SENSING THE VISIBILITY RANGE AT LOW COST IN THE SAFESPOT ROADSIDE UNIT

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ABSTRACT
In the framework of the SAFESPOT European project, we have designed a roadside system which aims at detecting and characterizing critical environmental conditions such as dense fog and strong rain showers. The proposed system is located in the roadside unit whose functional architecture is recalled. The whole data chain from the sensor to the data fusion is presented, as well as the whole work carried out which ranges from the user needs to the system integration. This sensing system is prone to be used in Hazard & Incident Warning and Speed Alert infrastructure-based SAFESPOT applications.

KEYWORDS cooperative systems, visibility range, image processing, situation refinement, weather conditions, local dynamic map, road-side equipment.

INTRODUCTION

By combining data from vehicle-side and road-side sensors, the SAFESPOT project will allow to extend the time in which an accident is forecasted from the range of milliseconds up to seconds thanks to V2V and V2I communications [1]. Hazard & Incident Warning (H&IW) and Speed Alert (SpA) applications triggered by degraded weather conditions are among the foreseen infrastructure-based SAFESPOT applications [2]. To reach this goal, a camera-based sensing system as well as a cooperative data fusion framework has been designed to detect the weather conditions and estimate the visibility range in the vicinity of the roadside unit (RSU). In this paper, we present the whole data chain from the sensor to the data fusion whose final results are written in a dedicated Local Dynamic Map (LDM) [3].

THE SAFESPOT INFRASTRUCTURE PLATFORM

The principal functions of the SAFESPOT RSU are data acquisition, processing and storage. The data input come from several different sources. The most important are the roadside sensors but also the SAFESPOT vehicles. To improve the quality of information provided by the different inputs, the RSU performs three levels of processing:
- Pre-processing transforms raw sensor data into information useful for data fusion.
- Object Refinement (OR) merges data from different sources in order to improve the confidence of detection of moving objects, to extend the knowledge associated with objects and to locate of these objects by means of map matching algorithms;
- Situation Refinement (SR) is responsible for data fusion describing traffic situations such as congestion, road weather or other black spots. In contrast to the object refinement, the incoming data are merged concerning a particular situation with an unambiguous reference to the road map. In this functional architecture, the weather and visibility range monitoring are processed by the roadside sensors, circulate through a VANET and are refined by the so-

called 'Environmental Consolidator'. An overview of the different components of the infrastructure platform is shown in Figure 1.

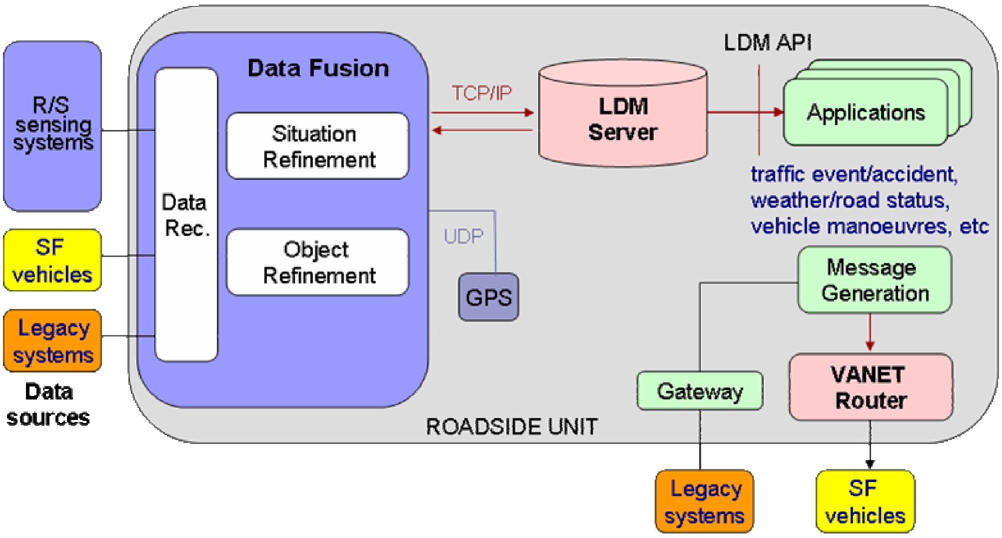


Figure 1. Overview of the reference infrastructure platform specified by SAFESPOT.

USER NEEDS AND SYSTEM REQUIREMENTS IN VISIBILITY RANGE SENSING

User needs

Based on the EITSFA[1], the system shall be able to enhance the vision of the driver in adverse visibility conditions (e.g. in fog) and to measure the range of visibility and to detect visibility reductions caused by adverse weather and pollution conditions (but not darkness).

System requirements

Based on the French standard NF P 99-320, the system shall detect visibilities below 400m and assign the low visibilities to one of the four categories of table 1 and detect the origin of the visibility reduction (fog, hydrometeors, water projections).

Table 1. Visibility ranges issued from the French standard NF P 99-320.

Visibility range	Visibility distance [m]
1	200 to 400
2	100 to 200
3	50 to 100
4	< 50

CAMERA BASED SENSING SYSTEM

Cost-benefit analysis

Currently, fog and rain detection sensors are dedicated optical sensors. They are quite expensive compared with the price of a single high-end camera (at least x4 higher). Furthermore, existing fog sensors have some accuracy problems in dense foggy weather and inhomogeneous fog, since the detection is done in a very small volume [4]. Our detection algorithms can be implemented in existing video-based traffic monitoring systems. In this

[1] European ITS Framework Architecture

way, the road operator has no supplementary hardware to install on the roadside. He has just to install new software in the RSU and to run the different software simultaneously. In the case of a new traffic monitoring system installation, our work allows the multiplication of applications based on roadside cameras and thus reduces the installation cost, since the benefits are higher.

Principle

Common vision-based traffic monitoring systems rely on background modelling methods, where each video-frame is compared against a reference or background model to identify moving objects. Due to illumination changes and "long term" changes within the scene, it is necessary to constantly estimate this background model. Thereafter, the time constants are generally set equal to the average time a moving object needs to cross the image. Adverse weather conditions have different temporal dynamics. Fog is generally considered as relatively steady weather, whereas rain and snow are dynamic phenomena. Based upon these considerations, the background model (BG) can thus be used to detect and estimate the fog density whereas the foreground model (FG) can be used to detect rain or snow presence. This principle is summarized in Figure 2.

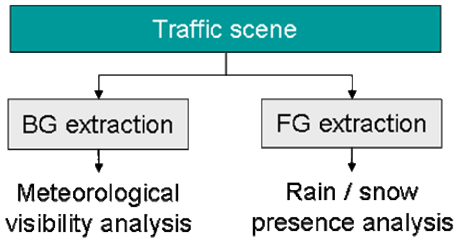


Figure 2. Principle of foreground (FG) and background (BG) models separation for weather conditions processing.

Designed detection algorithms

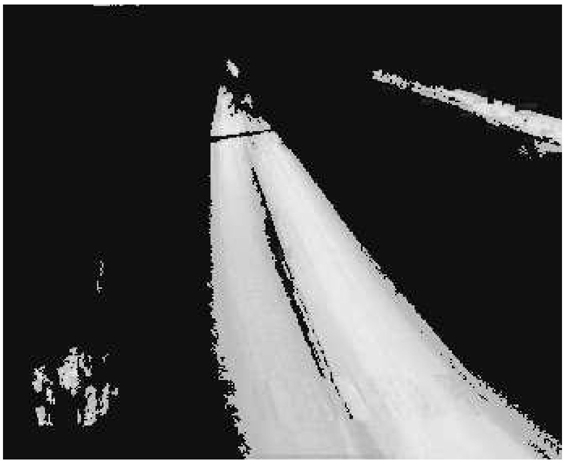
Table 2 gives the different functionalities of the image processing software developed for the SAFESPOT project.

Table 2. Overview of the functionalities of the camera-based detection algorithms.

Functionality	Operation range
Fog presence	Day and night
Fog intensity	Day
Visibility range	Day and night
Rain presence	Day

For the daytime fog situation, we proposed a reference-free roadside camera-based sensor which not only estimates the visibility range in daytime but also detects that the visibility reduction is caused by fog, unlike previous methods [5]. Unlike previous approaches, we take the 3-D scene structure into account by detecting where driving space is, by filtering the objects in the region of interest and by studying the precision of the system with respect to the camera characteristics. Some results are shown in Figure 3.

(a) Urban intersection in daytime foggy weather



(b) Driving space area determined by the temporal accumulation of the FG model

(c) Daytime fog detection and meteorological visibility distance estimation (black line)

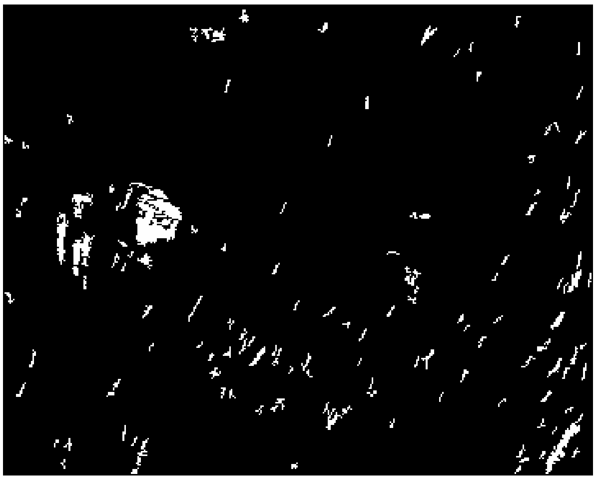
(d) Visibility distance estimation (blue line)

Figure 3. Daytime fog processing by the CCTV camera.

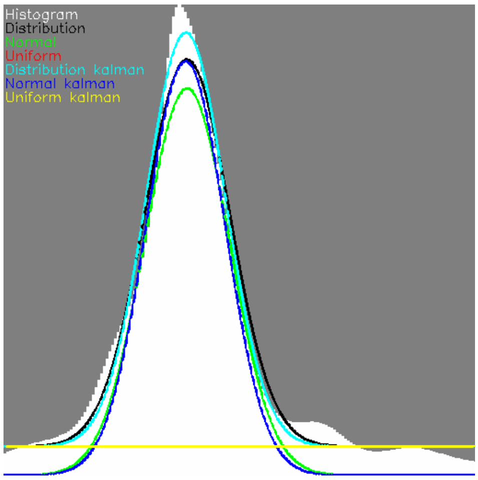
Concerning rain detection, once camera parameters are adjusted to see rain, background subtraction can be used to extract rain streaks from traffic videos, which are then assumed to be majority and to be almost vertically oriented. The gradients orientation is then computed on the rain streaks and a cumulative histogram is then computed. The remaining task is then to detect an eventual peak in the histogram which can be related to the rain or snow presence [6, 7]. Some results are shown in Figure 4.

(a) Original image

(b) Background image



(c) Foreground image



(d) Orientation histogram with different fittings

Figure 4. Rain processing by the CCTV camera.

For the other detection algorithms, the interesting reader is referred to [5].

Performances

On the tested video sequences, the 'daytime fog presence' component is able to detect fog with a great accuracy (100%). The 'visibility range estimation' component has accuracy smaller than 10% based on static images grabbed with an in-vehicle camera. The results can be extrapolated to a fixed sensor. The 'rain presence' algorithm has an accuracy of around 95% on different video sequences. The optical setting of the camera so as to see rain drops remains however an open issue. We may think that, at this moment, only hard rain showers, drizzle and falling snow, can be recognized by the component. Furthermore, due to a lack of data, we were not able to correlate the intensity of rain with the confidence on the results of our rain detection algorithm.

Camera specifications

Based on the sensitivity analysis of the previous detection algorithms, we have proposed a methodology to specify the relevant camera. The different technical solutions which have been found are detailed in table 3.

Table 3. Technical solutions found to fulfil the specifications of the SAFESPOT camera

Matrix [inch]	1/3	2/3	½
Mounting height [m]	5-6	5-6	6
Focal length [mm]	4.2	4.8	4.5
Pixel size [µm]	4.65	6.45	4.65
Horizontal resolution [pixel]	1040	1024	1360
Pitch angle [degree]	31-38	29-64	28-29

We have purchased cameras corresponding to the third solution of the Table 3, i.e. DALSA GENIE-M1400 (see Figure 5 right). The optimal configuration of this camera is schematized in Figure 5 left. Since such a camera can not be equipped with an auto-iris lens, we designed an algorithm to optimize the exposure time so as to obtain visually optimized images [8] thanks to the GigaE standard which allows configuring dynamically the camera.

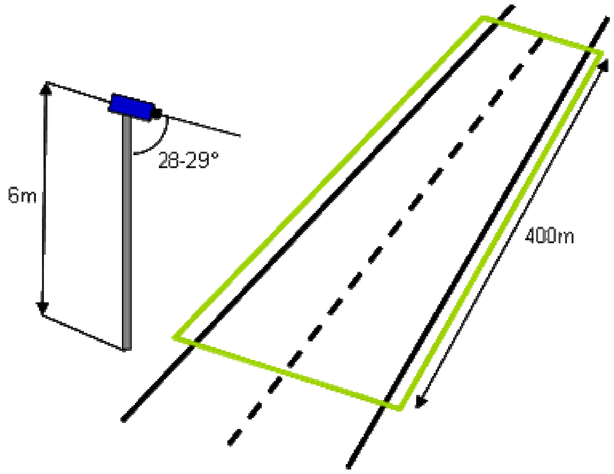


Figure 5. Left: Optimal configuration of the specified camera. Right: Purchased camera.

ENVIRONMENTAL CONSOLIDATOR

Principle

The camera along with the aforementioned processing algorithms is the main RSU environmental sensor. VANET data which comes from passing vehicles (e.g. wipers status, fog light status…) are complementary. Depending on existing road equipment, other environmental sensors (e.g. a weather station) can be connected to the RSU. To give a coherent view on the environmental conditions in the vicinity of the RSU, we designed a situation refinement module called the 'environmental consolidator'. First, the different sensor outputs are written in the LDM, which is considered, at this stage, as a simple storage. Thereafter, thanks to the notification mechanism of the LDM, the outputs of the RSU sensors trigger the creation of so-called environmental events in the LDM.

Application to fog refinement

For the refinement of fog situation, the proposed algorithm is as following:

1. Determination of fog presence by the CCTV camera
2. Confirmation or not by a weather station using physical properties of fog
3. Combination of the different sensors outputs to compute a single visibility range descriptor [5]

However, at that moment, the location of the event is still restricted to the immediate vicinity of the RSU. To extend or to reduce the extent of the environmental event, the data coming from the VANET are used. The visibility range is then the spatial barycenter of the different sensors outputs. The corresponding uncertainty of the measurements is the sum of:

- The uncertainty of the sensors themselves
- The uncertainty coming from the distance to the data sources
- The uncertainty coming from the status of fog lamps of SAFESPOT vehicles on the road section

The interesting reader is referred to [9] for the technical details of the 'Environmental Consolidator'. In this way, H&IW and SpA applications can be triggered by the notification of the creation of an environmental object with an associated confidence in the LDM. This process is illustrated in Figure 6.

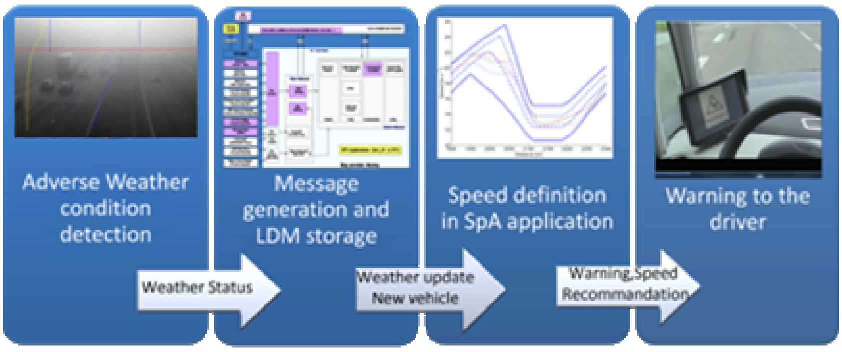


Figure 6. Illustration of the process from adverse weather condition detection to the speed warning to the driver.

SYSTEM IMPLEMENTATION AND INTEGRATION

The RSU which is developed by LCPC is composed of several PCs, a weather station (Davis Vantage Pro 2 Plus), a fixed camera and a Variable Message Sign unit. This VMS is used to replicate the in-vehicle warnings for non-SAFESPOT vehicles. The whole system is installed in a shuttle equipped with a pneumatic pole, allowing moving the RSU from one test site to another. The environmental detection algorithms run on the RT-Maps platform. The different components of the system are shown in Figure 7.

Figure 7. The different components of the RSU developed by LCPC: left: the shuttle where the RSU computers are located with its pneumatic pole. Middle: the weather station. Right: the VMS unit.

The SAFESPOT vehicles of LCPC are two Renault Clio Estate equipped with the standard SAFESPOT vehicle framework. The LDM used is the one developed by NAVTEQ running on the ADAS-RP platform. One of the vehicles is shown in figure 8.

Figure 8. Illustrations of one of the SAFESPOT vehicles assembled by LCPC.

CONCLUSION AND PERSPECTIVES

In the framework of the SAFESPOT project, we have designed a roadside system which aims at detecting and characterizing critical environmental conditions. In this paper, we presented the whole data chain from the sensor to the environmental object written in the LDM and the whole work carried out from the user needs to the system integration. Up to now, the sensing system is ready to be used in the SpA and H&IW SAFESPOT applications.

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