Analysis of traffic flow with a CCD-camera and a microprocessor

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SUMMARY

Traffic Surveillance and Control needs continuously more detailed information of the traffic stream. In this effort, the use of video seems to be a possible issue. In this paper a device is presented that makes use of a CCD-camera (CCD stands for Charge-Coupled-Device) coupled with a microprocessor to analyse the traffic stream parameters. Information is given about the research done and the working principles of the different parts of the device. Further research topics are also given.

1. INTRODUCTION

The research report was started in 1978 and has been conducted at the University of Leuven, in a joint project of the Department of Electrotechnics, Afd. ESAT (Electronics-Systems-Automatisation-Technology) and the Department of Civil Engineering - Research Group for Traffic Engineering and Physical Planning. The first is under the supervision of Prof. dr. ir. R. van Overstraeten, the second of Prof. ir. J. Mortelmans.
Some parts of the system have been built at the Katholieke Industriële Hogeschool van West-Vlaanderen at Ostend.
From the beginning of the project, it was stated that the device had to be of low cost and could be used for temporary measurement stations to set up traffic monitoring systems. The classical equipment in this field is mainly based on the use of inductive detectors, which have to be built in the road surface. Other difficulties encountered with inductive loops are wrong measurements due to lane changing manoeuvres and broken connections.
Through the use of a camera-system mounted on a bridge, a light column or a sign post, these difficulties could be surmounted. In other research laboratories similar projects were under way [1], [2], based on the use of normal VIDICON cameras.
The experience gained at the ESAT laboratory, in the field of solid-state imaging made it possible to use a CCD-camera. This gives the possibility to digitize the picture information in a much easier way, than can be achieved with vidicon-tubes.
For traffic monitoring purposes two parameters seemed to be of main importance : speed and time headway of the vehicles.
As the project went on, it became clear that many other features of the system can be used.
Firstly, the picture is of a quality that is comparable with normal television cameras. This gives the opportunity to use the system simultaneously for calculation of the traffic parameters and as a visual aid for police or traffic engineer. Secondly, the system is quite sensible to detailed information. It is possible to distinguish trailers from trucks, the lateral position of the vehicle on the road is easy to measure, the length of the vehicle can also be determined. Most important is however the fact that up to three lanes can be overlooked and analysed with one camera and one microprocessor.

2. OPERATING PRINCIPLE

The new measuring station contains a CCD-camera and a microprocessor. Besides these two devices, also a video interface is included and a minicomputer can be added to the system. To illustrate the operating principle of the video system, each part of it, as shown in figure 1, will get some explanation.

2.1. CCD-camera

The light-sensitive device or the device which converts an observed picture into an electrical signal is the CCD. It is situated behind the lens of the camera. CCD stands for charge-coupled device. The CCD of the camera used, contains about 10,000 pixels, arranged in a matrix structure : 72 rows and 128 columns. On each crosspoint of a row and a column, a light-sensitive cell is situated. In this cell, a quantity

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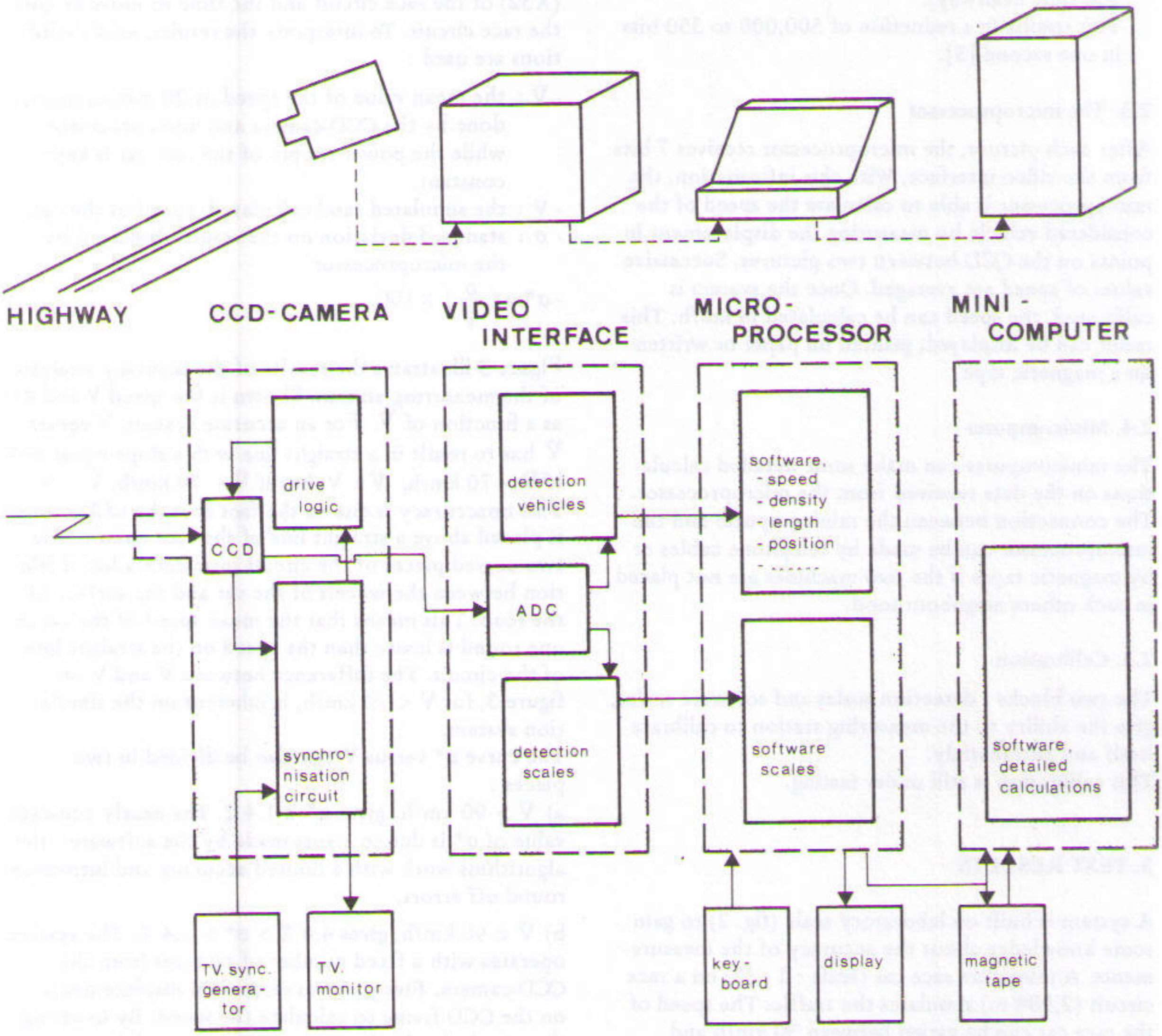

Fig. 1. Operating principle of the video system.

of electrons is generated, also called : a charge package. The size of each charge package is proportional to the quantity of light energy that penetrates the CCD on the pixel considered [3], [4]. This means, after the coverage of one image, during 20 ms, there are 10,000 charge packages in the CCD, each representative to the light intensity of the image in one point. During the output mode of the CCD, all the individual packages are transferred, row by row, to a common output stage of the CCD.

Here, each charge package is translated in an electrical voltage. To drive the CCD, an electronic circuit or drive logic is present. To visualise the video output signal on a TV monitor, a synchronisation circuit is added to the camera. The CCD used, was manufactured at the ESAT laboratory. The drive logic and the synchronisation circuit were built by BARCO, a Belgian firm, for their own specific purposes.

The CCD together with the monitor, can operate as an independent video system. It may be used as an optical control unit built upon a cheap camera with an adjusted resolution. Up to 16 CCD video pictures can be displayed on one TV monitor, by using a BARCO system under development, called 'mosaïc'.

2.2. The video interface

The video interface has two goals :

a) the conversion of the output signal of the CCD to a signal suitable for the microprocessor [5].
This translation is done by an analog to digital convertor or ADC.
This ADC was designed to operate at very high frequencies and gives a black-white image as output;

b) the reduction of information.
The system works with 50 pictures pro second and 10,000 points in one picture. This means 500,000 points pro second. It is impossible to evaluate all this information by a microprocessor. At the moment, the video interface sends only 7 information bits to the microprocessor in one picture event namely the front side of a vehicle on the CCD-frame (information necessary to calculate speed

and time headway).
This results in a reduction of 500,000 to 350 bits in one second [5].

2.3. The microprocessor

After each picture, the microprocessor receives 7 bits from the video interface. With this information, the microprocessor is able to calculate the speed of the considered vehicle by measuring the displacement in points on the CCD between two pictures. Successive values of speed are averaged. Once the system is calibrated, the speed can be calculated in km/h. This result can be displayed, printed on paper or written on a magnetic tape.

2.4. Minicomputer

The minicomputer can make some detailed calculations on the data received from the microprocessor. The connection between the minicomputer and the microprocessor can be made by telephone cables or by magnetic tapes if the two machines are not placed in each others neighbourhood.

2.5. Calibration

The two blocks : detection scales and software scales, give the ability to the measuring station to calibrate itself and automaticly.
This calibration is still under testing.

3. TEST RESULTS

A system is built on laboratory scale (fig. 2) to gain some knowledge about the accuracy of the measurements. A miniature race car (scale : 1 : 32) on a race circuit (2,988 m) simulates the traffic. The speed of the race car can be varied between 30 km/h and 200 km/h (simulated on a scale 1 : 32) by changing the power supply of the car.
The measuring station is manually calibrated to display the speed of the car, multiplied by 32. The real speed is calculated with the knowledge of the distance

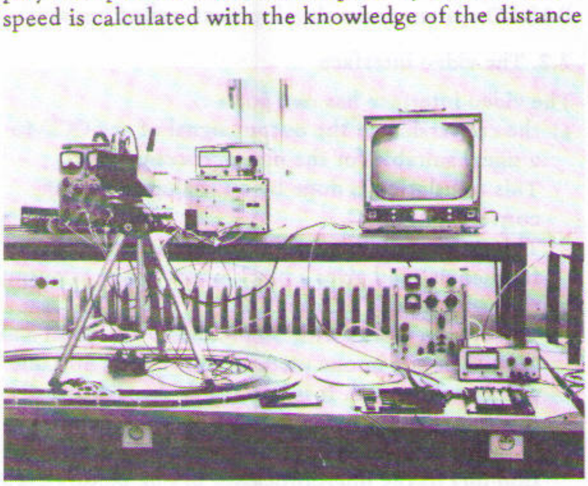

Fig. 2. Photo of the laboratory version of the measuring system.

(X32) of the race circuit and the time to move around the race circuit. To interprete the results, next definitions are used :

- $\overline{V}$: the mean value of the speed of 20 measurements done by the CCD-camera and microprocessor, while the power supply of the race car is kept constant,
- V : the simulated (and calculated) speed of the car,
- σ : standard deviation on the results displayed by the microprocessor,
- $\sigma^* = (\frac{\sigma}{\overline{V}}) \times 100$.

Figure 3 illustrates the results of the accuracy analysis of the measuring station. Shown is the speed V and σ^* as a function of $\overline{V}$. For an accurate system, V versus $\overline{V}$ has to result in a straight line with a slope equal to 1. If $\overline{V} > 70$ km/h, $\overline{V} = V$; but if $\overline{V} < 70$ km/h, $\overline{V} > V$. This unaccuracy is due to the fact that the CCD-camera is placed above a straight line of the race circuit. The two curved pieces of the circuit introduce a lot of friction between the wheels of the car and the surface of the road. This means that the mean speed of the car in one round is lower than the speed on the straight line of the circuit. The difference between $\overline{V}$ and V on figure 3, for $\overline{V} < 70$ km/h, is inherent on the simulation system.
The curve σ^* versus $\overline{V}$ can also be divided in two pieces :
a) $\overline{V} > 90$ km/h, gives $\sigma^* < 1.4$ %. The nearly constant value of σ^* is due to errors made by the software : the algorithms work with a limited accuracy and introduce round off errors,

b) $\overline{V} < 90$ km/h, gives $4.0\ \% > \sigma^* > 1.4\ \%$. The system operates with a fixed number of pictures from the CCD-camera. Five pictures result in 4 displacements on the CCD-frame to calculate the speed. By lowering the speed, the displacements are decreased, but the quantisation errors are increased and dominate the

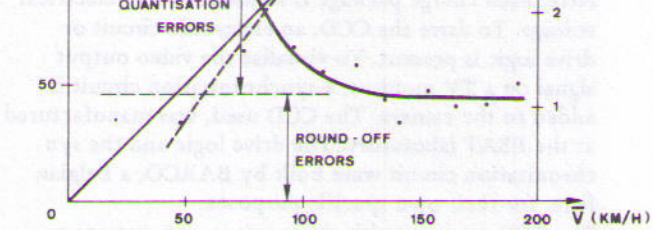

Fig. 3. Accuracy analysis of the measuring station.

round off errors.

The quantisation errors of the camera can be explained as follows : the front side of a vehicle has to be adjusted to a column of the CCD-matrix. If the boundary between the car and the road lies between two columns m and m + 1, the system has to make a decision and places the cars frontside on column m or m + 1.

To lower the quantisation errors, the systems software is going to be enlarged [6] to calculate the speed with a maximum number of displacements. The number is equal to the time the car is in front of the camera, divided by 20 ms. With this enlarged software it has to be possible to do measurements with σ^* less than 1.5 % under all circumstances.

4. FUTURE TRENDS

Recently a laboratory version of the measuring system has been demonstrated, which was able to measure the speed of vehicles on one traffic lane. At this moment, the system is enlarged to 3 traffic lanes and to measure speed, density, width, length, lateral position, etc. of the vehicles. Also an option is taken to manufacture a new CCD with a doubled active surface (to increase the accuracy of the measurements when one observes 3 traffic lanes), and to build a proto type of the system, to touch it on the real traffic situation.

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A method for calculating a group of algorithms for automatic incident detection

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SUMMARY

One of the problems in modern-day society is the volume of traffic on motorways where tailbacks stretching for miles are recorded daily. In recent years experiments have been carried out in several countries to try to maintain smooth traffic flows with the help of electronic systems. In order to do this, systems have been used to make numerous traffic measurements which can then be analysed so that information can, if required, be supplied to the motorist via signals. This article sets forth the ideas of the Public Works Department on the analysis of the measurements. These led to the development of a new type of incident detection algorithm and a new type of decision threshold which are also described in this article. It rounds off with a broad indication of a method for developing and improving the algorithms.

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