.R Sai Sudhir is currently pursuing his Bachelors degree program in Electronics and Instrumentation engineering in Amrita University, Bangalore, India. E-mail: kvrssudhir@gmail.com*
- *Sakshi Singh is currently pursuing her Bachelors degree program in Electronics and Communication engineering in Amrita University, Bangalore, India. E-mail: sakshisingh@gmail.com*

ISSN 2229-5518

2 Thermal Imaging

Infra-red (IR) radiations are often described as heat or thermal radiations. Objects on earth, at an average temperature of 300K, emit thermal radiations with wavelengths extending from 2µm to above 100µm and have a wavelength maxima around 10µm. All objects surrounding us are radiant due to their heat energy. However, because of limited wavelength response of human eye, it is impossible to see this thermal incandescence [4].

Wavelengths in the range of 0.75µm to 2.0µm belong to photographic infra-red region. The human eye only responds to radiations extending from 0.4µm to 0.75µm and is hence, insensitive to infra-red radiations. It can also see, measure and examine very hot objects when they emit red light of the visible radiation in the vicinity of 0.65µm. However, the majority of thermal radiations given off by cooler objects remain undetectable by it. The techniques of imaging similar to that of the human eye and other sensors like photographic films, plates and photo-emissive devices are all limited in their long wavelength response to less than 2.5µm. A thermal imager is capable of capturing this information and converting it into visual images that can be seen by the human eye. With the help of a phased array of infrared-detector elements (material sensitive to infra-red radiations), it creates a very detailed temperature pattern called a thermogram. It responds to the long wavelength radiation beyond 3µm by employing camera optics transparent in thermal bands.

The difference in the amount and type of radiation emitted by warm and cool objects form the foundation of this emerging technology. If we know the absolute temperature of the body and its emissivity, the spectral content of distinct objects can be evaluated over a spectral interval. Even if all objects were at the same temperature, we would find a variation in the radiant emittance because of emissivity variation.

The thermal imager used here comprises of optics, scanner, detector, cooler and primary electronics, all on a platform, along with the signal processor, image processor, display and eye piece. The target and the surroundings remain variable, but they always vary within a given range of temperature.

We record the average temperature of the target and that of the surroundings and based on the difference between these temperatures, we can see objects in pseudo color or black and white by passing IR radiations. The camera can produce either a color image (pseudo image) or gray scale image (black and white image). Though pseudo color enhances the ease of detection or interpretation of the image, its mapping into processable data is slightly more complex. Therefore, we employ gray scale for imaging here to keep the system simpler. For the present demonstration, an image in gray scale provides sufficient resolution.

3 Image Processing

The thermal image obtained from the camera has to be processed to generate some interpretable data that can be used for traffic regulation [5]. This research work uses Matlab 7.12.0 (R2011a) software in this method of implementation.

Most Thermographic cameras produce thermograms that show objects with normal temperature in gray scale and very high temperature objects in different pseudo-colors. These distinct colors indicate variation in the intensity (and hence, temperature), rather than variation in wavelength, as in case of visible light. Since, in traffic applications, no high temperature bodies (above 200 ºC) are involved, we directly process the gray-scale image produced by the camera. This involves two steps- Binary image conversion and Vehicle count generation, which are described here in detail.

3.1 Binary Image conversion

The gray scale image has to be converted to a binary image to differentiate between areas where a vehicle is present and where it is not.

We identify a temperature range within which the temperatures of all the vehicles would fall, say T1<Temp<T2, where 'Temp' is the temperature at a given point in the image.

The intensities or gray levels I1 and I2, corresponding to temperatures T1 and T2 are taken as thresholds to generate a binary image based on the following condition:

$$BW(i,j)=\begin{cases} 1, & I1 < I(i,j) < I2 \\ 0, & \text{otherwise} \end{cases}$$

3.2 Generation of vehicle count on each road

To find out the number of vehicles present on a road, we identify the different white regions in the thermal image. This is done by extracting the boundaries of all the white spots and counting all such boundaries.

MATLAB CODE FOR VEHICLE COUNT

```
imaqreset;
ser= serial('COM124','BaudRate',9600,'DataBits',8);
info = imaqhwinfo('winvideo', 1);
vid = videoinput('winvideo', 1, 'YUY2_160x120');
triggerconfig(vid,'manual');
set(vid,'FramesPerTrigger',1);
set(vid,'TriggerRepeat', Inf);
set(vid,'ReturnedColorSpace','rgb');
start(vid);
while(1)
  k=valuek(vid)
  k
end
```

Now, suppose if a human or stray animal walks through the road. There are chances that the generated IR emission profile is corrupt. In that case, this procedure will lead to negative results.

To avoid this, we utilize the difference in size of a human/animal and a vehicle, and only count boundaries with area greater than a specific value, say 'A'. This area 'A' is chosen after determining the scale of the thermal image with reference to the actual dimensions of the imaged objects. Its value is selected to be a little higher than the dimension of the image of a human, so that small vehicles and two-wheelers are not missed out erroneously [6].

MATLAB CODE FOR AVOIDING STRAY OBJECTS

```
function k = valuek(vid)
trigger(vid);
   im = getdata(vid);
   ig = rgb2gray(im);
   level = graythresh(ig);
bw = im2bw(ig,level);
imshow(bw)
[labeled,num] = bwlabel(bw,8);
graindata = regionprops(labeled,'basic');
k = 0;
for j = 1:num
if graindata(j).Area > 2
k = k+1;
end
end
k;
```

Once the vehicle count on each road is generated, all the gathered data is used to direct the timing and control of traffic signals. The simulated result obtained from the image processing camera is shown in the figure 2.

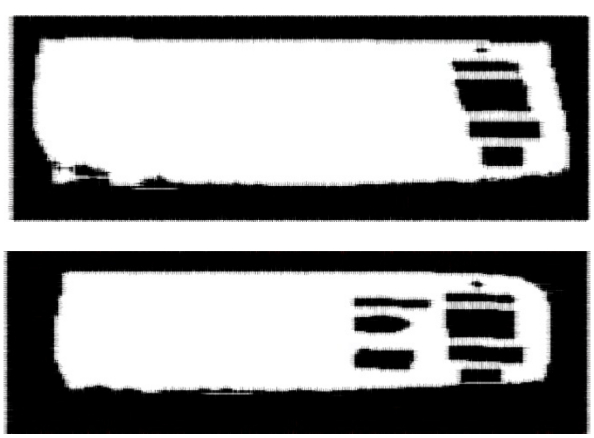
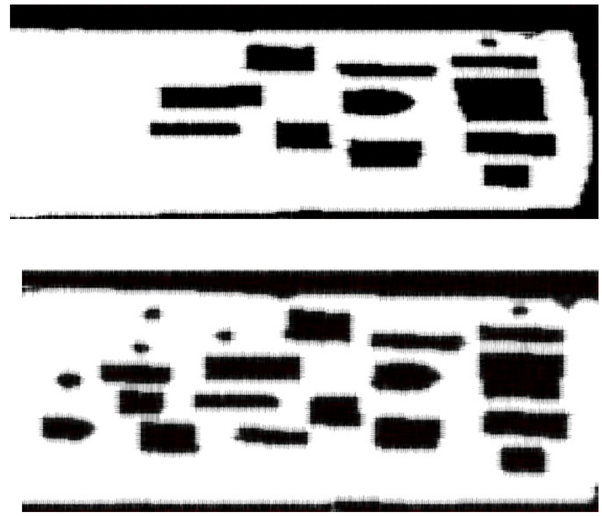


Figure 2: 2(a) The image obtained from MatLab simulations shows that the number of vehicles on the road is four. 2(b) Image showing the presence of seven vehicles (We can observe that few stray objects are present but are not taken into account for vehicle count).



2(c) & 2(d) Represent the number of vehicles. In both the cases multiple stray images are eliminated.

4 TIMING AND CONTROL OF TRAFFIC SIGNALS

Consider the junction shown in the figure 4 where four roads, A, B, C and D meet.

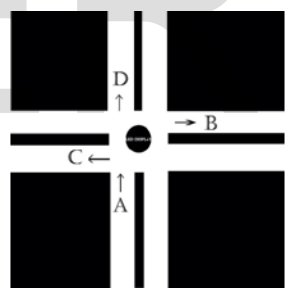


Figure. 3. A typical junction of four roads, A,B,C and D, taken into consideration to develop the timing equations

Let the count of vehicles on these roads be CA, CB, CC and CD respectively and the total count of vehicles present at the junction at a given time be CT. This information can be directly displayed at the junction on an LED display board to allow the traveler to choose the path with least traffic.

To allow fast movement of traffic, the transit time of the road with less traffic should be reduced compared to the one with more traffic.

Let the transit time or green signal duration for each road, A, B, C and D are tA, tB, tC and tD respectively. Supposing that the maximum signal duration for a road is 60 seconds, we use the following algorithm to determine appropriate values for these time intervals:

$t_A = (C_A/(C_A+C_B+C_C+C_D))*60$ seconds

$t_B = (C_B/(C_A+C_B+C_C+C_D))*60$ seconds

$t_C = (C_C/(C_A+C_B+C_C+C_D))*60$ seconds

$t_D = (C_D/(C_A+C_B+C_C+C_D))*60$ seconds

One thing to be taken care of is that the minimum green signal timing should not be less than 10 seconds to make sure that sufficient time is allowed for the passage of vehicles. Hence the following condition is tested-

If $t_x < 10$ then $t_x=10$ (where, x is either A,B,C or D, representing signal timings for roads A,B,C or D respectively)

This way the green signal timing is varied relative to the amount of traffic on each road and waiting time is reduced to minimum. The entire cycle of signal timing generation keeps on repeating after the vehicle count inputs from the image processing unit are received. Since it takes a minimum of 40 seconds for all the four roads to finish a green signal turn, which is a sufficient enough time for the capturing and processing of the thermal images, duration of each signal can be varied according to the traffic density.

5 LED DISPLAY

The output obtained after processing the images captured by the thermal imaging cameras give the exact count of number of vehicles on the road. This information is displayed at every junction of the city using LED displays. The LED boards are arranged in a matrix and depending on the values to be displayed, the respective LEDs are turned ON as cited in [2].

6 FUTURE DEVELOPMENTS

1. Higher frame rate thermal imaging cameras can be employed in future to capture traffic images at a faster rate and increase the speed of the entire system.
2. The idea can be extended to enable detection of accidents and presence of explosive materials (on triggering an alarm) by gathering temperature related data involved in the respective situations.
3. Use of satellites instead of separate thermal cameras on each road for capturing thermal images can reduce the cost further.
4. Temperature measurement capability of thermal cameras (with accuracy up to 0.1ºC) can be exploited to detect fire accidents and report them to fire stations.

7 CONCLUSION

Using the method discussed in this paper, the amount of traffic on a particular road can be estimated to a very high degree of accuracy. Besides, since thermal cameras can function even in complete darkness, the limitations of using the conventional CCTV cameras for monitoring (which are of no use in the absence of ambient light or in low visibility) are also overcome. As we have seen, this technique not only serves the purpose of traffic monitoring, but also helps in manipulating and managing it automatically with the help of dynamic traffic signaling. This reduces a lot of human effort in countries where intelligent traffic systems are not developed. Moreover, its low cost and potential to detect security threats (like presence of explosives or fire accidents) make it a very efficient and promising solution to all the traffic issues in various cities.

ACKNOWLEDGMENT

We would like to express our sincere gratitude for all the help and support provided by our college, Amrita University, Bangalore in carrying out the essential research work for developing this paper.

REFERENCES

[1] Cyrille Bertelle, Antoine Dutot, Sylvain Lerebourg and Damien Olivier, "Road Traffic Management Based on Ant System and Regulation Model", MAS Conference,2003.

[2] R. Sivaraman, S.K.Vasudevan, Akash Kannegulla, A. Salivahana Reddy, "Sensor Based Smart Traffic Regulatory/Control System", Information Technology Journal, pp. 1863-1867, 2013.

[3] Naveen Chintalacheruvu and Venkatesan Muthukumar, "Video Based Vehicle Detection and its Application in Intelligent Transportation Systems", Journal of Transportation Technologies, pp. 305-312, 2012.

[4] "Understanding Infrared Camera Thermal Image Quality", Sofradir EC Resource Centre: Thermal Imaging White papers, http://www.electrophysics.com/DbImages/WP-Understanding_IR_Camera_TIQ-TH-v07_tiq.pdf pp. 1-11, 2013.

[5] W.K. Wong, Z.Y. Chew, H.L. Lim, C.K. Loo, and W.S. Lim, " Omnidirectional Thermal Imaging Surveillance System Featuring Trespasser and Faint Detection", International Journal of Image Processing. Vol.4. Issue 6, pp. 524-525

[6] K.A. Steen, A.V. Henriksen, O.R. Therkildsen and O. Green, "Automatic Detection of Animals in Mowing operations using Thermal Cameras", Sensors 2012, pp. 7588-7595, 2012.