EWGT2013 – 16th Meeting of the EURO Working Group on Transportation

Urban traffic analysis through an UAV

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Abstract

In order to realize a precise and accurate traffic study, a method to evaluate the real traffic flow conditions in urban areas based on videos acquired by an UAV, Unmanned Aerial Vehicle, is proposed. In this way it does not require additional equipment to earth and, not being invasive, does not influence the driver behavior.
This paper presents the results obtained in terms of vehicular traffic flow along a way in the city of Palermo. The results have been compared to experiments using macroscopic simulation models and the eventually differences have been discussed.

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Keywords: urban traffic analysis; UAV; drone; real traffic flow conditions; macroscopic models; video analysis.

1. Introduction

High level of urban traffic conditions is a problem for the Public Administrations because they need punctual and effective solutions, since this problem cannot be ignored any more. Due to the variability of the transportation demand, knowledge of the road network and the traffic conditions is essential to optimize urban mobility, to analyze and solve the environmental problems affecting urban areas. The fundamental variables for the analysis of traffic congestion are density, capacity and traffic flow.

When flows are at maximum capacity of the road, the consequent is the congestion with affect on travel times, reliability and fuel consumption. The negative externalities of this phenomenon are environmental noise and pollution, especially in the existing interregional and international road infrastructure, principally if they are arranged near urban areas, where long-distance and local traffic come together (Baindur and Viegas, 2011).

In order to realize a precise and accurate traffic study in short time development, taking into account the geometrical aspects of retail infrastructure and driver behavior, micro/macro simulation models are generally used. They are able to analyze and simulate the instantaneous movement of each vehicle present on the road

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network in function of mathematical/physical relationships that are related to movement vehicles and driver behaviors. Their outputs are the kinematic characteristics of the traffic flow (position, speed and acceleration).

Alternatively, it is possible obtained real traffic flows using manual data collection or through probe vehicles equipped with GPS (Robertson, 1994). These types of measures might be more or less affected by errors due to human error and the use of GPS analysis, in particular, might be not correct for driver behaviour that knows to be monitored.

The aim of this paper is to develop a new methodology to evaluate the real traffic flow conditions in urban areas with the videos acquired by a UAV.

In this paper we analyze the review of scientific literature (section 2) and we describe the area of interest in the section 3 and the equipment used for the traffic analysis (section 4). The section 5 shows the methodology proposed and, finally the comparison with other literature models (section 6). Conclusions and future developments are in the section 7.

2. Review of scientific literature

In order to realize a precise and accurate traffic study in short time development, is need to take into account the geometrical aspects of retail infrastructure, traffic density, capacity and traffic flow. In literature All known mathematical models, in fact, rely on this three, variables (Greenshields, 1935, Greenberg, 1959, Underwood, 1961, Drake, 1967, Drew, 1968). As a consequence, the computation process requires a large database obtained by monitoring at least two of the three variables, leading to high costs both for survey and analysis.

This traffic flow models are not representative of the real flow conditions that generally occur in urban areas. any authors used a vehicle probe GPS-equipment for tracking its moving in the urban road network and for determining experimental outflow curves derived from statistical methods relating the cinematic variables (position, speed and trip duration) to the geometric characteristics of the road (Salvo et Caruso, 2007).

Other methods to acquire the parameters of traffic conditions like traffic flow, average speed, the length of queue and traffic density use the video analysis (Micchalopoulos, 1991, Wang et al, 2008). So, the vehicle detection and tracking techniques are used to find traffic data collection (Dickmanns, 2002, M. Bertozzi, et al., 2000). Some studies detect and tract vehicle from stationary rectilinear cameras (Bishop, 2000, Bertozzi et al., 2002, Meng Cao et al., 2007). The camera position, however, introduces errors in the measurement of vehicle kinematic variables caused by the prospect of recovery often oblique.

Airborne and spaceborne traffic monitoring has developed by some authors until 2006 (Hinz et al. 2006, Lenhart et al. 2008). Who consider spaceborne sensors able to do cover very large areas, but because of their relatively short acquisition time and their long revisit period, such systems contribute to the periodic collection of statistical traffic data to validate and improve certain traffic models (Lenhart et al. 2008).

The aim of this paper is to evaluate the real traffic flow conditions in urban areas from videos acquired by a UAV already used in other civil and environmental applications (Montagna et al., 2009; Pampalone et al. 2011; Sarazzi et al., 2011; Scordo et al. 2011). UAVs, also called simply drones, have the ability to change the flight altitude allowing to study the correlation between speed, flow and density. Then they collect a database of flow conditions in urban adhering to prevailing traffic conditions.

3. Area of interest

This study presents the results obtained in terms of vehicular traffic flow along a way in the city of Palermo (tab. 1), which is crossing the city and at the same time in the service for the internal mobility.

In recent years environmental pollution due to vehicular traffic is a serious problem especially for all large cities where public administrators must reduce this phenomenon. Negative traffic externalities are principally present in those city where number inhabitants per kmq are high and where street capacity and public transport

are insufficient respect of transport demand. In Palermo, in fact, urban density is about 4,000.00 inhabitants per kmq and the number of vehicles are about 550,000 (70.6% are cars, 22.1% motorcycles and 7.3% others) (Panormus, 2011).

Table 1. Palermo data (Source: ISTAT 2011)

Features	Value
Extension	About 160 kmq
Resident population	657,561 inhabitants
Density	4,136.20 inhabitants per kmq

The traffic flow is equal to 898,352 (of which 69,104 during the period 07:30 - 08:30). Of the 69,104 travel during this interval critical, make 56,910 trips within the city and are, therefore, the internal mobility of residents and the remaining 12,194 are related to the movement of exchange and crossing the city center.

Traffic congestion is also fostered by the increase of private car and by the increase of illegal parking of vehicles. These features reduce the roadway capacity and increase the commercial speed of public transportation.

The selected area is a portion of Ernesto Basile road, across the City connecting the older town with the main access roads to Palermo. This road is a dual carriageway with two lanes in one direction. We choice the interest area so that you can verify the conditions required by chosen macrosimulation models for at least a sudden, in order to test the goodness of the proposed methodology.

4. Equipment used for the traffic analysis

In this paper we used a Vertical Take-off and Landing micro-drone for 4 propellers that can be used in any context and it is able to follow flight planning for automated flights through a radio control system. It has a sophisticated inertial system and subsystems of integrated flight and it is equipped with a compact digital camera that can record video in high quality.

UAVs compared to other traditional platforms aerial or satellite have many technical and logistic advantages:

- low altitude operations (very high spatial resolution)
- timeliness for data obtained
- reduced operating costs.

During flight operations you have feedback in real time from the video camera but also from telemetry.

The follower figure shows instrument that we used (fig. 1): the UAV equipment with High Definition video camera (a), the display integrated in the remote control (b) and the ground control station where the telemetry of flight are transmitted (c).

Fig. 1. Equipment employer for video recording: UAV with video camera (a), remote control (b) and ground control station (c).

In the table 2 there are the micro-drone technical features.

Table 2. Micro-drone technical features

Technical features	Description
Body	Carbon fibre
Rotors	brushless motors
Payload	300 g
Power	LiPo battery
Flight time	about 10 min
Wind speed	until to 4 m/s
Operative Temperatures	From 5°C to 40°C
GPS	Yes
Drive mode	Manual / flight planning
Video quality	HD (1280 x 720 pixel)

5. Methodology proposed

The proposed method is based on the assumption that from a video by a drone in flight (nadir point of view), it is possible to obtain the flow conditions of vehicular traffic.

It is divided into three steps:

- HD video recording by UAV
- video processing
- evaluation of traffic kinematic data

This methodology can be used as a survey tool for analyzing the dynamics of the traffic at any point in the city, with a reduced time and at low cost. It does not require additional equipment to earth and, not being invasive, does not influence the driver behavior.

5.1. HD video recording by UAV

The preliminary phase of this research involves the flight planning to calibrate the points of take-off and

landing, the route and the flight altitude.

In particular considering that to record a video in HD quality is characterized by a pixels resolution of 5 cm, the parameters used for flight planning are:

- take-off points coincident with the landing
- flight altitude is 70 m
- single point of stationary hovering conditions (zero velocity and constant flight altitude)
- two drive modes: automatic while hovering and manual for takeoff and landing

Furthermore ground control points (GCP) having dimensions and forms known are positioned in the portion framed by the camera. This procedure is necessary to simplify processing steps and to extract the frame from the video captured by UAV (Fig. 2).

During survey operations, conducted on January 16, 2013 from 13:00 to 14:00, they made 3 flights during which they acquired a total of 15 minutes of video with 10 frames per second in HD quality (1280x720). The choice to use 15 minutes of video analysis derives by technical limitations due to tools and equipments used (i.e. UAV battery autonomy, fly drone stability, manual image co-registrations, etc...) that can suitably improved in terms of performance. However this time range is sufficient for tested the methodology showed.

Fig. 2. GCP in the area of study

5.2. Video processing

The second step is the video processing. UAV during flight has small fluctuations due to the wind but also to the rotation of four rotors. So for minimize fluctuations the steps are:

- removal not significant frame from video (take-off and landing)
- extraction of a frame for each second of video captured during the flight
- frame co-registration using a specific open source software (with 10 GCP for each image)

Table 3 presents the statistics of each flight. It contains the number of frame, the point for the co-registration and the RSM error (the average error for each flight).

Table 3. Overview table

Flight	Frame numbers	RSM error
1	192	0.516
2	201	0.624
3	177	0.549

5.3. Evaluation of traffic kinematic data

This phase of the methodology is the analysis of the video frames obtained from the drone through the software open-souce "Tracker" (a free video analysis and modelling tool built on the Open Source Physics (OSP) Java framework). In this way it was possible to derive the kinematic quantities of each vehicle in the area.

The generation and analysis of data consists of 6 steps:

- open co-registrated images
- calibrate the video scale
- set the reference frame origin
- track objects of interest (vehicle barycentre)
- tracking and analyze of the tracks
- export of kinematic data for each track

The speed data output of each vehicle are processed statistically (Table 4) in order to obtain the average speed ($v = 35.4$ km/h). In this way it is also obtained the real flow of vehicles transited in term of equivalent vehicles ($q_{real} = 2,250$ vehicle/hour).

Table 4. Data from UAV in 15 min

	Numbers	Average speed [km/h]	Standard deviation
Car	463	35.0	4.80
Bus / heavy vehicle	11	32.0	3.20
Motorcycles	133	37.0	4.50

6. Comparison with other literature models

The flow values experimentally obtained were compared with the output data of the models of Macrosimulation that analyse uninterrupted flow. This mode is valid in those arcs of road infrastructure characterized by stationary conditions and regular flow with the elimination of conflict points and stops along the route. In the area of study we have been verified the stationary condition and regular flow. Models used are:

- Greenshields;
- Greenberg;
- Underwood;
- Drake;
- Drew.

The first step was to determine the capacity C for Basile Street, that is the maximum number of vehicles that can go through a section in a given time interval.

A methodology from of the "Handbook of the capacity of the Roads" of the American Association of State Highway Officials (AASHO) was used, where the capacity depends on the number of lanes in the roadway and on the type of infrastructure, percentage of traffic commercial and the bus traffic.

Obtained capacity value of Basile street (about 3,300 veh / h), we proceeded to calculate the traffic flow q. If the flow is stationary it is directly proportional to the spatial density k and to the velocity v ':

$$q = k \ v' \quad [\text{vehicles/h}] \tag{1}$$

The spatial density k, the number of vehicles in a given instant are included in a unitary section of road, depends by the model of uninterrupted flow used, by free flow speed v_0 (speed imposed by the Highway Code, in this case is 50 km / h), by the capacity of the road and by the average speed v (we used the average speed obtained from processing video). The flow velocity v' given by the model used is a function of spatial density k, of the capacity C and the free flow speed v_0.

The flow values of the models have been compared with the real flow of video from drone (fig. 3).
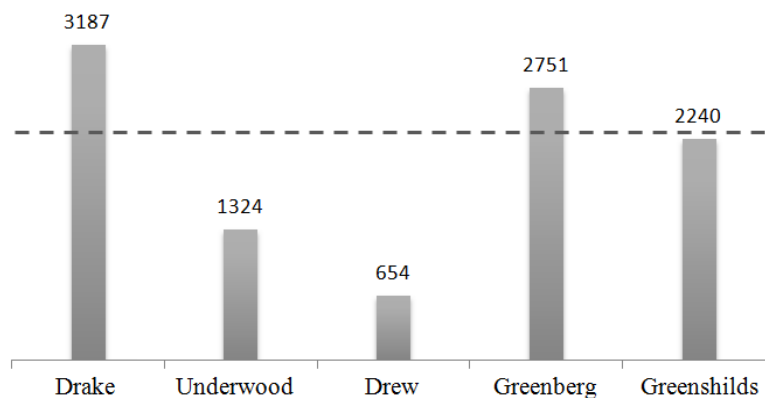

Fig. 3. Comparison between traffic flow obtained whit models and that real (dashed line).

Underwood, Drew and Drake's models are not representative of traffic conditions that occurs during the field survey, because the kinematic variables of traffic conditions in the study area are different from theoretical parameters of these models in term of valid ranges (Cantarella, 2001), providing simulations with large errors (Drake's error of +41%, Underwood -41% and Drew -70%). Greenberg's model gives a values flow overestimated (+ 22%). Finally, Greenshilds's model is more representative of traffic conditions (-0.50%).

7. Conclusions and future developments

In this paper we evaluated the technical characteristics of the UAV in order to develop a methodology to derive the kinematic quantities of real vehicular flow. The measured data for the region of interest have been compared with the models of macrosimulation, highlighted so the limitations of these algorithms.

The methodology presented constitutes a solid instrument of reality knowledge, that must be understood not so much as a model you are looking through mathematical formulas to simulate the real phenomenon of traffic but as an operational tool.

The main advantage of these devices is to not influence the driver behaviour. Also for their operation it does not need any kind of intervention on the road infrastructures. In this way it is possible to investigate the dynamics

of traffic flow, the queue length, the manoeuvres performed and driver reaction time.

UAVs date output could be used as input data for calibrating models of micro-simulation, in order to have simulations that are more representative of the reality. Other possible operations are the classification and the counting of vehicles in transit to the next statistical purposes. It also allows reliefs and analysis with a reduced time and at low cost and lends itself to be used as a survey tool for analyzing the dynamics of the traffic at any point in the city.

These analysis and the equipment used must not be compared to the traditional techniques of traffic flow (continuous acquisitions) but can be used for particular situations in which it is not economical the install of fixed detectors.

Other problems found, however, consists in the limitations due to the geomorphology of the region of interest (presence of mountains, the presence of strong electromagnetic fields, of the prevailing winds, areas of "no-fly", etc. ..) and the constraints technicians of the drones (autonomy, load capacity, weather, etc. ..).

Acknowledgements

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