# TRAFFIC SIGNS RECOGNITION FOR DETAILED DIGITAL MAPS DEVELOPMENT AND DRIVER ASSISTANCE SYSTEMS

**F. García[1*], F. Jiménez[2], J.E. Naranjo[3], J.M. Armingol[1], A. de la Escalera[1], F. Aparício[2].**

[1] Universidad Carlos III de Madrid. Intelligent Systems Lab
LSI. Avda. De La Universidad 30, 28911 Leganés (Madrid). Spain.
Telephone: +34 91 624 99 70. E-mail: fegarcia@ing.uc3m.es

[2] Universidad Politécnica de Madrid. University Institute for Automobile Research
INSIA. Campus Sur UPM. Carretera de Valencia km 7, 28031 Madrid (Spain)
Tel: +34 91 336 53 17, E-mail: felipe.jimenez@upm.es

[3] Universidad Politécnica de Madrid. Computer Science School
EUI. Campus Sur UPM. Carretera de Valencia km 7, 28031 Madrid (Spain)
Tel: +34 91 301 30 29, E-mail: joseeugenio.naranjo@upm.es

## ABSTRACT

Digital maps are considered as an additional sensor in many of the new ADAS, but these systems usually require a higher level of accuracy and detail of the maps. Among the important information that the maps should contain, we can find the road geometry and traffic signs. In the first case, it is interesting to use accurate and fast methods for measurement. In the paper, a method based on a datalog vehicle is used. Satellite positioning and inertial measurements systems data are combined and dynamic behavior of the vehicle body is corrected measuring the movements of the suspension system. On the other hand, the information provided by traffic signs and route-guidance signs is extremely important for safe and successful driving. An automatic system that is capable of extracting and identifying these signs automatically would help human drivers enormously; navigation would be easier, allowing them to concentrate on driving the vehicle. A Computer Vision System is used to recognize and classify the different families of traffic signs combining it with GPS information to develop detailed and accurate digital maps. This sign recognition can also be used for real time warnings to the driver. Some results of test carried out in real situations are shown.

# INTRODUCTION

Digital maps are considered as an additional sensor in many of the new ADAS in order to improve the sight distance of the driver and obtain a larger electronic horizon [1], [2], but these systems usually require a higher level of accuracy and detail of the maps [3]. Among the important information that maps should contain, road geometry and traffic signs also can be found [4]. This higher level of accuracy involves specific measurement methods and correction algorithms [5]

On the other hand, landmark detection and recognition are related to the success of the driving and to reach to the destination, which is the goal of the driver's navigation task. Advance driver-assistance systems (ADASs) are designed to help (or substitute) human drivers in these two tasks. Traffic signs and route-guidance signs are located in streets, roads, and motorways to help drivers. The first are designed to help with the piloting task, providing information of either the maximum or minimum speed allowed, shape of the road, forbidden maneuvers, etc. Route-guidance signs help with the navigation task, providing information of destination, junctions, exits, distances, etc.

These systems usually divide the tasks into two stages: detection and recognition of the road sign. The first one commonly uses different color spaces in order to enhance road signs typical colors. RGB [6] is easily implemented but usually needs post-processing as histogram enlargement to minimize lighting changes, or morphological transformation as opening or closing to reduce noise. HSI, HSL, HSV [7], [8], are very similar and commonly used since the Hue component does not vary too much under distance or illumination changes. Some authors do not find color segmentation reliable so they prefer using grayscale since it is invariant to the illumination changes and shadows [9]. Achromatic spaces [10] have been defined in order to separate color and non color regions.

In the recognition stage, neural networks [11] are used because of their flexibility since they can deal with occlusions, rotations or road sign aging; but they have the disadvantage of a high computational cost. Normalized correlation [7], [12] allows fast algorithms implementation, obtaining high scores in detection and recognition. The drawback is that depends too much on the models used and on the image quality.

# ROAD GEOMETRY MEASUREMENT

When talking about road geometry, it should be distinguished horizontal and vertical alignments. In the first case, X-Y coordinates are obtained [5], [13]. This information is relevant, for example, for simple navigation applications. However, when dealing with more advanced driver assistance systems, other information of the vertical alignment such as road grade and superelevation are necessary (for example in curve warning systems that estimate the safe speed on curves or fuel optimization systems that take into consideration the following stretches of the road). Datalog vehicles are quite a common method for measuring road geometry [14], [15]. In this case two main solutions are proposed: satellite positioning and inertial measurement systems. The first one provides an absolute reference, but it has problems of signal losses and degradations, it is not possible to obtain superelevation and vertical data usually has large errors. The second one does not have these limitations but the results contain a cumulative error when traveled distance increases [5]. Although combination of both systems is a very widespread solution for correcting results of the horizontal alignment, this solution is not sometimes appropriate for vertical alignment because:

1. For road grade measurement, z-coordinate of GPS data is not reliable enough in most cases and inertial systems include the cumulative error (X-Y GPS coordinates are much more reliable than Z coordinate)
2. For superelevation measurement, there is no useful GPS data, so the only information source that can be used comes from the inertial system.

Considering previous ideas, vertical alignment in digital maps development should rely mainly (but not in every case for road grade if GPS signal is accurate enough) on inertial systems (speed sensors and gyroscopic platforms). But, in this case, if the gyroscope is fixed to the sprung mass of the vehicle, dynamic movements of the body of the vehicle are included in the road geometry measures so they are not as accurate as desired. There are different solutions such as:

- Cancellation of the suspension
- Installing the instrumentation in the unsprung mass
- Measure the displacements of the suspension in order to insert the correction
- Estimate movements using mathematical models

In this paper, digital maps are developed using the combination of GPS receivers and inertial measurement systems on a datalog vehicle. In order to solve the inaccuracies in vertical alignment measurement, the third method is used because options 1 and 2 involve difficult assemblies on the datalog vehicle and option 4 can be slightly less accurate than the third one because the results are not derived directly from experimental data, but a model (with its inaccuracies and uncertainties) is used. Then, the following instrumentation is used:

- RTK DGPS Topcon GB-300 receiver that provided differential corrections of positioning and, in good operating conditions, centrimetric accuracy can be achieved
- Correvit L-CE- non-contact speed sensor to measure the speed and distance

travelled

- RMS FES 33 gyroscopic platform to measure the angles drawn around three axes
- 4 ASM displacement sensors (specifically used for suspension effect correction)
- 12-bit National Instruments DAQCard-6062E acquisition card and a laptop

The GPS signal is used when type 4 accuracy level is achieved, and inertial measures are used when this signal is degraded or lost. To obtain the corrected vertical alignment, more specifically, road grade when GPS signal is degraded or lost and superelevation in any case, the following method is used. The method considers that the gyroscopic platform includes the road grade – superelevation and the pitch – roll angles together. Using the measures of the displacements of the suspension, a plane is fitted and angles of this plane with the reference coordinates system provides actual pitch and roll angles, so subtraction of these values to the absolute values of the gyroscopic provides actual road grade and superelevation. Figure 1 shows a stretch of the horizontal alignment obtained combining GPS positioning and inertial systems. Figure 2 shows the results for road grade (vertical alignment), considering the correction that provides the measurement of suspension displacement.

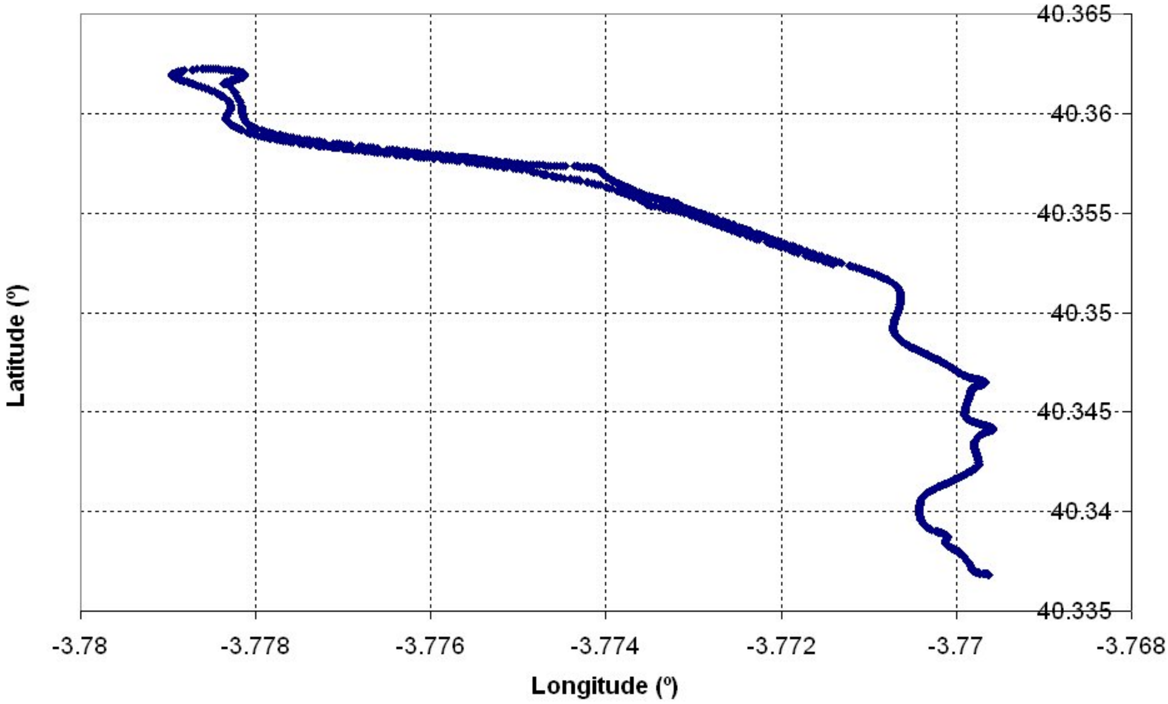


**Figure 1. Horizontal alignment**

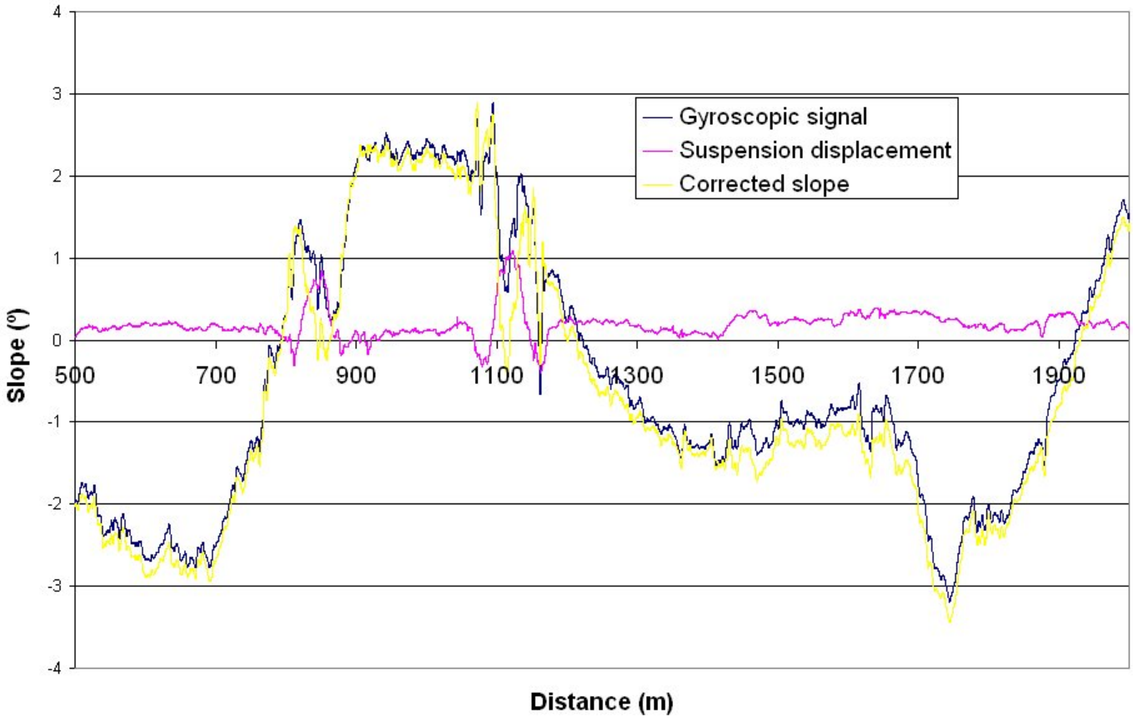


**Figure 2. Vertical alignment (suspension displacements and corrected road grade)**

## DETECTION AND RECOGNITION OF TRAFFIC SIGNS

Two different techniques will be applied in the detection process: in one hand, the vision system uses the HSI color space to enhance the red and blue component of the road signs, since its values do not vary very much under lighting [16] or distance changes. What will be obtained is a grayscale image where the white color means high presence of red or blue, and the black, absence of these colors (Figure 3). On the other hand, an achromatic space has been defined to isolate the end of limit road signs as they are black, grey and white. Data is managed statistically to have a mean value that will be the threshold that separates color and non-color region.


**Figure 3. Grayscale enhanced image.**

To improve the searching time over an image, a pinhole model and homogeneous transformation based method has been developed, flat world and no angle camera movement has been considered. It allows changing the reference system, obtaining on the screen representation of the position of a point in the world. Geometrical restrictions are based on traffic rules that set the dimensions of the road sign (Figure 4).

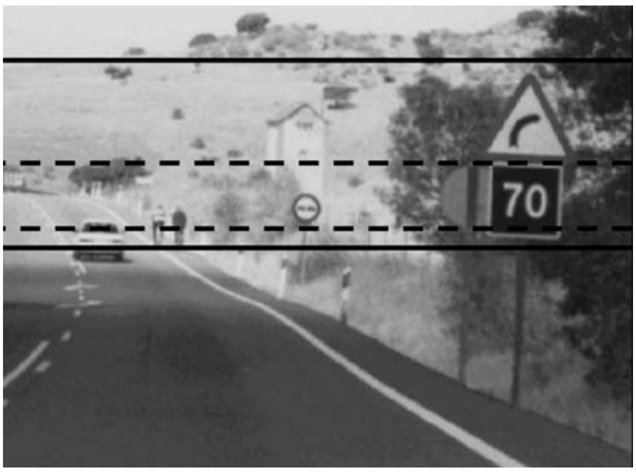


**Figure 4. Geometrical restrictions.**

Due to camera movements, distance or weather conditions, the edges of the road sign borders are often fuzzy. Blurred models deal with these problems since their edges are fuzzy, so they are more realistic and obtain better scores. Different blurred models are defined in order to fulfill the majority of the situations that fuzzy the edges of the plates. As it can be seen in fig. 5, the profiles of the blurred models fits better the profiles of the borders than if a perfect model had been used.

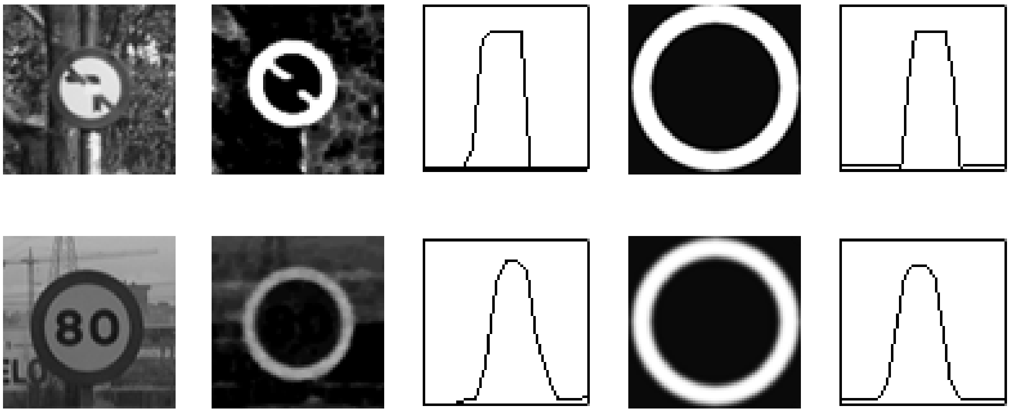


**Figure 5. Blurred model definition.**

Once the road sign is cut off from the grayscale image and normalized, it is used as a model over the template that contains the whole road signs (fig. 6). Normalized correlation is used again, and the output obtained with this operation gives the traffic sign recognized (fig 7). The correlation formula is:

$$C = \frac{\sum_i \sum_j (f(i,j) - \bar{f})(h(i,j) - \bar{h})}{\sqrt{\sum_i \sum_j (f(i,j) - \bar{f})^2 \sum_i \sum_j (h(i,j) - \bar{h})^2}}$$

A horizontal and vertical displacement of pixels is allowed giving nine correlation values one for each displacement. The maximum of these nine correlation values is found for every prototype sign. The overall maximum is considered for the classification.

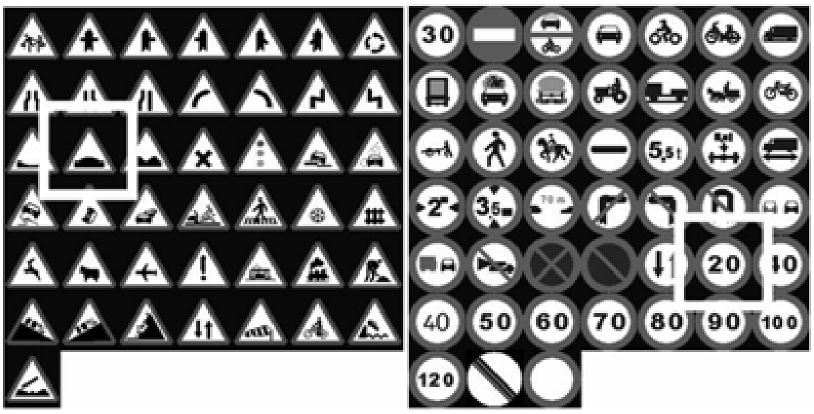


**Figure 6. Road signs templates.**


**Figure 7. Traffic signs correlation results.**

After a road sign detection and classification GPS information is retrieved, thus every road sign has its own real word coordinated associated. This information is combined with the presented on the first part of the paper to automatically develop a detailed digital map. Another use of this information is real time driver warning, providing him the information of road signs as he drives, showing the relevant information on a display inside the vehicle.

# CONCLUSIONS

In this paper, some crucial topics of accurate and detailed digital maps development are tackled. More specifically, a method to remove the effect of the suspension displacement when measuring road grade and superelevation is proposed. This method includes measures of these displacements and a plane is fitted to those points so roll and pitch angles of the sprung mass are calculated. These angles are subtracted to the angles measured by gyroscopic platform in order to obtain the real grade and superelevation of the road.

Additionally, algorithms based on computer vision are developed for traffic signs detection and recognition. These detections and recognitions, combined with geometrical measurements, are used to give a detailed and accurate digital map. Tests under normal driving conditions in difficult environments are shown and the results are quite satisfactory.

## ACKNOWLEDGMENTS

The work reported in this paper has been partly funded by the Spanish Ministry of Science and Innovation (SIAC project TRA2007-67786-C02-01 and TRA2007-67786-C02-02)

## REFERENCES


(1). Njord, J., Peters, J., Freitas, M., Warner, B., Allred, K.C., Bertini, R., Bryant, R., Callan, R., Knopp, M., Knowlton, L., López, C., Warne, T. "Safety applications of intelligent transportation systems in Europe and Japan". Federal Highway Administration. U.S. Department of Transportation. 2006

(2). Wevers, K., Lu, M. "Digital maps, driving systems and traffic safety: the data chain for in-vehicle map databases". *6th European Congress and Exhibition on Intelligent Transport Systems and Services*. Aalborg: 18 – 20 June 2006

(3). Jiménez, F., Naranjo, J. E. "Nuevos requerimientos de precisión en el posicionamiento de vehículos para aplicaciones ADAS". Dyna Ingeniería e Industria. 2009, 84, (3), pp 245 – 250 (in Spanish)

(4). eSafety Forum. 2005. "Digital maps Working Group Final Report". European Commission (eSafety Forum), Brussels.

(5). Jiménez, F., Aparicio, F., Estrada, G. "Measurement uncertainty determination and curve fitting algorithms for development of accurate digital maps for Advanced Driver Assistance Systems". *Transportation Research Part C: Emerging Technologies*. 2009, 17(3), pp 225-239

(6). Bahlmann, C., Zhu, Y., Visvanathan, R., Pellkofer, M., Koehler, T. "A system for traffic sign detection, tracking, and recognition using color, shape, and motion information". *Proceedings of the Intelligent Vehicles Symposium*. 2005, pp 255 – 260.

(7). De la Escalera, A., Armingol, J.M., Pastor, J.M., Rodriguez, F.J. "Visual sign information ex-traction and identification by deformable models for intelligent vehicles". *IEEE Transactions on Intelligent Transportation Systems*. Volume 5, Issue 2, 2004, pp 57 – 68.

(8). Fleyeh, H. "Color detection and segmentation for road and traffic signs". *IEEE Conference on Cybernetics and Intelligent Systems*, Volume 2. 2004, pp 809 – 814.

(9). Soetedjo, A., Yamada, K. "Traffic Sign Classification Using Ring Partitioned Method". *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences*, Vol. E 88-A, Nº 9, 2005, pp 2419 – 2426.

(10). Sotelo, M.A., Rodríguez, F.J., Magdalena, L. "VIRTUOUS: Vision-Based Road Transportation for Unmanned Operation on Urban-Like Scenarios". *IEEE Transactions on Intelligent Transportation Systems*, Vol. 5, Nº 2. 2004, pp 69 – 83.

(11). Garcia-Garrido, M.A., Sotelo, M.A., Martin-Gorostiza, E. "Fast traffic sign detection and recognition under changing lighting conditions". *Proceedings of the IEEE Intelligent Transportation Systems Conference.* 2006, pp 811 – 816.

(12). Betke, M., Makris, N. "Recognition, Resolution, and Complexity of Objects Subject to Affine Transformations". *International Journal of Computer Vision* 44 (1). 2001, pp. 5 – 40.

(13). Jiménez, F., Naranjo, J. E., García, F., Aparicio, F., Zato, J. G., Armingol, J. M., de la

Escalera, A. “Analysis of inertial measurement systems limitations for vehicle positioning in new ADAS applications”. *16th World Congress and Exhibition on Intelligent Transport Systems and Services*. Stockholm (Sweden), 21 - 25 September de 2009

(14). Yerpez, J., Ferrandez, F. “Road characteristics and safety. Identification of the part played by road factors in accident generation”. INRETS, Arcueil, 1986.

(15). EDMap Consortium. “Enhanced digital mapping project. Final report.” 2004.

(16). Chiung-Yao F., Sei-Wang C., Chiou-Shann F. “Road-sign detection and tracking”. *IEEE Transactions on Vehicular Technology*, Volume 52, Issue 5, 2003 pp 1329 – 1341.