Comparison between Floating Car Data and Infrastructure Sensors for Traffic Speed Estimation

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Abstract—**The development of new generation Intelligent Vehicle Technologies will enable a better level of road safety and CO2 emission reductions. However, the bottleneck of all of these systems is the need of a comprehensive and reliable data. For traffic data acquisition, two sources are available today: infrastructure sensors and floating vehicles. The first ones consist on a set of static underground sensors installed in the roads; the second ones consist of the use of intelligent vehicles as mobile sensors. Both of them make use of different communication systems, V2V, V2I and I2I. In this paper we present a comparison of the performance of both kinds of traffic data source for road traffic speed estimation. A set of real experiments has been performed in several traffic conditions, using infrastructure sensors and the information retrieved by one instrumented intelligent vehicle. After processing these data, the results show the better accuracy of the floating cat data as well as its low cost in the case of a massive implantation.**

I. Introduction

THE use of variable message signs allows infrastructure managers and authorities to control the traffic and to provide of information to the road users, which prevents dangerous situations, reducing accidents, and improves traffic flow, reducing the energy consumption and CO2 emissions. The main advantage of variable message signs over conventional traffic signs resides in that the information shown by the second ones is permanent and that they cannot adapt it to the different traffic conditions (queues, accidents, fog, slippery road, etc).

In [1] a list of different studies about the effectiveness of these panels is shown, obtaining a very wide range of results. However, all of these studies coincide in that through the application of these panels an important reduction of the injury accidents is produced, mainly when the information provided is related to accident warnings or weather condition that imply an speed reduction [2].

However, in order to provide the panel information, it is necessary to previously detect the different conditions on which to notice.

There are several methods to develop this task. This way, it is possible to use traffic video surveillance, whose images are visualized by operators in a control center where the warnings are emitted. In recent researches this visualization has been automated through computer vision for congestion detection. To analyze traffic intensity and speed, the most usual way is to obtain the information from sensors placed in the infrastructure, mainly magnetic spires under the road [3-6]. This kind of sensors has two main limitations:

1) Its performance should be based in magnetic principles that make them able of detecting the passing of metallic masses (vehicles) over it; the activation of two consecutive spires allows calculating an estimation of the speed. However, the resolution of this speed calculation is low and there are problems with the different configurations and sizes of the road vehicles.

2) The information provided by these sensors is related to concrete road positions. In consequence, if the sensors are not placed with a small separation, the resolution for incidence detection is very low.

On the other hand, a different solution to obtain traffic information is to use "floating vehicles" [7-13]. This is based in the circulation information record and transmission from an instrumented vehicle to a central station in real time. Although position and speed are the typical variables managed by these vehicles, it is possible to add any other information such as external temperature, light sensor activation or rain sensor activation. If this system achieves a sufficient penetration level [7], the information sent to the traffic control centers would substitute the one obtained through infrastructure sensors because it would allow estimations of average speeds, traffic intensity and other relevant conditions used to detect incidences, accidents and traffic jams with better accuracy and not only in some punctual instrumented road areas.

Although the information provided by the infrastructure sensors and floating vehicle data should be redundant, the limitations and uncertainty of both methods make that this does not happen and, consequently, it is necessary to analyze the coherence of the retrieved information. A combination of both sources of information is shown in [14].

This paper focuses to the comparison of the measurements of infrastructure sensors and floating car data. On one hand the information of the road sensors (magnetic spires) is retrieved through an Intelligent Agent that access in real time the public databases of the Spanish Directorate General of Traffic (DGT) through Internet. On the other hand, one instrumented vehicle will follow a route through an instrumented highway behaving like a floating vehicle and recording the necessary navigation information to be compared with the one provided by the infrastructure.

II. Experimental Equipment

A. Intelligent Vehicle Instrumentation

The testbed Vehicle used as floating vehicle is an instrumented Peugeot 307, equipped with an acquisition computer with CAN bus access, one non-contact speed sensor, a gyroscopic platform, several GPS receivers, UMTS Internet access and a touch panel accessible for the driver in order to manage the acquisition system (Figure 1).

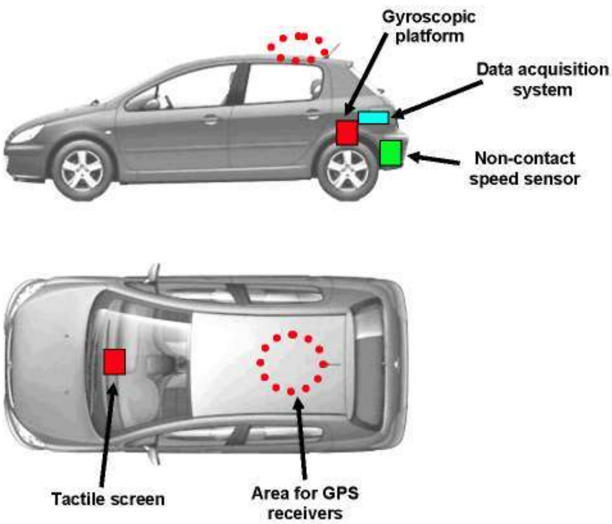

Figure 1. Outline of where the sensors are placed in the testbed vehicle.

The measured variables of the floating vehicle to perform the comparison with infrastructure signals are position and speed. The position is obtained by three GPS receivers with different accuracies and functionalities: Garmin eTrex H and Astech G-12 in autonomous mode and Topcon GB-300 with real time kinematics differential correction NTRIP via Internet, connected to the computer through the RS232 ports. This way it is also possible to evaluate the differences among the receiver models since in normal conditions, the mass-production vehicles equips low-performance receivers and, in consequence, the uncertainty of this measurement has to be taken into account when integrating the results.

It is possible to acquire speed using the GPS receivers. However, we obtain it from the vehicle CAN bus in order to make the experiments from standard equipment. Additionally, the instrumented vehicle equips a dedicated Correvit L-CE-non-contact speed sensor, used as high precision sensor in order to guarantee the accuracy of the measurement. In consequence, the accuracy of the speed measurement of the floating vehicle is about 0.24 km/h.

The record of the sensorial information is made using a laptop and a National Instruments DAQCard-6062E acquisition card.

B. Infrastructure Sensors Data Retrieving

Nowadays, there are several web based information sources that provide public and accessible real time traffic information. In Spain, the most important source is the DGT that provide information about the road incidences and traffic as well as the data of the sensors placed in these infrastructures, mainly in reference to highways. Although this information is public, its diffusion is made through web pages, being necessary a special authorization to directly query to the system database.

In our case we have selected to access the database using the web interface by the implementation of an Intelligent Agent, able of retrieving information from web pages and of reusing it in other applications, allowing the creation of mashups (web application that uses or combines data or functionalities from two or more external sources to create a new service). In this case, the problem consists on information extraction from semi-structured information. In order to obtain this traffic information, we have developed an information agent (software robot) that is able to:

- Realize a query of traffic incidences in the DGT web page.
- Extract relevant data related to traffic incidences in the city of Madrid (Spain), from the information obtained in the previous query.
- Realize a query of information of DGT's traffic sensors for the field operational test area (M40 road).
- Navigate to the web information of each one of the sensors.
- Extract the information of each sensor.
- Finally, every information will be retrieved each 40 seconds and will be logged in a file during the floating vehicles are performing tests, in order the information captured can be compared with the one obtained from the testbed vehicle.

The software robot has been implemented in Pyton programming language, used for regular expressions extraction.

An example of the captured information by the robot is shown in table I. In this table, the first column represents the identification of the road. The second one indicates the marker post (MP) kilometer where the sensors are placed. Third column indicate the direction (Crescent and Diminishing). The fourth column indicates the traffic intensity expressed in vehicle / hour and the fifth column is the average speed in km/h. In our application, this table updates every 40 seconds, since it is the update time of the web information available from DGT.

TABLE I

EXAMPLE OF THE DATA CAPTURED BY THE SOFTWARE ROBOT

Road	MP (Km)	Sense	Intensity (Veh./ hour)	Aver. Speed (km/h)	Road Occupati on (%)	Light Veh. (%)
M-40	Pk 10.3	C	1380	125	2	91
M-40	Pk 12.7	D	5760	98	10	78
M-40	Pk 16.7	C	-	-	-	-
M-40	Pk 16.7	D	3780	73	7	95
M-40	Pk 16.0	C	-	-	-	-
M-40	Pk 15.2	D	6000	92	13	96
M-40	Pk 15.2	C	-	-	-	-
M-40	Pk 14.3 5	C	-	-	-	-
M-40	Pk 12.7	C	3000	100	9	84
M-40	Pk 20.2	D	3300	99	8	98
M-40	Pk 20.2	C	5040	91	11	91
M-40	Pk 17.1	C	5100	98	9	95
M-40	Pk 17.1	D	5460	82	14	92
M-40	Pk 12.2	C	5700	121	11	87
M-40	Pk 12	D	4500	107	14	92
M-40	Pk 10.4	D	4380	116	8	87

C. *Field Operational Test Area*

Field Operational Tests have been performed in a segment of 10 kilometers of the Madrid's highway M40, instrumented with 16 traffic sensors (Figure 2) whose information is available in the public database of the DGT.

In this database, the identification of each one of the infrastructure sensors is expressed with a road number plus marker post (MP) kilometer plus direction (Crescent, Diminishing). However, in order to compare this information with the supplied by the instrumented vehicle equipped with a GPS receiver, it is necessary to geolocate all of these MPs. In table II is shown the GPS UTM position of every infrastructure sensor used in the field operational tests, all of these located in the M40 highway around the South Campus of the Technical University of Madrid.

TABLE II

GEOLOCATION OF THE KILOMETRIC POINTS OF THE M40 HIGHWAY

Road	MP	UTM North (m)	UTM East (m)
M-40	PK 15.2 D/C	4472559.34	446889.88
M-40	PK 16.0C	4471181.7	446371.89
M-40	PK 16.7C/D	4470833.63	446184.63
M-40	PK 17.1 C/D	4470085.26	445567.53
M-40	PK 14.35C	4473764.66	447381.63
M-40	PK 20.2C/D	4468243.68	443460.42
M-40	PK 21.8C/D	4468401.34	441273.48
M-40	PK 12D	4474671.17	448987.95
M-40	PK 12.7C/D	4474260.32	448112.99
M-40	PK 10.4C/D	4476429.97	449670.50

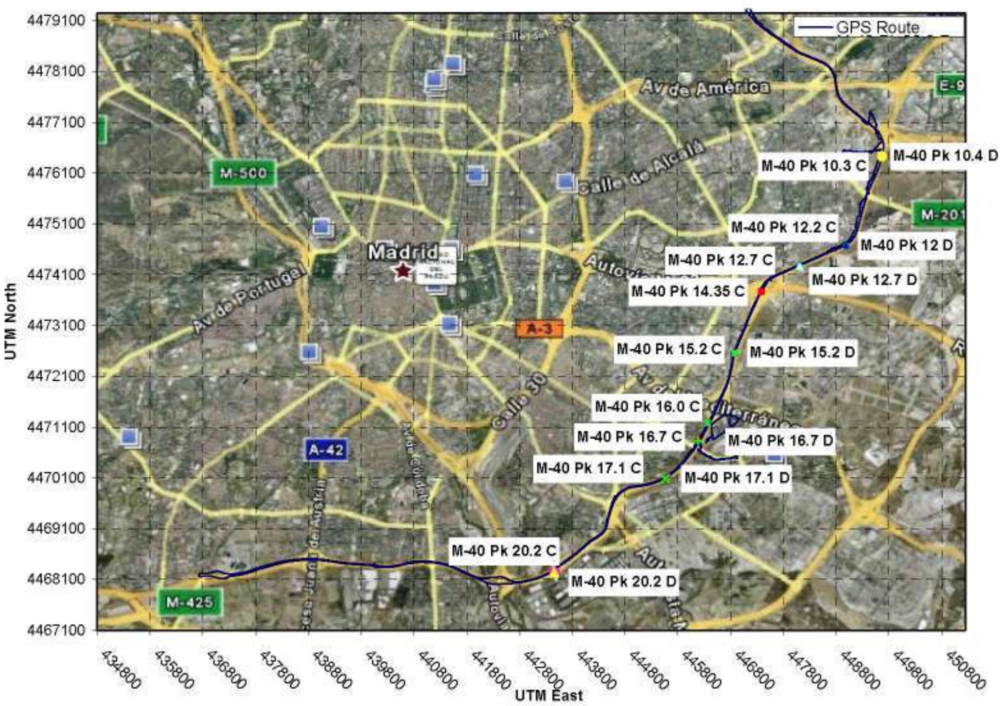

Figure 2. Field operational test area and position of the infrastructure sensors

With this information now it is possible to compare the results of the infrastructure information and the onboard vehicle information.

I. Related Experiments

A large set of experiments have been performed retrieving information of infrastructure sensors and floating vehicle data. In this paper we present two of these experiments on a route along the M40 road in increasing and diminishing directions, with a total length of 20 kilometers. The first experiment consists on a route in an non-rush hour, circulating in free traffic at almost top aped in the most part of the test. The second experiment consists on a route in rush hour. In this case the speed of the floating vehicle has to be adapted to the traffic conditions that could be low in some parts of the journey.

First experiment consists on a route through the M40 Madrid's highway, starting in the marker post 16.7 in increasing direction until the marker post 20.2, passing the infrastructure speed sensors installed in the MPs 17.1C and 20.2C. In this MP a change of circulation direction is made and the route continue in diminishing direction, passing the infrastructure speed sensors installed the MPs 20.2D, 17.1D, 16.7D, 15.2D, 12.7D, 12D and 10.4D. Once passed this last MP, a new direction change is performed and the route continues in increasing direction, passing the sensors installed in MPs 10.3C, 12.2C, 12.7C, 14.35C, 15.2C, 16.0C and 16.7C, where the test route finish.

In Table III is shown the results of the speed measurements made in the marker post where the infrastructure sensors are installed at the same time instant in which the floating car circulates over them. This information is also graphically shown, in figure 3. Because the high accuracy of the Correvit L-CE-non-contact speed sensor installed in the testbed vehicle, we will use its information as reference and will compare it with the one supplied with the infrastructure sensors. The analysis of this experiment shows that the speeds calculated by the infrastructure sensors are much less accurate than the one calculated by the floating vehicle, with an average error of 16.22 km/h and a standard deviation of 12.32 km/h. However, the interpretation of the information both sources clearly state that the traffic flow is almost free and that no congestion is detected in any of the marker posts. On the other hand, for ADAS applications that require more precision in the speed measurement the floating vehicle data is the only accurate enough for being used.

TABLE III
COMPARISON OF THE SPEED ACQUISITION IN THE FIRST EXPERIMENT

MP	Floating Vehicle Speed (km/h)	Infrastructure Speed (km/h)	Infrastructure error (km/h)
17.1C	86.91	96	9.09
20.2C	91.6	95	3.4
20.2D	97.26	99	1.74
17.1D	91.99	100	8.01
16.7D	91.6	104	12.4
15.2D	93.55	98	4.45
12.7D	94.14	107	12.86
12D	91.97	120	28.03
10.4D	71.28	124	52.72
10.3C	76.95	108	31.05
12.2C	93.95	121	27.05
12.7C	87.1	91	3.9
14.35C	93.16	0	0
15.2C	90.62	0	0
16.0C	94.14	0	0
16.7C	50.97	0	0

Second experiment represents the data capture from both available sources in a congested traffic situation. In this case and in order to take advantage of the rush hour traffic we have modified the marker post circulation sequence, starting

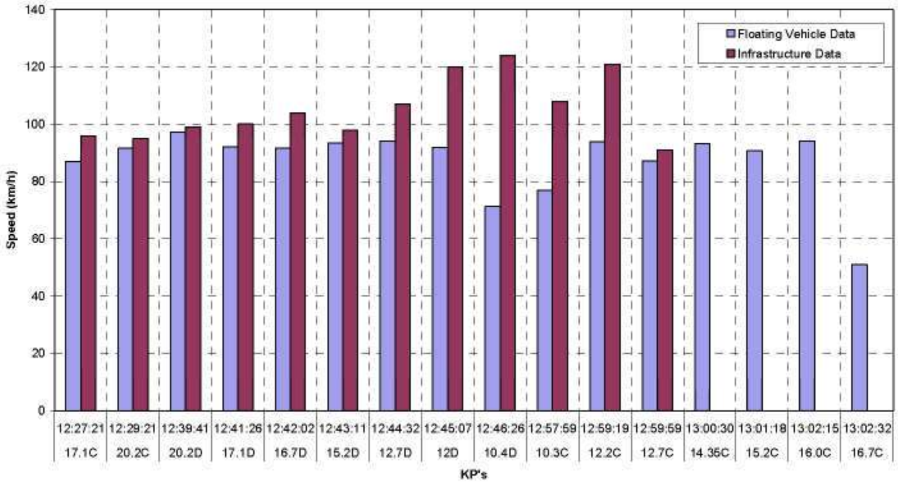

Figure 3. Comparison between speed profile of floating vehicle data and infrastructure data for the first experiment.

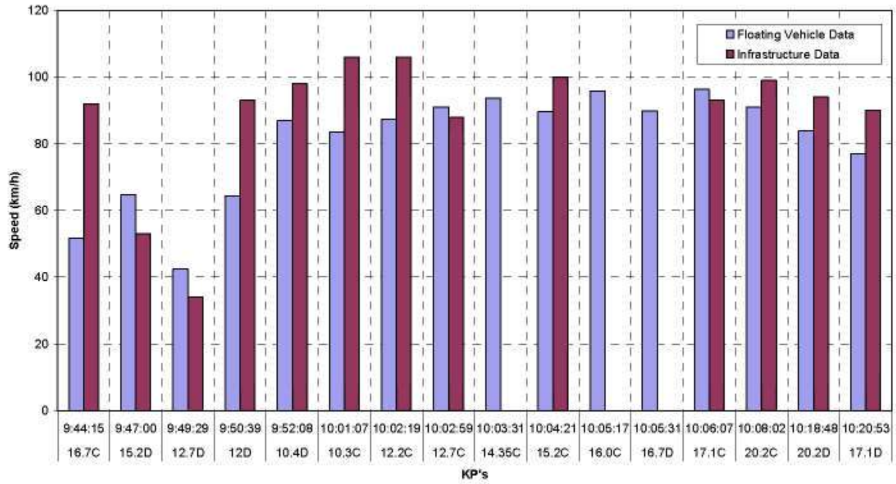

Figure 4. Comparison between speed profile of floating vehicle data and infrastructure data for the second experiment.

in the MP 16.7 in diminishing direction, across the MPs 15.2D, 12.7D, 12D and 10.4D. At this moment, a direction change is performed and the route is continued along the M40 in increasing direction, passing the MPs 10.3C, 12.2C, 12.7C, 14.35C, 15.2C, 16.0C, 16.7C, 17.1C, 20.2C and 20.2D. Finally, a last direction change is executed and we return to the starting point, passing through the MP 17.1D. In this case a traffic jam is located between MP 16.7D and MP 12D as is shown in Table IV and figure 4.

TABLE IV
COMPARISON OF THE SPEED ACQUISITION IN THE SECOND EXPERIMENT

MP	Passing Time	Floating Vehicle Speed (km/h)	Infrastruc. Speed (km/h)	Infrastruc. Error (km/h)
16.7D	9:44:15	51.75	92	40.25
15.2D	9:47:00	64.64	53	-11.64
12.7D	9:49:29	42.38	34	-8.38
12D	9:50:39	64.25	93	28.75
10.4D	9:52:08	86.91	98	11.09
10.3C	10:01:07	83.59	106	22.41
12.2C	10:02:19	87.3	106	18.7
12.7C	10:02:59	91.01	88	-3.01
14.35C	10:03:31	93.75	-	-
15.2C	10:04:21	89.64	100	10.36
16.0C	10:05:17	95.7	-	-
16.7C	10:05:31	89.84	-	-
17.1C	10:06:07	96.28	93	-3.28
20.2C	10:08:02	91.01	99	7.99
20.2D	10:18:48	83.78	94	10.22
17.1D	10:20:53	76.95	90	13.05

In this case, the average speed error between both sensorial sources is 8.02 km/h and the standard deviation 9.73 km/h. Reviewing table IV information and similarly to the previous experiment, the infrastructure information is accurate enough to deduce that there is a traffic jam in the mentioned section of the road. However, the results are not accurate enough for other ADAS applications. It is interesting to note that speed data provided by the infrastructure sensors are lower than real values for congestion situations and they are higher than real values for free flow traffic situations.

I. Conclusion

In this paper we have compared the information about traffic speed from two different sources: infrastructure sensors and floating vehicles. The data from infrastructure speed sensors have been obtained from public databases of the Spanish DGT through the usage of an intelligent information agent. The data from floating vehicles have been obtained using an instrumented vehicle that moves along a route in the same area where the infrastructure speed sensors are installed. Two real experiments along the M40 Madrid highway have been included in this paper. The results of these experiments show that the floating car data are more accurate than the information from infrastructure sensors. Furthermore, they provide a continuous information flow over the complete route. On the other hand, infrastructure speed sensors provide low accuracy data and only in punctual road situations. This means that their information can only be used for ADAS applications with low precision requirements like traffic monitoring. The floating vehicle data can be used as information source for ADAS with high accuracy requisites as well as for continuous traffic monitoring. Although no floating car data information is available today and there exist only for research purposes, mass-production vehicles only require V2I communications to provide this information using their default onboard equipment.

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