Quantify and improve GNSS quality of service in land transportation by using image processing

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1. INTRODUCTION

Most of the Intelligent Transport Systems rely on GNSS positioning information. Unfortunately, most of their uses occur in dense urban areas where signal propagation is degraded by surrounding obstacles because of the reception of NLOS (Non Line-Of-Sight) signals. Since the end of the 90's, as a research institute concerned by transport applications, the LEOST team of IFSTTAR pursues research on the impact of the surroundings of a GNSS antenna on the receiver's performances and in particular on NLOS cases when the direct path is not present or it is undetectable due to its low power compared to the rest of path. NLOS detection and mitigation remains an open research problem that can be studied from different angles: at signal processing level, at observable level and at PVT level [1].
First works of LEOST have dealt to the development of a satellite availability prediction tool based on image processing already (PREDISSAT [2]) for guided transport modes. Then, in collaboration with the Ecole Centrale of Lille, signal processing techniques have been developed to model the evolution of the satellite states of reception versus time and propose pseudo-range error models linked to the different states and in particular the NLOS case where reflected signal can be received without a direct ray. Recent activities are performed in the context of the CAPLOC research project. The main objective of CAPLOC, in collaboration with the Technical University of Belfort Montbéliard, described in [3], is to provide an innovative tool for the positioning function, relying on satellite-based technologies, GPS and EGNOS, and mitigating the difficulties linked to the constricted environment of reception. In the same way than users of 3D models [4-7], our goal is to compare satellite positions to obstacles in order to detect satellite states of reception. Our approach relies on video records of the environments. In this paper, we will present how the images sequences provided by several cameras installed on the roof of the vehicle allow characterizing GNSS performance and we will give a quick overview of how they are used for accuracy enhancement in the CAPLOC project.

2. USE OF IMAGE PROCESSING FOR GNSS PERFORMANCE CHARACTERIZATION

The main aim of the image processing is to classify pixels into sky and not-sky areas. Such a classification allows us to obtain several data: the horizon line separating masking obstacles from open sky, and an evaluation of the size of the sky area. In this section, the first objective is to show in particular how the percentage of sky, given by image processing can allow a qualification of the GNSS performance obtained by the terrestrial transport user. The tests presented in this section are carried on a database acquired in the city of Belfort (France). This database contains: a reference trajectory, a GPS measurement set, and a sequence of images. To benefit from a path reference and be able to estimate positioning error and geo-referenced images, we have used a GPS-RTK (Real Time Kinematic) receiver. The positioning data are given by an uBlox receiver implemented in a Safedrive receiver, without any additional sensor. The image database relies on a fisheye camera (characterized by a wide field of view -180°-), which is located on the roof of the vehicle and oriented upwards to capture images of the sky. The image database contains 173 real images with their reference (given by an expert in order to evaluate the quality of the image processing strategy). Figure 1 illustrates an example of images acquired in Belfort during the data collecting campaign.

Figure 1: Fish-eye images acquired in the city of Belfort (France)

In order to provide information such as the percentage of visible sky in the image or the horizon line, we propose an image processing strategy, which is composed of several steps illustrated in figure 2:

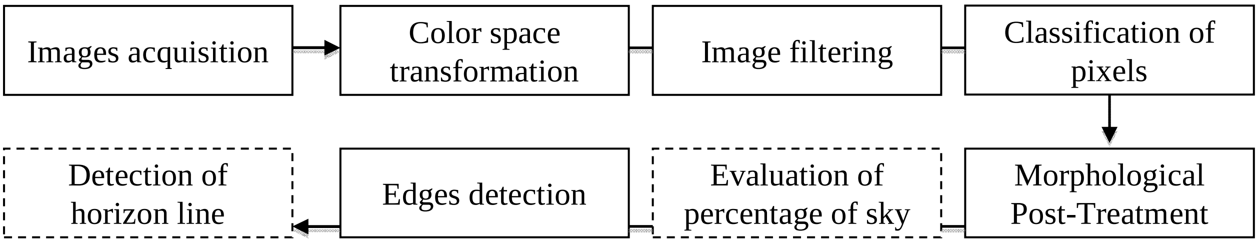

Figure 2: Synopsis of image processing to evaluate the percentage of sky and the horizon line

Once the image acquisition made, the second step consists in transforming the acquired image in a most appropriate color space (which guarantees a better detection/classification of objects of interest). The third step concerns the image filtering in order to simplify the acquired image. A classification of pixels is also made in order to classify each pixels of the simplified image into two classes (sky and not-sky). But some pixels can be classified incorrectly, that is why, a morphological post-treatment (based on a neighborhood study) is also used. The sixth step consists in evaluating the percentage of visible sky in the image (the number of pixels labeled sky compared to the total number of labeled pixels in the image). To detect the horizon line, a supplementary step of edge detection is added to the previous steps. The proposed method has been evaluated on the CAPLOC database (173 images) and provides a good classification rate of 96,3% (in HSL color space, with a median filter and a classification of pixels into two classes with the Fisher algorithm on the luminance component). Figure 3 illustrates the good classification rate and the percentage of visible sky for all images of the CAPLOC database.

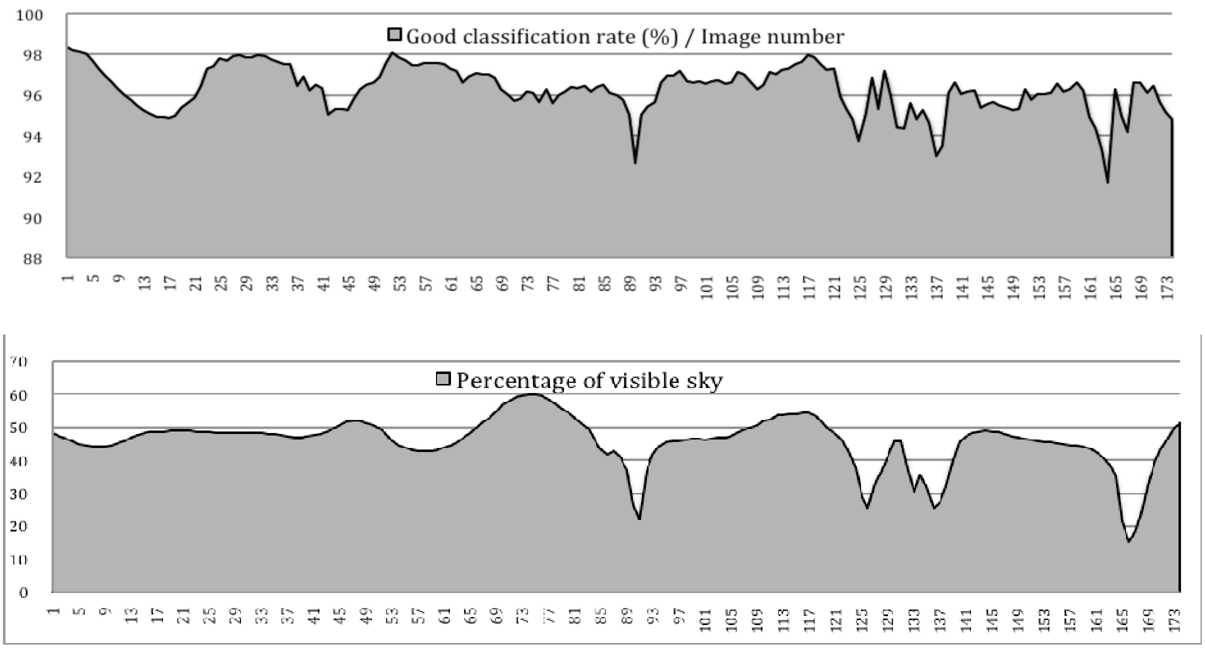

Figure 3: Classification results and percentage of visible sky for all images of the CAPLOC database

A work in progress consists in defining a relation between this percentage and the positioning error or more generally the GNSS availability and accuracy. In the current database, the percentage of sky varies from 15,3 to 59,8% of the image and the GNSS availability is no more guaranteed or its quality is too weak to be used if the percentage of visible sky is below 40%. Considering only this percentage and the accuracy, this trajectory does not allow drawing a correlation. DOP is linked to the percentage of sky in the image but also to the geometry of the mask. Some complementary inputs will be studied in close future.

3. USE OF IMAGE PROCESSING FOR GNSS PERFORMANCE ENHANCEMENT

In the CAPLOC project, we have also proposed two other strategies of image processing: the first one consists in identifying in real time where satellites are located in a sky regions (with direct signals) and then excluding those located in non-sky regions (reflected/blocked signals) when calculating the position. The proposed strategy, illustrated in figure 4 is composed of several steps described below.

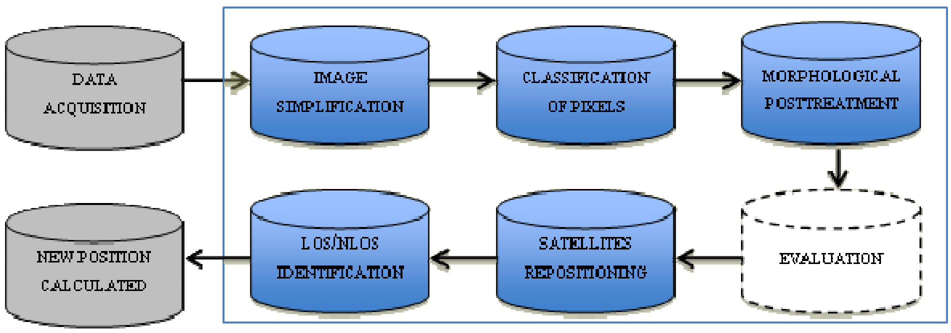

Figure 4: Synopsis of image processing strategy for GNSS performance enhancement (source: [CAPLOC project])

This strategy is composed of several steps. Once data have been acquired, the first step of image processing consists in simplifying the acquired image using a geodesic reconstruction by dilatation (RGD) with an optimum parameter of contrast H or a segmentation using color/texture information [8]; The second step consists in classifying all pixels into two classes (sky and non-sky). In previous works [9], the authors have compared the performance of different clustering algorithms on a smaller database and conclude that Fisher and kppv algorithms give the best results. A morphological post-treatment, which consists in reclassifying incoherent pixels, can be added to enhance the classification. The fourth step consists in satellite repositioning in the acquired image and in the classified image. The last step of image processing consists in identifying which satellite is located in a sky region (received with a direct signal) and in a non-sky region (with blocked/reflected signals) in order to calculate a new position (more precise) including the exclusion of some of them. Figure 5 illustrates, for one image of the database, the satellite states of reception (satellites with direct signals are represented in green, and satellites with blocked/reflected signals are represented in red).

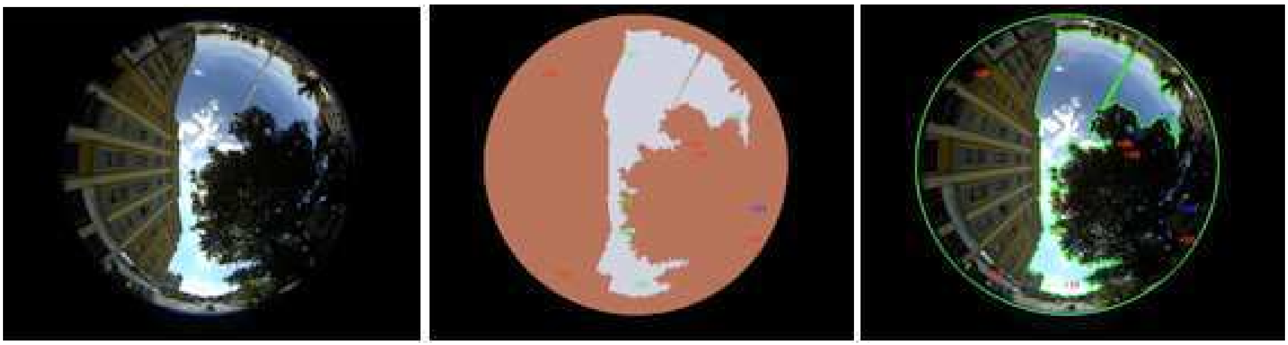

Figure 5: Example of image, its classification and satellite states of reception (source: [CAPLOC project])

Figure 6 illustrates the position calculated with a classical EKF, using all the available satellites (blue points) or only the LOS ones detected by the image processing strategy (green points). The results are compared to the ground truth measured with a RTK receiver (red points). One can conclude that the results are mixed but promising. Indeed accuracy is increased, in particular when the vehicle is static (the first part of the trajectory). There multipath is well-detected and eliminated. In the rest of the trajectory, the image-based exclusion has been too severe and degrades accuracy because of a poor resulting geometry of the used satellites. But, this work is being continued in the CAPLOC project and we hope to increase the results by taking into account other information and the vegetation influence.

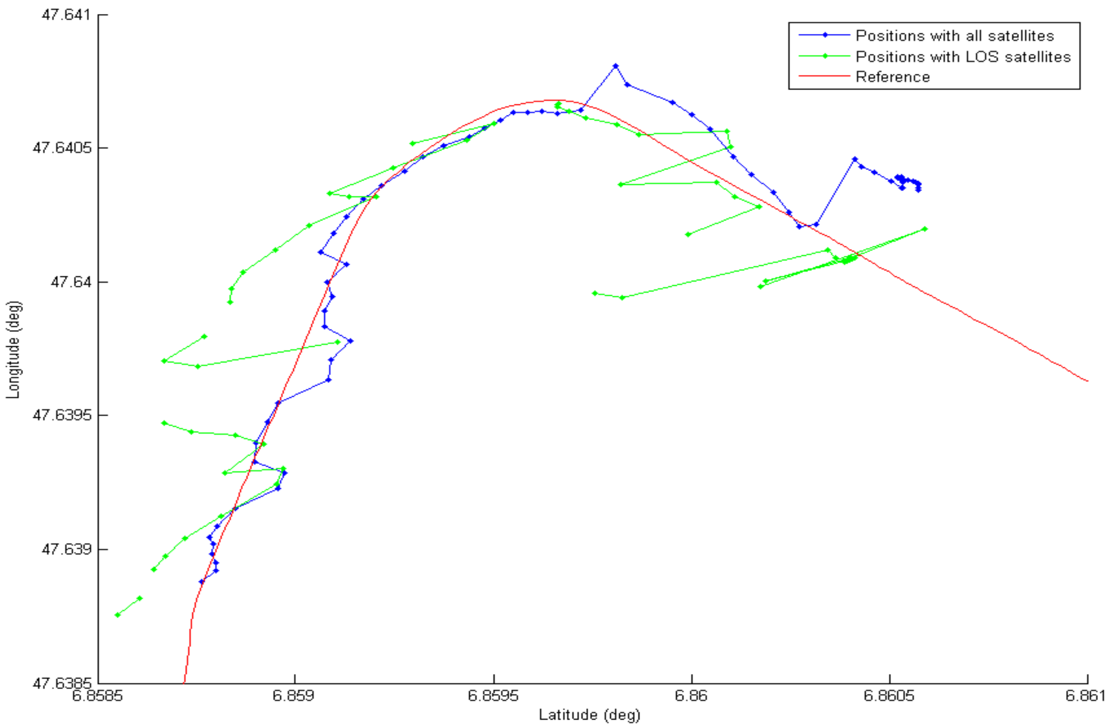

Figure 6: View of the vehicle's trajectory in Belfort calculated with a classical EKF, using all the available satellites (blue points) or only the LOS ones detected by the image processing strategy (green points).

The second strategy developed in the CAPLOC project consists in developing a process of 3D model creation in order to model the environment structure around the antenna. This 3D reconstruction is based on fisheye stereovision [10] that will allow us to estimate delays caused by reflections if the model can be used in a ray-tracing tool.

4. CONCLUSION AND PERSPECTIVES

The work presented here is focused on the characterization of the GNSS satellite visibility by the characterization of the surroundings of the antenna obtained by image processing. Automatic image processing developed for these tasks provides different information such as: classification of the image into two classes: sky or not-sky, elevation of the masking obstacles all around the antenna, percentage of sky visible, etc. All of these studies help us to optimize the use of GNSS signals in harsh environments in order to offer to a terrestrial user the best he can expect considering the reception conditions.

These data are used in different ways function of the projects: i) In the CAPLOC project, satellites states of reception are determined in order to enhance accuracy by choosing the best satellites to use; ii) The percentage of sky will be one of the indicators of GNSS performance, combined with DOP at least; iii) In the SATLOC railway-applied project, images will provide to a signal simulator real masking environments in order to evaluate equipment from a simulation point of view. Furthermore, this knowledge of the propagation environment is full of potential for other applications as in experimentation campaigns (propagation channel measurements for example) where the information of satellite state of reception is required.

5. REFERENCES

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