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Implementation of advanced software solutions and systems for transport traffic research and control

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Abstract. This study focuses on the topic of implementation of modern software solutions and systems in transport traffic research and control. The only correct approach to improve traffic organization on the existing road network at minimum cost is to "properly" manage traffic by implementing innovative methods and means to monitor, control, manage and optimize traffic flow indicators. The overall reorganization of road traffic is necessary for a better and safer functioning of the streets and improving not only safety but also the attractiveness and usability of the street network for pedestrians, cyclists and drivers. Ensuring traffic safety and greater security requires more than traditional "engineering, research and implementation".Extensive research is needed to successfully identify and implement the most effective methods and approaches for traffic reorganization and street design.

1. Introduction

The main approach to organizing and management of road traffic is the introduction of innovative methods and tools for monitoring, managing and optimizing traffic flow indicators.

Many studies show that congestion, at least twice a day, kills our productivity, pollutes our environment, damages our health, causes stress, leads to road aggression and turns our dynamic cities into isolated areas. Traffic psychology is a relatively new scientific discipline. Scientists are trying to understand the behavior of people and the mistakes they make that lead to about 90% of road accidents. So far, psychologists have been adamant that you are more likely to become aggressive if you are in your own car than in a public place, since the car's interior creates a false sense of security. On a daily basis we are direct witnesses: when we are behind the wheel and someone crosses our path or takes away advantage; incorrect crossing pedestrian lanes; careless cyclists and drones and more.

The advent of UAVs (unmanned aerial vehicles - drones) into the daily life and rapid development of the technologies in these systems allows them to be successfully used in accounting for the parameters of road traffic flow [1,2,3]. The big advantage of them is that they do not stop the movement in order to install the appropriate receiver (detector). The need to install video cameras to capture traffic at each intersection is eliminated, which is economically feasible and would save a lot of money. The ability to record and directly transmit traffic data in real time to an operator at a traffic management center is essential for good organization and management. Powerful and inexpensive software products are available to handle camcorder data. Mobility of aircraft (drones) is essential [4] because it enables traffic at different intersections to be taken into account, allowing it to be used by different teams and to investigate a sufficiently large number of thoroughfares for a sufficiently short period of time.

2. Prerequisites and ways to solve the problem

In aerial photography, information of a number of road traffic indicators can be obtained: distribution of correspondence between the entrances and exits of the examined thoroughfares; density of traffic flows; traffic flow intervals; time to cross the investigated junction; composition of transport flows; intensity of vehicles; vehicle speed and more. These indicators will cover the study of both road and pedestrian vehicles, cyclists and bicycle lanes. In this way, a large experimental database can be accumulated to enable optimization of the road network.

The advantages of the ability to process video images shot by drones are that they are shot over the road instead of on the road, the placement of vehicle detection areas can be done by the operator, the shape of the detection areas can be programmed for specific applications, and the system can be used for rail vehicles. The disadvantages are the need to overcome obstacles to detection caused by shadows, weather and reflections from the surface of the roadway. Disadvantages can be overcome by designing and installing hardware and designing software algorithms.

The complicated model of a modern road transport network [5,6,7] requires knowing the following parameters:

- Intensity of traffic;
- Vehicle speed;
- Distribution of correspondences between inputs and outputs;
- Density of transport flows;
- Traffic flow intervals;
- Time to pass through the investigated road sections;
- Composition of transport flows;
- Reporting of vehicle registration numbers, by districts in the road network of the given settlement, etc;
- Intensity of pedestrian and bicycle traffic.

All these parameters can be taken into account by video recording [8, 9] of the lane and automated software processing of the motion parameters.

3. Results and discussion

The use of unmanned aerial vehicles for tracking vehicle trajectories and for estimating traffic parameters [10,11,12] is an affordable procedure for determining time-of-flight traffic parameters and providing a useful tool for obtaining data from observations. In fact, the distribution and use of drones, although derived primarily from military applications, has been rapidly expanding for commercial, scientific, leisure, agricultural and other applications [13]. Uses are variable: by the police for surveillance; supply of products; aerial photography; smuggling; racing with drones, etc. [14]. Civilian UAVs now far outnumber military used in urban areas for research purposes to obtain accurate tracking information on video-based vehicles [15]. However, this technology, developed only recently, suffers from problems that have not yet been fully resolved. The level of accuracy of the results of its automotive flow analysis applications has not been adequately tested both under different shooting conditions and modes and under different road conditions.

The elements that form the annotation of the recorded road junctions are the following:

- lanes for traffic, bicycle traffic or pedestrian sidewalks can be defined as entry, exit and other;
- virtual lines at designated locations that register intersecting vehicles, bicycles or pedestrians may be indicated as entry, exit and other;
- geo-referencing of certain points in the picture;
- impact analysis between virtual objects.

Geo-referencing is the internal coordinate system of a map or aerial photo and may be linked to a terrestrial geographical coordinate system [16]. The corresponding coordinate transformations are usually stored in the image file, although there are many possible mechanisms for geo-referencing. The most beneficial effect of geo-referencing is that software can display terrestrial coordinates (such as latitude / longitude or Universal Transverse Mercator (UTM) coordinates) as well as measure terrestrial distances and areas. Geo-referencing means associating a particular aerial imaging area with locations in the physical space.

Experimental studies of traffic flow indicators were performed using an unmanned aerial vehicle. The use of a high resolution camera allows for high quality recording and the ability to track the movement of any pedestrian and vehicle, and hence to obtain the corresponding traffic flows. The software [17] processes the information from the recorded video, links image data (video), geo-referencing, annotations and trajectories of the monitored vehicles, etc. The pursued vehicle can be understood as either an object having an immediate position at any time, or as a complete trajectory in temporal space.

The surveys were conducted on the territory of the city of Sofia at the intersections designated in advance. In the study, the unmanned aerial vehicle was raised to 150 meters in height, with no time to capture traffic at the intersections of more than five minutes, since the software used allows video to be processed without purchasing a license within such a period. The first survey was conducted at the unregulated intersection of Kliment Ohridski Blvd. and Andrey Lyapchev Blvd., and the second survey was conducted at Andrey Lyapchev Blvd. and Andrey Sakharov Blvd. Once the video has been recorded and processed, it is possible to examine and analyze the existing data and manipulate only the view of that data. Figure 1 shows footage of the video footage of the intersections examined.

Figure. 1. Footage of the surveyed intersections.

From the statistical (log. Statistical) of the video footage processed, a total of 432 "elements" involved in the movement were recognized in the five minutes of recording. Type of traffic participant (car or truck, motorcycle, pedestrian, bus, cyclist, etc.), in the analysis is determined and tracked by different parameters: geometric dimensions; shape and speed. The other statistical parameters in the initial analysis are the following: total distance traveled, total follow-up time of all recognized objects, average speed, distance, etc.

Each trajectory of a recognized and identified traffic participant consists of a trajectory line and a marker in the form of a red flag and an identification number. The record can be selected by clicking on its label. The trajectory line is a double-colored green color representing the already traveled part of the trajectory, and the blue color represents the part of the trajectory to be travelled. The Vehicle List shows a list of all that have been detected (recognized) in a given video sequence. Each PPP trajectory can be selected by marking on its recording, providing the following information:

- unique identification ID number of each car;
- vehicle type classification;
- current speed the absolute size of the vehicle's current velocity vector, expressed in kilometers per hour;
- tangential acceleration of the vehicle, expressed in meters per second. A positive value means acceleration and a negative one means slowing down;
- lateral acceleration of the vehicle, expressed in meters per square second. A positive value means acceleration to the right, and a negative value means acceleration to the left;
- total acceleration in absolute magnitude of the direct acceleration vector;
- the average speed of the vehicle at the intersection (between inlet and outlet), expressed in kilometers per hour;
- the duration of the movement of the vehicle spent at the intersection, expressed in seconds;
- the duration of the vehicle spent in the intersection, expressed in seconds;
- the first vehicle ID number of the vehicle ID from the start of its field of capture;
- number of the last image of the vehicle from the beginning of its entry into the field of its capture;
- a unique entry ID through which the vehicle passed when entering the intersection area;
- unique exit ID through which the vehicle passed when exiting the intersection;

In traffic analysis, linear identifiers can be used, divided into three groups: input, output, and neutral. The following information is available for each: ID number; an explanation to it; number and type of vehicles passed through entry / exit (correspondence); time and speed for switching between inputs and outputs (figure 2), etc. It is possible to export data in CSV format with the following content:

- unique record number;
- the numbers of entrances and exits the vehicles pass on when entering / leaving the intersection;
- moment of vehicle passing through the inlet / outlet expressed in milliseconds;
- distance traveled by vehicles, between inlet and outlet, expressed in meters;
- average vehicle speed in the intersection zone (between inlet and outlet), expressed in meters per second;
- list of points in the vehicle path, each point having the following syntax: x [m]; y [m]; speed [m/s]; tangential and lateral acceleration [ms^2];
- position of the vehicle in the x and y coordinate system;
- time marker - the time from the beginning of the video frame when the vehicle was in a certain position.

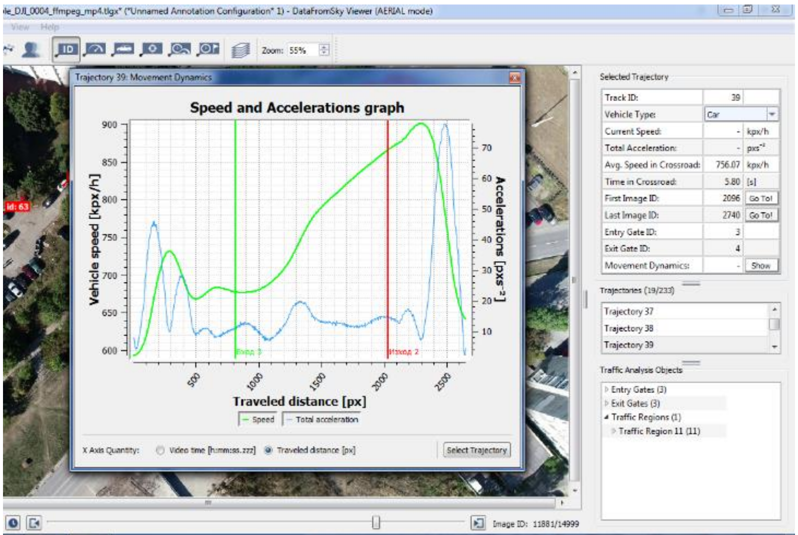

Figure. 2. Motion chart of a specific identified vehicle.

Table 1 presents the statistics of vehicles passing through the entrances and exits of the surveyed intersection for the five minutes interval, with 218 recognized traffic participants passing through the three entrances and 209 passing through the exits respectively.

Table .1. Statistics on vehicles passing through inputs / outputs.

Survey report - Gate Statistics						
	entry 1	**entry 2**	**entry 3**	**Exit 1**	**Exit 2**	**Exit 3**
Car count	89	46	57	70	62	56
Medium Vehicle count	9	7	6	6	5	8
Heavy Vehicle count	0	1	0	0	0	0
Bus count	0	2	0	2	0	0
Motorcycle count	0	0	1	0	0	0
Bicycle count	0	0	0	0	0	0
Pedestrian count	0	0	0	0	0	0
Number of all vehicles	98	56	64	78	67	64

In Table 2 are presents the data from vehicles passing through the entrances and exits, as well as from the overpass counting line. It is noteworthy that the difference between the passing vehicles (entry

/ exit) presented in the table is due to the fact that most of the vehicles passing under the bridge are lost by tracing their trajectory. After passing under the bridge, they are re-registered but as new road users, which is why they do not enter the statistics on the correspondence between inputs and outputs.

Table 2. Statistics on vehicles passing through entry / exit / overpass.

Survey report - Gate Statistics									
	entry 1	**entry 2**	**entry 3**	**entry 4**	**Exit 1**	**Exit 2**	**Exit 3**	**Exit 4**	**Overpass**
Car count	4	29	10	48	10	40	9	36	22
Medium Vehicle count	3	3	0	4	1	2	1	7	4
Heavy Vehicle count	0	2	1	2	2	0	1	2	0
Bus count	0	0	0	0	0	0	0	0	1
Motorcycle count	0	0	0	0	0	1	0	0	0
Bicycle count	0	0	0	0	0	0	0	0	0
Pedestrian count	0	0	0	0	0	0	0	0	0
Number of all vehicles	7	34	11	54	13	43	11	45	27

It shall be sufficiently detailed to include details of the vehicle identification and type, the time of entry and exit of the designated tail area, the average speed and acceleration in the tail area, and the dwell time (full rest) of vehicles in tail (total and maximum time of each car).

Additional analyzes can be carried out in specific areas: study areas; anonymous perimeter in the study area - unexplored area; traffic area; tail area; traffic area and more. It is possible to export the data in CSV format containing in addition to the above mentioned information and additional such:

- number of traffic participants in the designated area;
- time for movement and stay of each traffic participant in the designated area;
- in the tail area - the length of the tail and all possible times necessary to analyze the time in the queue, first and last in the queue, the acceleration time and the delay of vehicles in the queue (traffic in congestion),
- in the presence of a given anonymous zone in the study area, everything that falls within it is excluded from the analysis.

From the research performed, using an unmanned aerial vehicle on the traffic participants to determine the parameters of the transport process, it seems that the software products to assist the specialists involved in the organization and management of the traffic have evolved radically. It takes a little more time, desire and resource to join all the related units along the chain to achieve optimal operation in the management and optimization of road traffic using modern scientific and technical methods and tools.

4. Conclusion

According to the national strategy for improving the road safety of the Republic. Bulgaria for the period 2011 - 2020 [18], and they are the next ten year period 2021-2030. [19] commitments have been made to the European Economic Community and many tasks are set out to improve both the organization and safety of road traffic, the reduction of road traffic injuries and the optimization of road traffic indicators in order to improve its environmental performance to reduce harmful its impact on the environment and humans. In this regard, the approach to be used in the ever-increasing population and vehicles in major cities is to automatically collect data on traffic parameters and seek optimal solutions to improve them. The approach to solving this multifaceted task, such as optimizing the transport network and avoiding the heavy and expensive projects of deploying roadway detectors, is to use video recording, which will allow for a relatively fast reading of the parameters of transport traffic and its optimization in real time.

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