INFORMATION ACQUISITION FOR CITY TRAFFIC MODELS BASED ON IMAGE ANALYSIS

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ABSTRACT

Fast development of cities and increasing number of cars cause that metropolises need to improve their monitoring system. This paper presents the system which gathers information about traffic and help to monitor and model it. It is not as expensive as current solutions, because it is built on existing infrastructure and low-cost devices. The basic part of this system is a smart phone, on which application is implemented. It contains capturing device and processing unit, as a result it returns information about traffic. Information among other things includes time of the appearance, type of a car and its speed. Image analysis (processing) consist of pre-processing (geometry reconstruction and denoising), classification (geo-metrical methods), object detection and tracking algorithm, which based mostly on calculating gradient. Thanks to this solution, monitoring system can be easily implemented on the places, where it was not possible because of high cost and problem with creating infrastructure.

INTRODUCTION

Metropolises around the world are continuously rebuilding and expanding their boundaries so each year the number of highways and roads is increasing. The continuous growth of the number of vehicles driving on the road, makes a need for a traffic modelling obvious.

All these changes require appropriate decisions in planning and maintaining right functioning of city traffic. All tools, which support making decisions need reliable and actual data. As a result, many metropolises decide to improve their traffic monitoring systems. Current solutions for gathering data are very expensive and require special devices and infrastructure. It is often an impassable barrier for cities in developing countries where large and dynamical changes take place. Wrong decisions can bound potential of cities in the future. Two main disadvantages of existing solutions are:

- using of special devices
  - outlay increase
  - problems with spare parts
- special transmission infrastructure
  - outlay increases
  - importability
  - time-consuming installation

Above problems were the basis for creating new traffic data acquisition system built on popular low-cost devices and existing transmission infrastructure.

In solution presented in this paper a distributed network of sensors on large junctions will collect information about traffic volume and its distribution. A popular smart phone have been chosen as a single integrated sensor for capturing and processing visual data. Nowadays, those mid-end mobile phones are powerful small computers equipped with camera, fast processor, memory, Internet connection and operating system. Thanks to that smart phones can fulfil a role of independent image processing unit. GSM network which is an inseparable transmission channel for cell phones, small size and low power consumption can be a inexpensive substitute for existing commercial products. These essential features cause that system is not only economical but also more extensible and portable in implementation.

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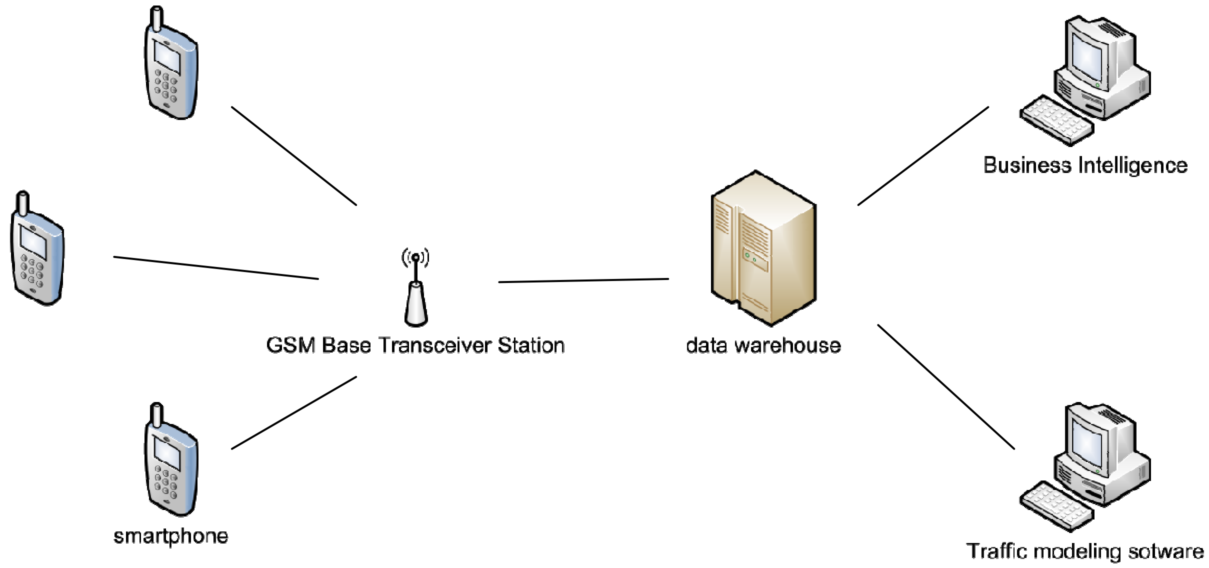

Figure 1. Architecture of the system.

STAGES OF WORK

The first stage of project was to develop a software tools for creating and testing different image processing algorithms. Created software enabled testing various methods on personal computer before implementing final method on smart phone. It also gives a future opportunity to modify algorithm for a special purposes. This software was developed in Java enabling users to easily extend its features by writing user libraries. The processing schema is defined as an XML file which contains processing order and all required parameters. Program has many built-in I/O modules (for reading movie files, image sequence files and real-time camera data) and processing modules (for filtering, segmentation and classification).

The second stage was to choose an algorithm for detecting vehicles. After testing several approaches, final algorithm was implemented on a smart phone. Because of differences between Java distribution for personal computers (Java SE) and mobile devices (Java ME) algorithm implementation needed some changes.

The last stage was to tweak an algorithm for a smart phone architecture. It was rewritten and recompiled for native phone system. This operation improved program efficiency dramatically.

CONCEPT OF THE SYSTEM

Figure 1 shows an architecture of a complete system. The basic element of the system is a smart phone. Table 1. shows the technical specification of an example testing phone. This device realize several crucial function for the system. Firstly, it is used as a capturing device which grabs visual data from the camera. Secondly, it is used as a processing unit which runs an image processing algorithm. As a result, it returns data about vehicles. After that, the smart phone transmits calculated results, using GSM infrastructure, to a data warehouse. Then info stored in the data warehouse can feed Business Intelligence (BI) software or the Traffic Modelling software.

CPU	332 MHz
Memory	160 MB + 2 GB
Operation system	Symbian OS
Size (width x height x depth)	99 x 53 x 21 mm
Weight	120 g

Table 1. Specification of the smart phone

IMAGE PROCESSING

The key element of the system is image analysis computed on smart phone level. Algorithm cannot be too complicated computationally, due to memory and computing power constraints.

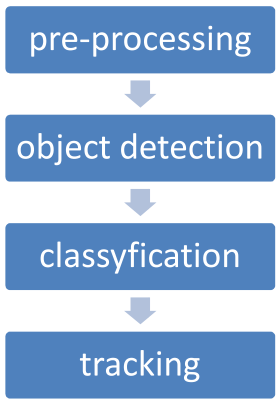

Figure 2. Processing scheme.

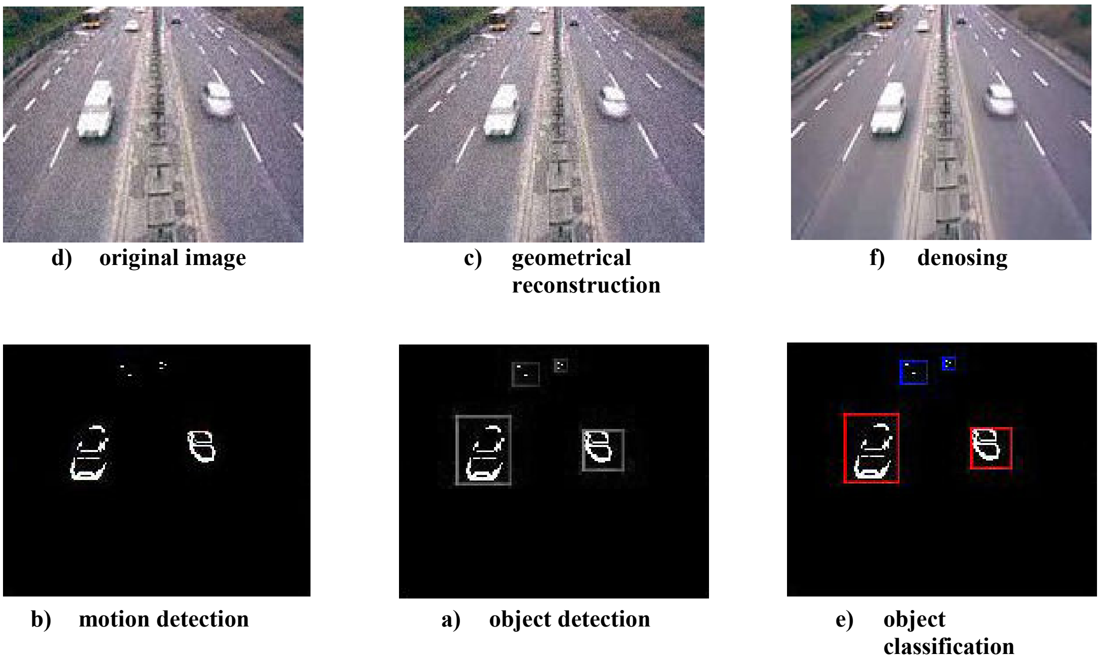

Figure 3. Phases of the algorithm.

Figure 2 presents general processing schema. There have been made some important assumptions about location of smart phone and environment, in order to save complex computations. Significant simplification is a relevant position of camera. As a result, it can be assumed that the vehicles move in specifically way and their shape change in specifically manner.

Pre-processing

Due to small size of optical set-up built-in smart phone the captured image is not perfect. It shows up as a noise and geometrical distortion.
That is why, before proper analysis, image data is pre-processed. In this case it means a geometry reconstruction and denoising. These operations are computationally inexpensive, but considerably improve quality of the further process.

Object detection

In order to find moving objects gradient between adjacent image frames is calculated. To speed up processing it is done only in a few pixels height stripe. More advanced algorithms have been also tested, but due to higher computational complexity and a small quality improvement gradient method has been chosen. Each detected object is added to the global list of vehicles.

Classification

Due to established assumptions about position and orientation of the camera it was possible to base classification on simple geometrical methods. These methods gave satisfying results in reasonable computational time.

Tracking

Parallel for each car from the list its position is being actualized by analyzing gradient between frames in a rectangular area where the front of a vehicle is expected. If no motion is detected, the object is deleted from the list. This method prevents from taking as cars these objects which appear only in one frame because of noise or light effects.
When a car crosses the last line of measurement, it is taken from the vehicles' list and its velocity is calculated. In order to make the results of our algorithm as close to the reality as it's only possible, the distance between pixels is converted into accurate distance using some trigonometric functions.

Figure 3 shows sequential phases of an algorithm.

CONCLUSIONS AND FUTURE WORKS

Presented system can be used as an inexpensive substitute for complex system. Due to its features it can be easy implemented in places where it was not possible because of high cost or problems with creating infrastructure. This system itself is also a prove that current complex systems solving sophisticated problems can be constructed on popular devices, which were not design for those purpose.

Future works should focus on improving quality of gathering data in weak light condition and at night. At the moment system cannot work properly when there is not enough light (for example unlighted street at night).

Besides, increasing computational possibilities will allow to implement more complex algorithms, which help to gather additional information about traffic and cars.

One of the possible ways of using data from presented system is to use flow network to model traffic. Using algorithms which find maximum flow in the graph, in which the crossroads are nodes and the streets are edges, we can match the capacity with our need.

Based on results of this experience and on the data from our system we can find out where should we extend or build roads to cut down large traffic jam. It can be also used to predict what happen during renovating when some roads or lanes will be closed or what happen when we apply some regulation such as speed limit.

We can also use Dijkstra algorithm in graph, where like in previous case, streets are edges and crossroads are nodes and costs depends on data from our system. Finding the shortest path, we can plan our journey as good as it possible and lost as short time as it possible staying in the jam.

Another type of models which can use data gathered with presented system are CFD based models. Street network is modelled as a set of connected pipes (Figure 4 shows example mesh for the center of Warsaw). Cross-section area of the each pipe reflects capacity of the street. The traffic flow is treated as a continuous fluid flow in fluid dynamics. Data from described system would be used as initial conditions. In the simplest model fluid would be uniform and input data would be density and mean velocity field. In more advanced case it would be possible to analyse fluid with microstructure, which would reflect diversification of the vehicles on the streets (for example large molecules would represent buses and lorries and small - cars).

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At the moment of writing this article works on commercial implementation of this project are in progress.

REFERENCES

Ali, M. and Clausi, D. 2001. "Using the Canny edge detector for feature extraction and enhancement of remote sensing images." in *Geoscience and Remote Sensing Symposium, 2001*. Vol. 5, pp. 2298-2300.

Jones, B.J.T. 1995. "Low-cost outdoor video motion and non-motion detection" in *Proceedings of the 29th Annual 1995 International Carnahan Conference on Security Technology*. pp. 376-381.

J. Lu and M. L. Liou 1997. "A simple and efficient search algorithm for blockmatching motion estimation" in *IEEE Circuits and Systems for Video Technology*, vol. 7, pp. 429–433, (Apr.)

Hsun-Jung Cho; Hsien-Hung Shih; Ming-Chorng Hwang 2003. "Numerical simulation of a multilane drift-diffusion traffic model" in *Proceedings of IEEE International Conference on Systems, Man and Cybernetics,* vol. 1, pp. 90-95 (Oct.)

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Figure 4. Map of center of Warsaw with corresponding mesh.

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