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Urban Traffic Control using IR video detection technology

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Introduction

In previous traffic researches the inductive loops were used to collect data [1]. However it was noticed that the inductive loops are not always the best choice to collect traffic data. Sometimes it is technically impossible to install the inductive loop on the road. When using the inductive loop it is impossible to collect such important data like the speed of the car, the length of the traffic jam, the direction of the traffic, the accidents etc.

While using the video detection technology it is possible to gather much more data on traffic than using inductive loops or other sensors of traffic identification. One video camera can substitute several inductive loops [3].

The research has shown that most common video detection algorithms have a lot of weaknesses. Some of those weaknesses are related to weather conditions: strong light, rain, fog, darkness, and other interferences. Others are related to physical interferences, such as vibration of the camera, interference in the video transmition etc. With the recent development of the video technology new ways of solving such problems emerge. The use of new generation video processor allows faster and more efficient image analysis, in many cases even inside the camera itself.

The interferences created by the unwanted weather conditions can be avoided by using IR cameras. Recently the application of thermo-vision technologies becomes more popular in Lithuania in such fields as energetics, mechanics, and electronics. Transport management can be one of the fields where thermo-vision technologies may be applied.

Problems of standard video detection technology

Various video detection algorithms are used for traffic detection. The optical flow algorithm and background estimation algorithm are the most common. I used Horn-Schunck and Lucas-Kanade optical flow detection method [2].

The second video detection algorithm that I used is the background estimation algorithm [4].

In order to prove the precision/accuracy of these two algorithms an experiment in one of the Kaunas city crossroads was conducted. During the experiment traffic was filmed using a digital video camera in different weather conditions. The traffic was filmed in the following weather conditions: sunny, very sunny, night, rain, and evening.

Also the shaking of the video camera was simulated. The data gathered during the experiment was analyzed with optical flow and background estimation algorithms using the “Matlab” software/programming package.

The summarized data analysis results using the optical flow method are shown in Fig. 1.

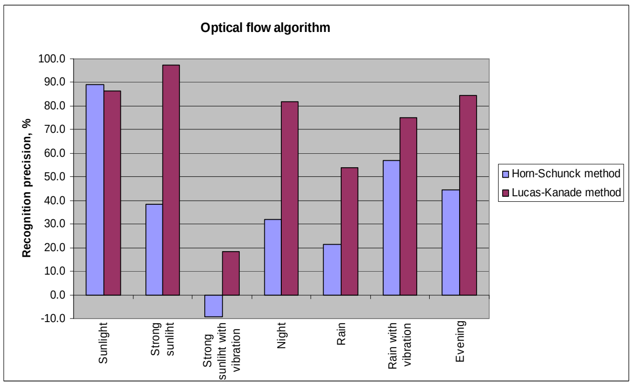

Fig. 1. Results using optical flow algorithm

While detecting the traffic using the Horn-Schunck method the worst results are received when there is shaking of the camera, at night and when raining. The best results are received when there is an average amount of light. The Lucas-Kanade method is the best when the light is strong. It performs the poorest when there is shaking of the camera.

In the second stage the background estimation algorithm was applied. The summarized data analysis results using the background estimation method are shown in Fig. 2. Using background estimation method the worst results are received at the evening. The best results are received when raining and at strong sunlight.

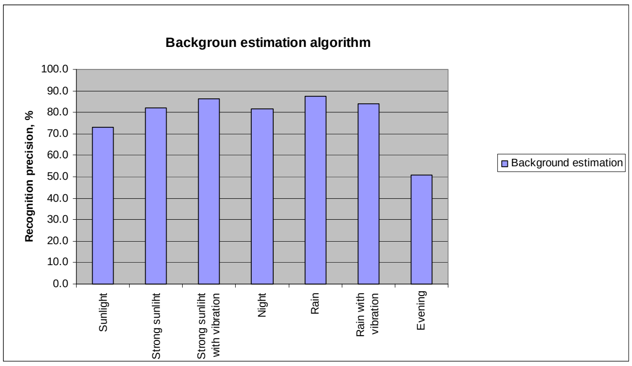

Fig. 2. Results using background estimation algorithm

Experiment results analysis

The experiment has shown that traffic detection using the optical flow method has a lot of weaknesses. Fig. 3 shows the traffic detected when there was average amount of light. As it can be seen in the picture, the most common mistake is the grouping in pairs of several cars.

Fig. 3. Vehicle flow recognition at sunlight

When using the optical flow algorithm at night the amount of erroneous traffic detection highly increases. This happens because the traffic lights are reflected by the road surface and are treated as a separate object or a group of objects. Fig. 4 shows the false/erroneous detection of the object caused by the reflected lights.

Fig. 4. Vehicle flow recognition at night

When using the background estimation algorithm the errors in traffic detection are similar to the ones of the optical flow algorithm.

IR video detection technology solution

After conducting an analysis of the experiment we can see that a lot of detection errors are made when using either one or other method. Various methods can be used to solve these problems. In order to eliminate the shaking of the camera both physical means (different placing of the camera for example) as well as programming means (various picture stabilization algorithms) can be used. In order to eliminate the interferences caused by the weather conditions, the parameters of the algorithm may be changed, such as the threshold used in segmentation; also as the usage of the various filters may be applied. The change of the parameters in the real system is extremely complicated to implement. In order to do so one has to have the data on lightning, temperature, humidity, visibility, and other environmental factors.

One of the ways to solve the problem is the usage of electronic means. Using the modern video processor it is possible to process the picture with the appropriate algorithm, next to the camera or even inside it, and to transmit the processed information.

When using the IR ray cameras it is very easy to eliminate the interferences related to weather condition. The infrared rays are the electro-magnetic waves, which are common to every body, in other words, it is a thermal radiation

Video cameras can be sorted in these types:

- Visible light video cameras (wavelength 380- 750 nm)
- Near infrared cameras (wavelength 380- 880 nm)
- Short wavelength IR cameras (wavelength 3- 5μm)
- Far wavelength IR cameras (wavelength 7,5- 13 μm)

Cameras with the wave length up to 750 nm are most commonly used in the household, in the security systems. The cameras with the wave length of up to 880 nm are mostly used in the security systems. These cameras can "see" even in the dark by using IR ray sensitive video sensors and IR ray spotlights.

Cameras that operate in a ray range from 3μm to 13μm are referred to as the thermal-vision cameras. Fig. 5 shows the block diagram of the thermal-vision camera.

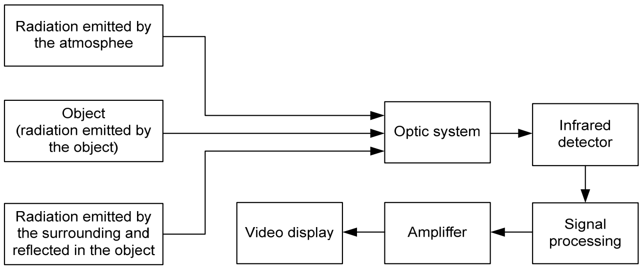

Fig. 5. Block diagram of thermovision

All bodies radiate infrared waves of various lengths. Since it is thermal radiation, all mechanical bodies also radiate it. A car can also be assigned to such bodies. Fig. 6 shows a thermo-gram of a car.

Fig. 6. Vehicle's thermo diagram

From the provided thermo-gram we can see that the hottest parts of the car are the hood, the lights, the brake discs, and the exhaust.

Results of experiment with IR camera

The second experiment was conducted using the thermo-vision camera "Agema Thermovision 570" with the following technical characteristics/parameters: object temperature measurement range from –20°C to 500°C, the precision of the measurement ±2°C, IR spectral range from 7.5 to 13 µm. While using this thermo-vision camera and the digital camera the traffic was filmed simultaneously. The traffic was filmed at noon, in the afternoon and at night. Since the "Agema Thermovison 570" has not only the automatic measurement range mode but also the manual, there was an opportunity to change the range of the measured temperatures. Also the scale of the imaged colors was changed as well as the background of the thermo-gram. Fig. 7 shows the results of the experiment conducted at noon using the optical flow and the background estimation algorithms.

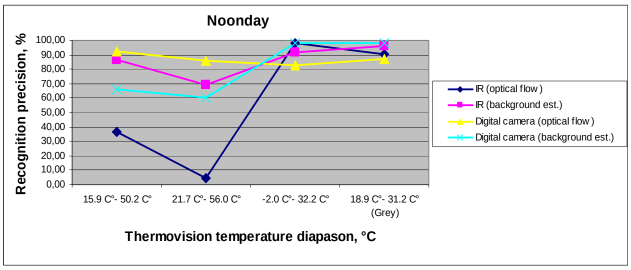

Fig. 7. Results using IR camera and digital camera at noonday

The results of the experiment conducted at noon show that when using IR camera the poorest detection of the traffic is at temperature range from 15.9 C° to 50.2 C°, and from 21.7 C° to 56.0 C°. When the temperature measurement range is 18.9 C°- 31.2 C° and the device is set on grayscale mode, the detection precision is 90% (when using the optical flow algorithm), and 96% when using the background estimation algorithm. When filming with a digital camera the precision of traffic detection is 87% (using the optical flow algorithm) and 98% (when using the background estimation algorithm). We can conclude that at particular range settings of IR camera the detection precision is practically the same as the one using digital camera when applying the optical flow algorithm as well as the background estimation algorithm.

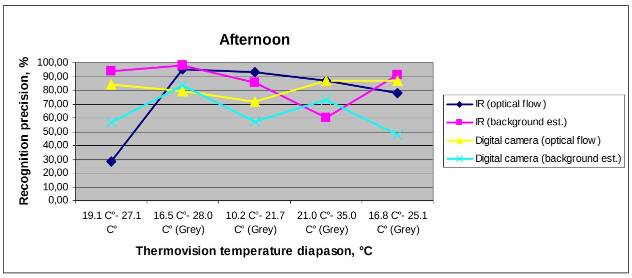

Fig. 8. Results using IR camera and digital camera at afternoon

Fig. 8 shows the results of experiment conducted in the afternoon. As we can see, the best detection results when using thermo-vision camera are in the second and third temperature ranges. It is possible to increase the traffic detection precision by 16% when using IR camera and the optical flow algorithm as compared to ordinary digital camera; when applying the background estimation algorithm this precision can be increased by approximately 14%.

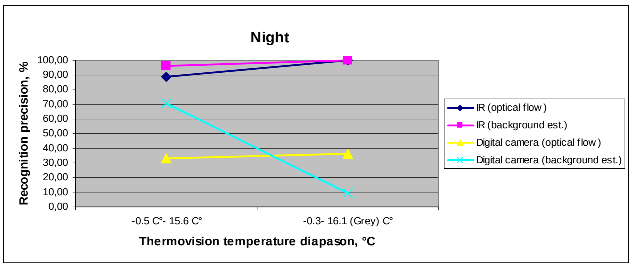

Fig. 9. Results using IR camera and digital camera at night

Fig. 9 shows the results of the experiment conducted at night, when there was poor lightning of the streets. As we can see from the chart/picture the traffic detection results of the infrared camera, using either temperature measurement range, are much more precise than those of the ordinary camera. When using the IR camera, at the temperature measurement range from -0.5 C° to 15.6 C°, and using the optical flow algorithm the detection precision was increased by 55% as compared to the one of the digital camera; when applying the background estimation algorithm the detection precision was increased by 26%. When using the IR camera, at the temperature range from -0.4 C° to 15.7 and the color palette was set to grayscale, the precision of the optical flow algorithm was increased by 74% as compared to the one of the digital camera; when applying the background estimation algorithm the precision was increased by 91%.

Experiment results analysis

The conducted experiment has shown that it is best to use the IR ray camera at night and in the afternoon. Fig. 10 shows the traffic detection errors at night time.

Fig. 10. Vehicle flow recognition at night

As we can conclude from the Fig. 10, the main detection errors when using the digital camera are related to car lights. In a given scenario the car lights are reflected from the road surface. Such reflection creates serious difficulties when solving traffic detection problems. This problem can be easily solved by using IR ray cameras.

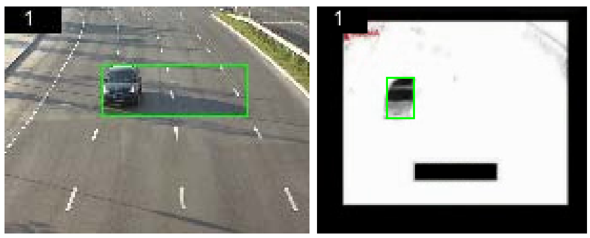

Fig. 11. Vehicle flow recognition at afternoon

The detection errors of the experiment conducted in the afternoon are shown in Fig. 11. Both the picture from digital and IR camera was processed applying background estimation algorithm. As we can see, the most common traffic detection errors are related to shadows caused by the passing cars. This also decreases the precision of detection. In order to avoid these problems, we can use IR ray cameras. On the right side of Fig. 11 we can see how the car is detected using the IR camera.

Conclusions

- The conducted experiment has shown that the traffic detection precision is only equal to 39% when applying the optical flow algorithm according to Horn-Schunck method, and 71% when using the Lucas-Kanade method.
- After evaluating the results of the conducted experiment, the detection precision was estimated to be 77.9%.
- When using the IR ray camera the detection precision was increased by up to 16% in the afternoon (when applying optical flow algorithm) and by up to 14% (when applying the background estimation algorithm) as compared to results of the digital camera.
- When using the thermo-vision camera the range of the measured temperature is set to -0.4 C°- 15.7 and the color palette is set to grayscale, the detection precision was increased by 74% by applying the optical flow algorithm, and by even 91% by applying background estimation logarithm, as compared to the precision of the digital camera.
- There was no significant increase in detection precision in the noon.

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When using the video detection technology we can gather much more information about traffic rather than using other traffic identification sensors. The conducted research has shown that most the most common video detection algorithms have a lot of weaknesses. Some weaknesses are related to weather conditions: strong lightning, rain, fog, darkness, and other interferences. Other weaknesses are related to physical interferences, such as shaking of the camera, interferences in video transmition etc. It is possible to avoid the interferences caused by unwanted weather conditions by using IR cameras. Recently the application of thermo-vision technologies becomes more popular in Lithuania in such fields as energetics, mechanics, and electronics. Transport management can be one of the fields where thermo-vision technologies may be applied. Ill. 11, bibl. 4 (in English; abstracts in English, Russian and Lithuanian).

К. Бальсис, А. Валинявичюс, Д. Эйдукас. Управления движением городского транспорта при помощи ИР -видео технологии // Электроника и электротехника. – Каунас: Технология, 2009. – № 8(96). – С. 43–46.

При использовании видео технологии можно собрать гораздо больше информации о транспортных потоках, чем при помощи других датчиков идентификации транспортного потока. Проведенные исследования показали, что большинство наиболее распространенных видео алгоритмов имеют много недостатков. Некоторые недостатки, связанные с погодными условиями: сильный свет, дождь, туман, темное время суток, и другие помехи. Другие недостатки связаны с физическим вмешательством, например, тряской камеры. Неблагоприятных погодных условий можно избежать при помощи ИР-камер. В последнее время применение ИР технологий становится все более популярной в Литве в таких областях, как энергетика, механика и электроника. Управление транспортом может быть одной из тех сфер, где ИР технологии могут быть, успешно применены. Ил. 11, библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

K. Balsys, A. Valinevičius, D. Eidukas. Miesto transporto valdymas taikant IR video detekcijos technologiją // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 8(96). – P. 43–46.

Taikant videodetekcijos technologiją, galima gauti daug daugiau informacijos apie transporto srautus, nei naudojant kitus transporto priemonių identifikavimo jutiklius. Atliktas tyrimas parodė, jog dažniausiai naudojami video detekcijos algoritmai turi daug trūkumų. Vieni trūkumai yra susiję su oro sąlygomis: dideliu apšviestumu, lietumi, rūku, tamsa ir kitais trukdžiai. Kiti – su fiziniais trukdžiais, tokiais kaip kameros drebėjimas, vaizdo perdavimo metu atsirandantys trukdžiai ir kt. Nepageidaujamų oro sąlygų sukeltų trukdžių galima išvengti naudojant IR kameras. Pastaruoju metu Lietuvoje termovizorinės technologijos vis plačiau taikomos įvairiose srityse: energetikoje, mechanikoje, elektronikoje. Viena iš termovizorinių technologijų pritaikymo sričių gali būti ir transporto valdymas. Il. 11, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).