Recent Advances in Civil Engineering and Mechanics

NORTH ATLANTIC UNIVERSITY UNION

Editors
Marina V. Shitikova
Luige Vladareanu
Claudio Guarnaccia

Recent Advances in Civil Engineering and Mechanics

- *Proceedings of the 5th European Conference of Civil Engineering (ECCIE '14)*
- *Proceedings of the 2nd International Conference on Computational and Experimental Mechanics (CEM '14)*
- *Proceedings of the 2nd International Conference on Optimization Techniques in Engineering (OTENG '14)*

Florence, Italy, November 22-24, 2014

Mathematics and Computers in Science and Engineering Series | 36

RECENT ADVANCES in CIVIL ENGINEERING and MECHANICS

Proceedings of the 5th European Conference of Civil Engineering (ECCIE '14)

Proceedings of the 2nd International Conference on Computational and Experimental Mechanics (CEM '14)

Proceedings of the 2nd International Conference on Optimization Techniques in Engineering (OTENG '14)

Florence, Italy
November 22-24, 2014

Published by WSEAS Press
www.wseas.org

All papers of the present volume were peer reviewed by no less that two independent reviewers. Acceptance was granted when both reviewers' recommendations were positive.

ISSN: 2227-4588
ISBN: 978-960-474-403-9

Gap acceptance analysis in an urban intersection through a video acquired by an UAV

GIUSEPPE SALVO, LUIGI CARUSO, ALESSANDRO SCORDO
Department of Civil Engineering, Environmental, Aerospace, of Materials
University of Palermo
V.le delle scienze ed.8, Palermo 90128,
Italy
giuseppe.salvo@unipa.it, luigi.caruso@unipa.it, alessandro.scordo@unipa.it
http://portale.unipa.it/dipartimenti/dicam

Abstract: - Purpose of this paper is to apply a methodology previously developed to achieve an accurate measurements of the real traffic condition thought the use of a video acquired by an UAV (Unmanned Aerial Vehicle) and a probe vehicle equipped with a differential GPS. The used methodology is not invasive and thus, it doesn't influence the driver behavior. The used equipment must not be compared to the traditional techniques of traffic flow but it can be used for particular situations in which the installation of fixed detectors is not economic.

In particular, we have analyzed the gap acceptance for an urban intersection between a main road with dual carriageway and two lanes in one direction, that connects the older town of Palermo with a main access roads (via E. Basile) and a secondary road used for local traffic and composed by a single carriageway with one lane for each direction (via U. Solarino).

Key-Words: - real traffic condition, gap acceptance, urban intersection, UAV, differential GPS, video analysis

1 Introduction

The high number of daily displacements that there are on the roads causes an increasingly negative impact for the environment and especially for the cities, where the consequences of a not sustainable mobility are considerable and clear to everybody (growth of the environment pollution and diseases correlated to it, decrease of the urban accessibility, reduction of commercial and tourist attraction of the city, etc...). For these reasons, the study of the freight and people mobility becomes priority in the referential urban context. In this sense, the traffic microscopic simulation models are able to represent traffic condition and their evolution over time. Their reliability depends on the schematization level of the road network and the calibration of some parameters that characterize both the driving behavior, that can be more or less aggressive, and the different vehicle typologies (cars, buses, heavy vehicles, motorcycles, etc...) which are on the road network. These elements are not always easily available. The realization of accurate and periodic monitoring campaigns of the main kinematic sizes of the vehicles can guarantee an increase of the knowledge of the real dynamics of the road flow. This necessity is of greater importance especially in urban context, where the high levels of road congestion can cause different problems, for example the increase of the average travel time and the growth of the environment pollution.

The paper is organized in sections. After this introduction, the second section is a review of scientific literature on video techniques used for the analysis of traffic flow characteristics and on the gap acceptance. Section 3 describes the survey methodology and the used equipment. The case study is in section 4 and finally there are the obtained results (section 5).

2 Review of scientific literature

In order to realize a precise and accurate traffic study there are several models that use the video analysis in literature. Some authors propose to use fixed cameras (Micchalopoulos, 1991; Cao et al., 2007; Wang et al., 2008), but the camera and its angle may introduce errors and, therefore, the obtained data are often qualitative. Video-based vehicles tracking methods can be classified (Guido G. et al, 2013) into six categories: 1. model-based tracking, 2. region-based tracking, 3. active contour-based tracking, 4. feature-based tracking, 5. Markov random field tracking and 6. colour and pattern-base tracking. Others authors used airborne vehicles for traffic monitoring (Hinz et al., 2006; Lenhart et al., 2008); however, the survey has a high cost (instruments and operators). Due to several limitations in image acquisition by satellites and manned aircrafts shows high launch/flight costs, slow and weather-dependent data collection, restricted maneuverability and limited availability, in recent years, Unmanned Aerial Vehicles (UAV) image acquisition technologies have been developed. In particular, UAV systems are commonly employed in photogrammetry ambits, in which acquired images need to be georeferenced and combined with existing data in Geographical Information Systems (GIS).

Some authors have used images acquired from UAV to realize a precise and accurate traffic study (Hyondong et al, 2013; Remondino et al, 2011, Salvo et al., 2014). Compared to the others aerial platforms, the UAV have many technical and logistic advantages such as the opportunity to acquire with an high spatial resolution, the rapidity to be operative and obtain data and the reduced operating costs. On the other hand, their use is influenced by some limiting factors such as climatic factors (wind, rain, electromagnetic fields, etc.), those due to physical obstacles (buildings, urban canyon, etc.), instrumental factors (moderate maximum range of the battery, low payload, etc.) and those linked to the normative (possibility of “no-fly zone”).

In this paper, the gap acceptance was estimated in the case of an urban intersection without traffic lights regulated by the STOP signal with using of two 'non infrastructure based' tecniques: a differential GPS installed on board of a probe vehicle and a video acquired by an UAV that was in flight at sixty meters over the intersection. The driver who is preparing to lead into the principal traffic stream must evaluate, among the available gap, that one that allows him to realize the insertion manoeuvre in safety conditions. It means that he must chose if to accept or reject a gap (or lag) of a determined time dimension in the primary traffic stream (Troutbeck and Brilon, 1992). Some authors (Rossi et al., 2013, Farah et al., 2009) have showed how the acceptance decision-making process is influenced by different factors, for example the driver features (age, sex, etc.), the temporal and spatial amplitude of the gap, the speed of the primary stream vehicles, the waiting time and the features of the vehicle.However, the same driver changes his driving behavior over time in terms of gap acceptance (Daganzo, 1981). To evaluate the parameters which describe the gap acceptance theory there are two families techniques in literature: the first one is based on a regression analysis between the number of users who accept an interval and its dimensions (Siegloch, 1973), while, the second one is based on a probabilistic approach, for example the Raff methods (Vasconcelos et al. 2011), Ashworth (1977), maximum likelihood (Troutbeck and Brilon, 1992) Wu (2006) and Logit (Polus et al., 2005).

3 Methodology

This section shows the methodology used (Salvo et al., 2014) for the traffic monitoring based on the joined use of a remote controlled UAV equipped with a video camera and a probe vehicle equipped with a differential GPS.

The methodology is made up of three steps:

- survey of the kinematic features of the probe vehicle and the traffic flow through the joined use of two instrumentation typologies;
- comparison between the speed values measured by the differential GPS placed on the probe vehicle (V_{GPS}) and those obtained by the processing of the videos acquired by UAV (V_{UAV});
- determination of traffic kinematic data for all vehicles of the flow that have transited through the intersection analyzed.

In the following sections the steps of the methodology are described in detail.

3.1 Survey of the kinematic features of the probe vehicle and traffic flow

This step has the purpose of acquiring the vehicle probe position over time, and thus the its kinematic features, with two different survey typologies simultaneously: the differential GPS on board and the video recorded by UAV.

The parameters of the first typology are set for recording the vehicle position using the function "trajectory" (one point for each second). In this way, thanks to the correction of the differential position, it is possible to obtain the vehicle probe position with centimetric precision.

Regarding the realization of the flights it is necessary to acquire at least ten minutes of useful video using a professional UAV equipped with a video camera able to capture films in HD quality or higher. The survey must be preceded by an activity of pre-flight in which is necessary to define the take-off and landing points, the route (it is composed by a single acquisition point) and the

ISBN: 978-960-474-403-9

flight altitude. Furthermore, to make easier the following steps of processing, it is necessary to position near the intersection some ground control points (GCP) having dimensions and forms known.

3.2 Comparison between the speed values measured from GPS and obtained by UAV

This step of the procedure is oriented to determinate the relationship between the speeds measured by the probe vehicle (V_{GPS}) and those obtained by the elaboration of the videos acquired from UAV (V_{UAV}).

To determinate the speed values V_{GPS}, it is necessary processing and exporting the acquired data from the differential GPS placed on the probe vehicle in GIS environment (Salvo et Caruso, 2007).

On the other hand, for the determination of the values V_{UAV} it is necessary to extract a frame for each second of useful video and cutting the irrelevant sections of the videos (take-off and landing). After, there is the georeferentiation of extracted frames. In this operation, to minimize the oscillations caused by the wind and by the vibrations of rotors, it is necessary to use, for each image, a set of ten GCP dislocated on the ground (Salvo et al., 2014) and see that the RSM error (the georeferencing total error) is not too high (less than 2-3 pixels). In this way, once located the position of a characteristic point of the probe vehicle (for example the barycenter of the front hood) in all the frames in which the vehicle is present, it is possible to determinate the speed values (V_{UAV}) during the different passages of the vehicle in the monitored area.

Finally, is necessary positioning the couples of velocity values in a scatterplot and determinate the equation of the trend line which represents better the data. The interpolating equation must be a straight line passing through the origin and, in order to have a good accuracy level, the coefficient R^2 must have very high values, near the unit.

3.3 Determination of traffic kinematic data of the vehicles monitored

Having established the relationship in which the probe vehicle velocity obtained from a video recorded by an UAV can estimate those measured by differential GPS, it is now possible to estimate the main kinematic data of all vehicles that have transited the intersection analyzed.

The information acquired during this typology of survey can be used to study many events, for example to estimate the “real” driving behavior of drivers and to analyze the car following, gap acceptance and line change. Furthermore, it is possible to obtain other information’s typologies such as the presence of mobile obstacles which can cause slowdown to the normal traffic flow.

4 Case study

In this study we have applied the survey methods described in the previous section in an urban intersection without traffic lights regulated by the STOP signal near the University of Palermo. This intersection leads from the secondary road of U. Solarino into E. Basile street, which is a main street with two separated carriageway, each one with two lanes. The figure below shows a Google Earth image of the studied area.

Fig. 1. Google Earth image of the studied area

The first phase of the methodology consists in realizing the survey with the differential GPS and a professional UAV with eight propellers. The survey has been realized simultaneously by two team, one for the UAV micro-drone and one for the differential GPS on board of probe vehicle. Before starting the survey, some GCP have been placed inside the scene acquired from the video camera (fig. 2) in order to simplify the following elaboration phases of the video acquired from UAV.

Fig. 2. Some GCP placed inside the scene acquired from the video camera

There have been made five flights with an UAV at an altitude to 60 meters and for each flight, it was used an unique acquisition point (zero speed and constant altitude). During the five flights there have been acquired about 20 minutes of videos in Full HD quality and at the same time the probe vehicle, equipped with a differential GPS, has travelled along the road analyzed for several times, about 15. The figure below shows the UAV used during the survey.

Fig. 3. UAV used during the survey

The second phase of the methodology consists in realizing the comparison between the speed values measured from GPS and those obtained from UAV.

The data acquired from the differential GPS have been imported in a GIS and have been obtained the trajectories of the probe vehicle long the road investigated. The planimetric position's accuracy obtained using is about fifteen centimeters.

The videos from UAV were processed as shown in a previous study (Salvo et al., 2014), in particular the following steps were realized:

- removal of fisheye effect;
- selection of significant parts of the video;
- extraction of frames;
- georeferencing of extracted frames;
- identification of speed profiles of the probe vehicle.

The first three operations are preliminary and are finalized to selection of useful frames (for 1 second) that need to be georeferenced with the use of 10 GCPs. After these operations, each frames has been georeferenced (WGS 84 / UTM zone 33N) through a software GIS with the use of ten couples of control points positioned on the ground. The mean accuracy of the georeferencing process is about 20 centimeters, for each images. Finally, always using a software GIS, the probe vehicle positions over time and, thus, the velocity profiles have been identified. The pictures below (figure 4) show three couples of speed profiles obtained by GPS and by DRONE (UAV). If we analyze two different v-t trends it can be seen that they are very similar between them, even if there are small deviations.

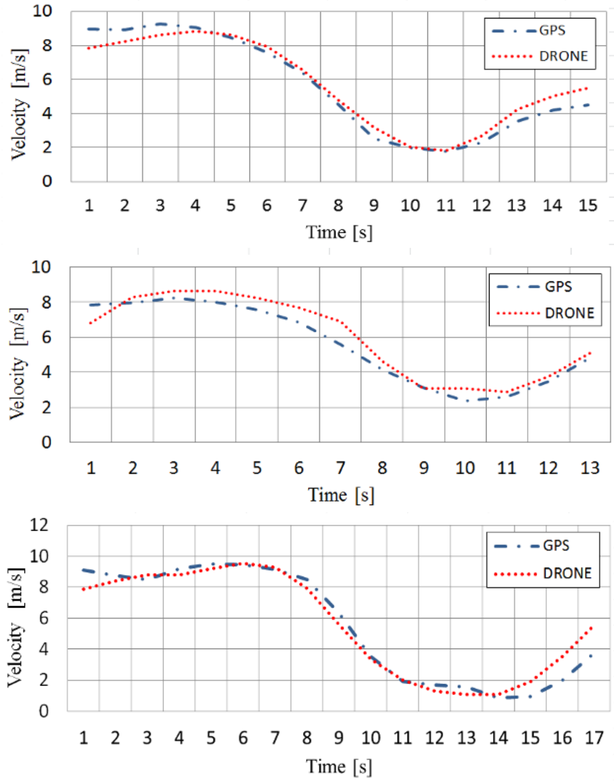

Fig. 4. Three couples of different speed profiles

Finally, the third step of the methodology consists in the determination of gap acceptance of all vehicles (from U. Solarino road to E. Basile street) during the UAV survey realized by the used UAV between 12:00 and 13:00 in a typical work day and, in particular, in this study we have analyzed the aspects concerning the gap acceptance. Analyzing the acquired video it was possible identify the number of vehicles that in twenty minutes have crossed the intersection analyzed, both from Solarino road to Basile street and vice versa (see table 1).

from \ to	E. Basile street	U. Solarino road
E. Basile street	575	102
U. Solarino road	74	- - -

Table 1. Number of equivalent vehicles passed through the investigated crossing during twenty minutes.

The table 2 shows the accepted gap of the vehicles (except that probe) which is divided into three classes: in the first one the accepted gap is very low (lower than three seconds), in the second one it is between three and six seconds and in the last one it is greater than six seconds. In this analysis we don't have taken into consideration the heavy vehicles and the motorcycles because their number during the survey is negligible.

Vehicles typologies	Gap accepted [s]		
	< 3	3 - 6	> 6
Alone	16	7	1
Leader	11	5	1
Follower	2	8	7
Total	29	20	9

Table 2. Value range of accepted gap for vehicles that have crossed the intersection analysed

The data of the previous table show that of the 57 vehicles analyzed on 30% of them has accepted a gap greater than six seconds, 49% a gap between three and six seconds while the remaining percentage has accepted a gap of less than three seconds. Finally, we evaluated the driving behavior of drivers who have arrived in the main traffic flow with a gap acceptance time less than six seconds given that the other vehicles had no obstacle to entry into the main road.

Doing so seventeen vehicles were excluded and, therefore, the driving behavior has been analyzed only for forty vehicles. The figure below (figure 5) shows, for those vehicles, a graph in which in the *x* axis there is the waiting time and in that one *y* there is the number of rejected gaps. By analyzing the picture it is possible to identify three different driving styles:

- aggressive, in which there are modest waiting times and a number of high rejected gap
- cautious, the opposite condition
- neutral, in which the waiting times are similar to the number of gap rejected.

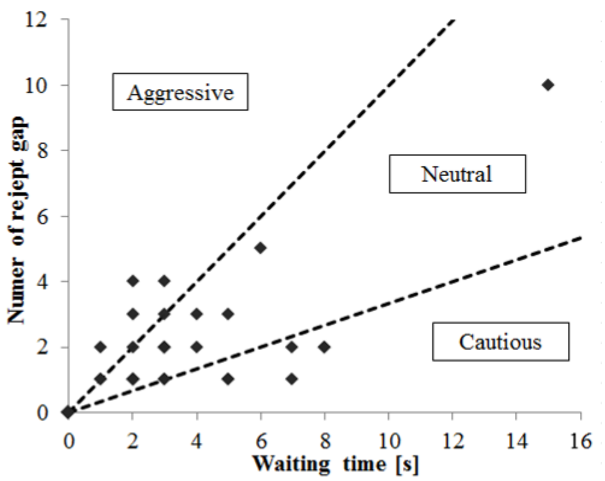

Fig. 5. Typologies of driving behavior of drivers tested during the survey derived starting from the waiting time and the number of gaps rejected

The next figures show two of the frames of the captured video in which some vehicles are seen near the intersection.

Fig. 6. In the top image is shows a neutral driving behaviour (gap: 4 s) while the lower one shows an aggressive behaviour (gap of 1 s)

5 Conclusion

This study have been applied a survey methodology developed to achieve an accurate measurements of the real traffic condition through the use of a video acquired by an UAV (Unmanned Aerial Vehicle) and a probe vehicle equipped with a differential GPS. This methodology is particularly effective because it isn't invasive and it allows to obtain useful information about the real driving behaviour without the influence of the used instrumentation during the survey. The study highlighted that the use of the UAVs is not conditioned by climatic factors, factors due to the presence of physical obstacles or instrumental factors. However, the extension of the methodology to other territorial fields could be bound by possible norms which limit the UAV use in densely populated areas. In the light of the obtained results, the described methodology can't be replaced to the traditional monitoring techniques of the traffic, but it can be used to complete data coming from the other typologies of detectors.

The main goal of the study has been to evaluate the gap acceptance in an urban intersection between a main road (via E. Basile) and a secondary road (via U. Solarino). The survey have been realized in a typical working day and the information collected was processed mainly with GIS software. By comparing the two different velocity profiles, those of differential GPS (real data) and those derived from captured video from the UAV (data derived), it is verified the reliability of the methodology applied. Next, has been analyzed the gap acceptance of all vehicles, except those probes, which are entered from the secondary street into the main one. Finally, the only vehicles that have accepted the gaps less than six seconds, we identified three different types of driving behavior (aggressive, neutral and cautious) as a function of their waiting time at the crossing and the number of gaps rejected before to get into the main road.

Acknowledgements

The authors gratefully acknowledge the company E. Lab S.r.l., Academic Spin-Off of University of Palermo, for their cooperation during data acquisition.

References:

[1] R. Ashworth, C. G. Bottom. Some observations of driver gap-acceptance behaviour at a priority intersection. *Traffic Engineering and Control*, 18 (12), 1977, pp. 569–571.

[2] M. Cao, A. Vu and M. Barth. A novel omni-directional vision sensing technique for traffic surveillance. *IEEE Intelligent Transportation Systems Conference*, 2007, pp. 678-683.

[3] C.F. Daganzo. Estimation of gap-acceptance parameters within and across the population from direct roadside observation. *Transportation Research* B, 15, 1981, pp. 1–15.

[4] H. Farah, S. Bekhor, A. Polus, T. Toledo. A passing gap acceptance model for two-lane rural highways. *Transportmetrica* 5, 2009, pp. 159–172.

[5] G. Guido, A. Vitale, F.F. Saccomanno, V. Astarita, V. Giofrè. Vehicle tracking system based on videotaping data, *Procedia - Social and Behavioral Sciences* 111, 2014, pp. 1123 – 1132.

[6] S. Hinz, R. Bamler, U. Stilla. Airborne and space-borne traffic monitoring. *Journal of Photogrammetry and Remote Sensing* 61, 2006.

[7] O. Hyondong, K. Seungkeun, S. Hyo-Sang, A. Tsourdos, B. A. White. Behaviour recognition of ground vehicle using airborne monitoring of unmanned aerial vehicles. *International Journal of Systems Science*, 2013, pp. 1-16.

[8] D. Lenhart, S. Hinz, J. Leitloff, U. Stilla. Automatic traffic monitoring based on aerial image sequences. *Pattern Recognition and Image Analysis,* 18 (3), 2008, pp. 400 – 405.

[9] P. G. Micchalopoulos. Vehicle detection through video image processing AUTOSCOPE System [J]. *IEEE Transaction on Vehicular Technology,* 40 (1), 1991, pp. 21 - 29.

[10] A. Polus, S. Shmueli, Y. Shiftan. Evaluation of the waiting time effect on critical gaps at roundabouts by a Logit model. *EJTIR,* 5 (1), 2005, pp. 1-12.

[11] F. Remondino, L. Barazzetti, F. Nex, M. Scaioni, D. Sarazzi. UAV photogrammetry for mapping and 3D modeling: current status and future perspectives. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXXVIII, 2011, pp. 25-31.

[12] R. Rossi, C. Meneguzzer, M. Gastaldi. Transfer and updating of Logit models of gap-acceptance and their operational implications. *Transportation Research Part C,* 28, 2013, pp. 142–154

[13] G. Salvo, L. Caruso. L'utilizzo di sistemi di posizionamento GPS per la determinazione di curve di deflusso in ambito urbano. *Atti 11a conferenza nazionale ASITA*, 2007, pp. 1 - 6.

[14] G. Salvo, L. Caruso, A. Scordo. Urban traffic analysis through an UAV. *Procedia - Social and Behavioral Sciences,* 111, 2014, pp. 1083 – 1091.

[15] G. Salvo, L. Caruso, A. Scordo. Comparation between vehicles speed profiles acquired by differential GPS and UAV. *Proceedings of the EURO Working Group on Transportation,* 2014.

[16] W. Siegloch. Capacity unsignalized intersections. Calculations for unsignalized intersections. *Schriftenreihe Strassenbau and Strassenverkehrstechnik*, 154, 1973.

[17] R. J. Troutbeck, W. Brilon. Unsignalized Intersection. *Theory – Chapter 8", Revised monograph on traffic flow theory, U.S. Department of transportation, Federal Highway Administration*, 1992, pp. 1-47

[18] L. Vasconcelos, A. B. Silva, A. Seco, G. Rouxinol. Estimation of critical headways at unsignalized intersections – a microscope approach. *3th international Conference on*

Road Safety and Simulation, 2011, Indianapolis, USA, pp. 1-18.

[19] G. Wang, D. Xiao, J. Gu. Review on Vehicle Detection Based on Video for Traffic Surveillance. *Proceedings of the IEEE International Conference on Automation and Logistics,* 2008, pp. 2961 - 2966.

[20] N. Wu. A new model for estimating critical gap and its distribution at unsignalized intersection based on the equilibrium of probabilities. *Proceeding of the 5th International Symposium on Highway Capacity and Quality of Service, Yokohama*, 2006, Japan, pp 1-10.