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Evaluation of the Quality of the Free/Busy Car Park Information on the Basis of Certainty Factor of Hypothesis

Marek Stawowy
Warsaw University of Technology, Faculty of Transport

Andrzej Szmigiel
Warsaw University of Technology, Faculty of Transport

The paper demonstrates an estimation method of the number of vacant parking spaces on the basis of video monitoring data. It provides a method for determining the quality of free/busy car park information using uncertainty modelling method based on certainty factor of hypothesis. The value of quality information IQ (CF) has been calculated with the help of a computer program. The simulation of results was performed depending on the input values change according to the normal distribution.

Keywords: modelling, free/busy, car park

1. INTRODUCTION

There are several methods of detecting whether a car park is free or busy. Each of these methods is not error-free [10]. Thus at times drivers receive wrong information about car park vacancies. This article presents one of the methods of acquiring data on free/busy car park. This method is considered mediocrity precise. How such mistakes come about when counting car park vacancies with this method of evaluating free/busy parking spaces is the topic of this article. A trial was conducted to evaluate the impact of specific elements on the precision of counting car park vacancies. To that end one of the methods of modelling uncertainty was adopted, which uses certainty factor of hypothesis (CF).

A similar problem is considered in [3]. Yet, without definite solutions for the traffic. Considerations presented in this article might lead to a more effective utilization of car parks. A similar topic regarding the efficacy of car parks is raised in [1].

2. CONTROL SYSTEM OF CAR PARK AVAILABILITY

In order to determine whether there are free parking spaces, several methods can be adopted. One of them, presented below, evaluates the number of free parking spaces using video monitoring. The camera can observe many parking spaces at the same time (Fig. 1).

The precision of this method depends on the applied detector, the transparency of air, the correctness of defining virtual detection spaces (Fig. 2). and the efficiency of the software in detecting free/busy spaces.

The purpose of this method is to create a possibility to inform parkers about vacant parking spaces, e.g. like the display in Fig. 3. Due to such displays drivers do not have to search for car parks with vacancies. It is enough to place such displays in key areas e.g. next to cities' main entry roads.

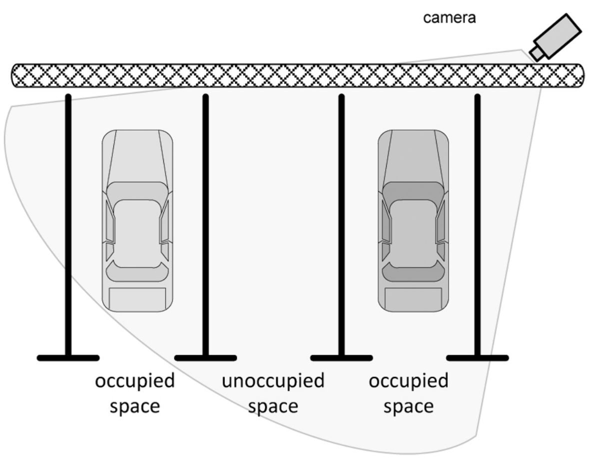

Fig. 1. Observing the car park vacancies with the use of a camera. Prepared by authors.

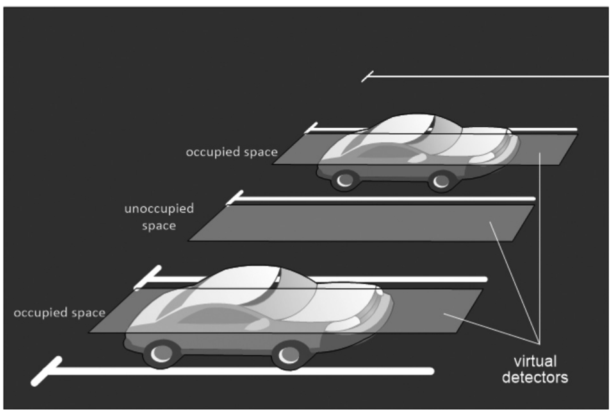

Fig. 2. Observing the car park vacancies with the use of a camera. Prepared by authors.

Fig. 3 An example of an information display for parkers. Prepared by authors

The above mentioned method seems the most cost-effective, but only if we base it on already existing monitoring system. In case of building a free/busy parking space detection system from scratch the costs are higher. It is not necessary to realize additional investments into the parking system infrastructure, if the monitoring system is efficient enough to observe and detect availability with vision methods. The next considerations are based on this method. [1, 6, 10]

3. CONTROL OF THE AVAILABILITY OF PARKING SPACES BY THE MEANS OF VIDEO MONITORING

In the previous chapter the method described was chosen on the basis [10] of i.e. its costs. A block diagram of the free/busy car park information system for motorists is presented in Fig. 4.

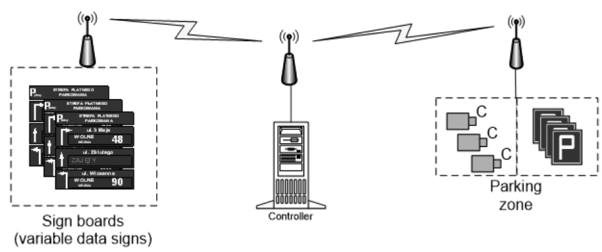

Fig. 4. A block diagram of car park occupancy information system for clients. Prepared by authors.

3. 1. THE DETECTION OF MOTION AS AN INSTANCE OF PARKING SPACE OCCUPANCY CHANGE

To detect change in parking space occupancy a system of motion and direction of the motion detection can be implemented. To do so it is best to apply an operation of defining the motion mask and its centre of gravity described with an algorithm in Fig. 5.

It is assumed that the following data is known: width W of the image (in pixels), height H of the image (in pixels), brightness matrix It of the image at moment t, brightness matrix It-1 of the image at moment t–1 and constant PL (allowed difference value threshold in pixels) and PC (motion mask surface threshold). Both PL i PC parameters are determined by adapting the method described in this article [6].

The algorithm works cyclically until it detects motion. If motion is not detected on two consecutive

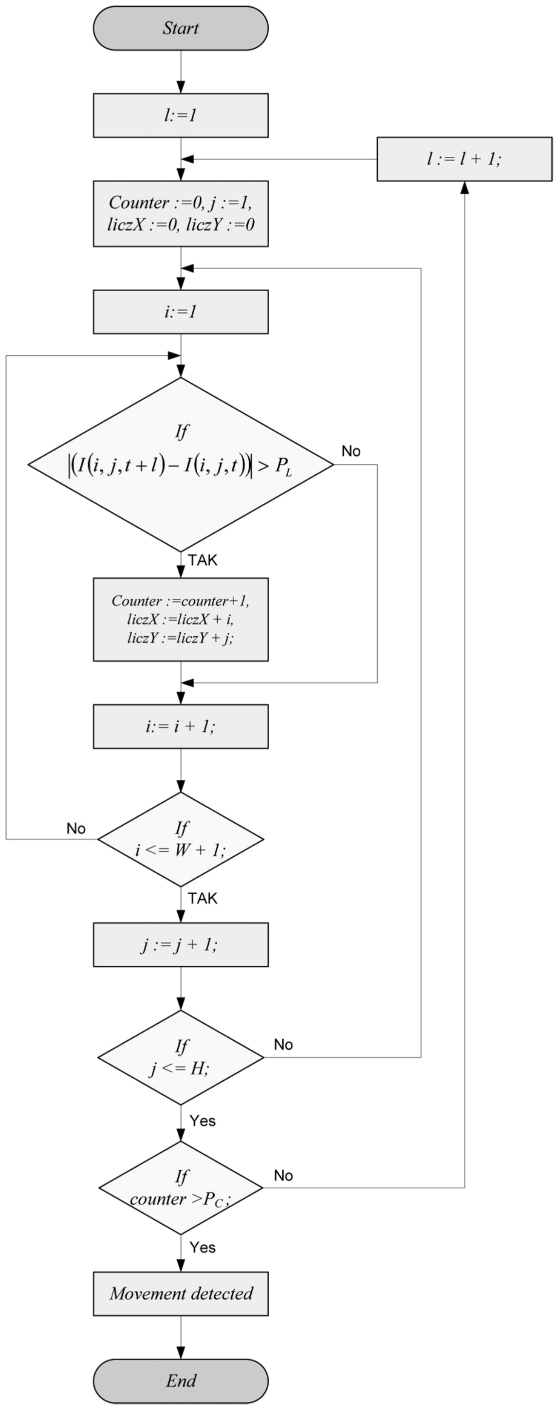

Fig. 5. Algorithm for determining the differences in the images and defining the divergence range[6].

frames another image is taken and again the motion mask is calculated for the new pair of images.

The algorithm results with:
the value of the counter, including the number of pixels differing in both images to a higher extent than constant P_L;
x_s and y_s including motion mask centroid coordinates.

Detection of free/busy parking space

Having obtained vehicle's central motion mask coordinates, it is enough to follow the changes of its position and on this basis detect if the vehicle is entering or leaving the parking space by determining the motion mask displacement vector.

If the camera is situated lengthways the parking space, it is sufficient to track the motion mask position change alongside of one of the vectors. Which is the one parallel to the parking space.

On this basis we can describe two instances:

1. x_{st-1}-x_{st} > 0 – the vehicle enters the parking space.
2. x_{st-1}-x_{st} < 0 – the vehicle leaves the parking space.

Index *t* and *t-1* relate to consecutive objects motion masks. At this point it should be specified how big the motion must be to classify it as of a vehicle entering or leaving and not manoeuvring on spot [6].

4. THE PARKING SPACES OCCUPANCY LEVEL MODELLING USING VIDEO MONITORING

In order to model parking space occupancy information by employing video monitoring, the hypothesis certainty factor (CF) method was applied. The proposed model can be called Information Quality model. Based on the CF model it can consist of one final hypothesis:

h – the number of vacant parking spaces is detected correctly and the information is sent and displayed for the motorists.

The final hypothesis will consist of two intermediate hypotheses:

h1 - the occupancy of parking spaces was detected correctly

h2 – the information for the motorists was displayed correctly

The observed causes for the intermediate hypothesis h1 are the following:

e1.1. motion occurrence,
e1.2. scene image interference,
e1.3. software failure,
e1.4. detector failure,
e1.5. computer failure.

The observed causes for the intermediate hypothesis h2 are the following:

e2.1. correct information display,

e2.2. correctly sent forward, but incorrectly displayed,

e2.3. incorrectly sent forward,

e2.4. data communication failure.

These observations are presented as examples in order to demonstrate universality of this method. Many other observations can be added to this model. [4, 5, 7, 9]

4. 1. UNCERTAINTY MODELLING BY USING CERTAINTY FACTOR OF HYPOTHESIS

As above-mentioned a convenient model for describing information quality is a model based on CF of hypothesis. It is assumed, that the value of this factor would directly be the value indicating the information quality related with the given hypothesis. E.g.: a vehicle moves in the area observed by the camera. The sheer fact that the vehicle is moving is information about the vehicle. Simultaneously it becomes a hypothesis deduced on the basis of presumptions analysed by a visual surveillance system. The measure of the information quality about the vehicles would be the CF of this hypothesis.

A solid presentation requires characterising formalisms [2]. A simplified formal description of the certainty factor would be as follows:

$$CF_{(s)} = MB_{(s)} - MD_{(s)} \tag{1}$$

where:

CF – certainty factor,

MB – knowledge mapping i.e. measure of belief,

MD – ignorance mapping i.e. measure of disbelief,

s – hypothesis based on a given piece of information

It is important to remember that:

$$MB \to [0,1]; MD \to [0,1] \text{ then } CF \in (-1,1) \tag{2}$$

The interpretation of the measures of belief MB and the measures of disbelief MD in connection with probability can look as follows:

$$CF_{(s)} = \begin{cases} 1 & P_{(s)} = 1 \\ MB_{(s)} & P_{(s)} > P_{(\neg s)} \\ 0 & P_{(s)} = P_{(\neg s)} \\ -MD_{(s)} & P_{(s)} < P_{(\neg s)} \\ -1 & P_{(s)} = 0 \end{cases} \tag{3}$$

where:

P – probability,

s – hypothesis based on a given piece of information.

As it was mentioned before, it is not our aim to determine probability, because our quality measure is connected with the CF of the final model hypothesis.

There are many varieties of CF modelling, therefor the basic for this article dependents [8] are presented below.

<u>Basic parallel model</u>

The formula to resolve crossings according to Fig. 6 between two parallel observations and a hypothesis is as follows [2]:

$$CF_{(h,e1,e2)} = \begin{cases} CF_{(h,e1)} + CF_{(h,e2)} - CF_{(h,e1)} \cdot CF_{(h,e2)}, & CF_{(h,e1)} \geq 0, CF_{(h,e2)} \geq 0 \\ \dfrac{CF_{(h,e1)} + CF_{(h,e2)}}{1 - \min(|CF_{(h,e1)}|;|CF_{(h,e2)}|)}, & CF_{(h,e1)} \cdot CF_{(h,e2)} < 0 \\ CF_{(h,e1)} + CF_{(h,e2)} + CF_{(h,e1)} \cdot CF_{(h,e2)}, & CF_{(h,e1)} < 0, CF_{(h,e2)} < 0 \end{cases} \tag{4}$$

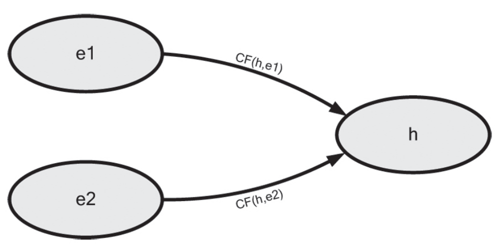

Fig. 6. Parallel crossings between two observations and a hypothesis.

Basic series model

Fig. 7. Series crossings between two observations and a hypothesis.

In the case of a series model for positive values (and such appear in the model described further on) according to Fig. 7, the following dependents are applied as shown below [2]:

$$CF_{(h,e1,e2)} = \begin{cases} CF_{(e2,e1)} \cdot CF_{(h,e2)}, & CF_{(e2,e1)} > 0 \\ 0, & CF_{(e2,e1)} \le 0 \end{cases} \quad (5)$$

Both parallel and series connections, can be reduced to one connection as in Fig. 8. This feature makes it possible to simplify calculations in the model presented in the next chapter.

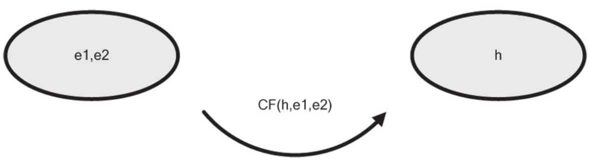

Fig. 8. The result of the simplification on the basis of formula (4) or (5).

4. 2. DETERMINATION OF INFORMATION QUALITY OF THE CHOSEN FREE/BUSY CAR PARK INFORMATION SYSTEMS WITH THE AID OF CERTAINTY FACTOR OF HYPOTHESIS

Table 1 contains exemplary CF values for graphs in Fig. 9 and 10 and 11 after calculation in first step.

Table 1: Values of Certainty Factors of hypotheses

h1	h2
$CF_{(h1,e1.1)} = 0,9$	$CF_{(h2,e2.1)} = 0,9$
$CF_{(h1,e1.2)} = -0,1$	$CF_{(h2,e2.2)} = -0,1$
$CF_{(h1,e1.3)} = -0,1 * 10^{-3}$	$CF_{(h2,e2.3)} = -0,1 * 10^{-3}$
$CF_{(h1,e1.4)} = -0,5 * 10^{-6}$	x
$CF_{(h1,e1.5)} = -0,3 * 10^{-4}$	x

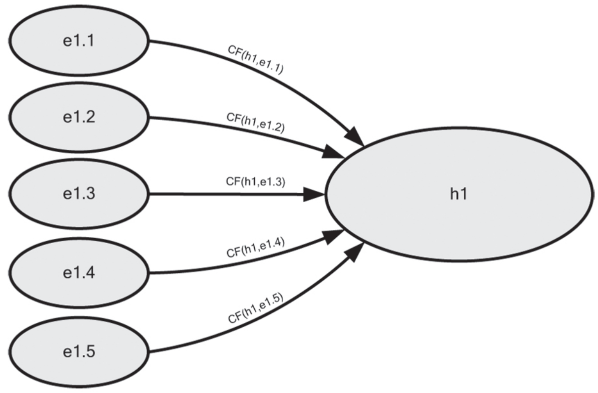

Fig. 9. Hypothesis 1 model graph [5,11].

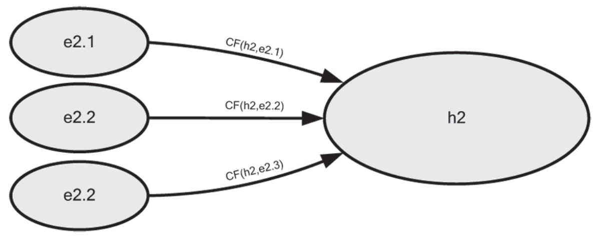

Fig. 10. Hypothesis 2 model graph [5,11].

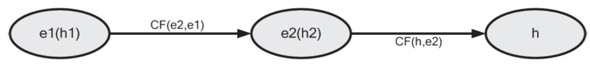

Fig. 11. Hypothesis h model graph [5,11].

CF value (h,e1.1,e1.2,e1.3,e1.4,e1.5,e2.1,e2.2,e2.3) in short CF(h,e).

If we assume that CF(h,e) = IQ, the result of the calculations when using the applied uncertainty model indicates the size of information quality. Here with regard to free/busy car park information quality. In this case IQ(CF) will stand as its symbol in order to differentiate it from the uncertainty modelling method applied to define IQ.

The assumed observations factors values were applied to a software programme to calculate the IQ and to run simulations presented in the next part of this article.

In order to count IQ(CF) a special computer programme was written. In this programme the same CF values were used as proposed in table 1. The given result was the value IQ(CF) = 0,94803.

The next step was the simulation to determine IQ. A special computer programme was written to carry out this simulation. This programme applies normal distribution with standard deviation of 10% value of the expected value. Distribution was limited by value range, which can adopt IQ(CF) according to formula (2). As expected values CF values were taken, which were used to compute IQ(CF) (in [8] was shown different method for IQ calculation) value from table 1., 1000 simulations were run. The solution of these simulations is presented in Fig. 12.

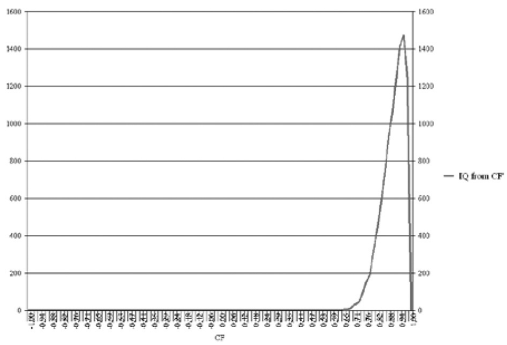

Fig. 12. IQ(CF) determination simulation. Prepared by authors with the aid of the author's computer programme.

The simulation indicates, that the observation probability value change has a direct influence on the result of the calculation. This is due to the fact, that the final value (here IQ(CF)) is linearly dependent on the observation probability value within the same model.

5. CONCLUSIONS

This article presents a method of modelling the uncertainty of detected results and the estimation of free car park space. On this basis the car park availability information quality was defined.

The chosen method for estimating the number of vacancies, was evaluation of the number of free spaces on the basis of parking fees. The method of estimating the number of car park vacancies was described mathematically and with an algorithm.

The presented method gives the means to estimate car park spaces without investing in the car park's infrastructure. It is enough to use the data registered by the monitoring system.

The next chapter demonstrated a method of determining free/busy car park information quality with the aid of information uncertainty modelling method based on the certainty factor of hypothesis. The information quality rate IQ(CF) was defined with the aid of the uncertainty modelling computer programme written by one of the authors. The simulation of results was performed depending on the change of input values according to normal distribution.

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Marek Stawowy
Warsaw University of Technology, Poland
mst@wt.pw.edu.pl

Andrzej Szmigiel
Warsaw University of Technology, Poland
asz@wt.pw.edu.pl