Abstract

The paper deals with the PANsafer project which aims at improving safety at Level Crossings. This project integrates several tasks; First a fine statistical analysis is carried out using accidents/incidents data basis as well as several other sources. At the same time we lead a human behaviour study at LX area in order to determine potential risky behaviours. Then a functional model integrating all the elements in the LX area is established. This model will serve as a basis to point weak-points at the LX safety chain and to determine the potential improvements that have to be carried. The paper mainly focuses on two main technological solutions that potentially improve global safety at LX by anticipating and detecting risky situations and provide useful information able to prevent accidents. The first system is based on video surveillance and the second is a wireless communication system. The architecture of both systems are roughly discussed within this paper.

I Introduction

Every year, more than 400 people are killed in over 1200 accidents at road-rail level crossings in the European Union. Together with tunnels and specific road black spots, level crossings have been identified as being a particular weak point in road infrastructure, seriously jeopardizing road safety. In the case of railway transport, level crossings can represent as much as 29% of all fatalities caused by railway operations. Up to now, the only effective solution appears to involve upgrading level crossing safety systems even though in more than 90% of cases the primary accident cause is inadequate or improper human behavior rather than any technical, rail-based issue.

Recently, the Coordination Action for the Sixth Framework Programme “Safer European Level Crossing Appraisal and Technology” (SELCAT) [1] provided recommendations for further actions intended to improve safety at Level Crossings, noted LX in the sequel. Considering existing input from other projects as well as its own analysis, SELCAT’s recommendations were developed around two major ideas: (a) the use of advanced technological
solutions designed to minimise the impact of human factors as the main cause for accidents at LXs and, (b) a joint rail and road sector strategy to control and reduce risks at LXs.

Among the major high level recommendations provided by this Coordination Action, one is to encourage society to recognise the bi-modality of road/rail interface and work closely with the road and rail sectors and all relevant governmental agencies, to help reduce levels of risk from LXs.

The PANsafer project (Towards a safer level crossing, [2], in response to the ANR-VTT, aims to contribute actively to the reduction of level crossing accidents by the:

- Collection, analysis of the existing accident data bases and the possibility of cross-collaboration between rail and road accidents circumstances.
- Highlighting of the principal causes of the accidents regarding the functional identification of the accidents scenarios: main actors involved and interrelations between them.
- Creation of circumstances whereby partners, in the rail and road sectors, can make a significant contribution to the reduction of accidents, injuries and fatalities at level crossings.
- Analysis of the users' behaviour and the behaviour linked to the infrastructure and its exploitation modalities,
- Sensing and detecting automatically some potentially dangerous situations at level crossing.
- Exploring new technologies and harnessing appraisal techniques to optimise the communication around the level crossing.

The activities of PANsafer should lead directly to the improvement and expansion of intermodal collaboration between the road and rail sectors.

The initial originality of PANsafer project, and which constitutes its main issue, is that it takes into account simultaneously rail and road safety components in transport. These two components are traditionally separately tackled because of the separation of the corresponding organisation authorities.

This project is largely fed by previous knowledge accumulated by passed research carried out by the different partners of the project.

PANsafer constitutes consequently a project with 3 levels of federation:

- Partners of different nature: Research Centre, Universities, Operators, industrials.
- Very different disciplines : accidents' experts, psychologists, technicians with a large communication between Engineering and Human Sciences
- Very different technologies: tools of telecommunication, of video surveillance with the associated data processing.

The project began in June 2009. The paper aims at presenting the main results achieved so far. The outline of this paper is as follows: in section II, the method to establish the functional model of the LX is discussed. We also explain how this model will be used to point weak-points in the LX safety chain to integrate improvements in the shape of either new operational procedures or as a technological solution. In section III, two potential technological solutions are discussed, and finally in section IV we conclude the paper while sketching the mains tasks to be undertaken within the PANsafer project.

II. From a Functional Model to a Detailed Specification of Potential Solutions

II.1 Functional model
Establishing a functional model is one of the tasks to be undertaken within the PANsafer project. In fact, we aim at developing a basis model which explicit all the functions delivered in the LX environment, this model will serve as reference to the subsequent tasks.

To obtain such a model, a detailed analysis of the LX environment will be carried out. First, all the actors involved in the LX area are inventoried, then a list of the services awaited by these actors is established. Moreover, these services are classified in such a way to bring out the main functions of the LX protection system, and the relations between all the identified functions are determined.

Let us recall here that the first tasks undertaken in the framework of the PANsafer project deal with the accidents/incidents statistics at LX and are assumed to give a fine analysis which points out the main causes and the potential situations which give rise to accidents at LXs. The idea then is to dispatch the results of the statistical analysis and its interpretation into the functional scheme of the LX environment. This way, all the weak points within the LX environment will be pointed out to give roughly the main elements to act on. In addition, the state of the art undertaken in the early work-packages of the project as well as the studies led earlier by the project partners show that several solutions, both organizational and technical, are potentially useful to improve safety at LX. Hence, according to the results of the previous tasks, namely the weak points within the LX functional model, a list of the retained solutions to be implemented will be established while indicating clearly the functions to be improved.

Figure 1 gives an overview on the different tasks undertaken in order to establish the LX functional model.

II.2 Specification of the retained solutions
The following step consists of a detailed specification of the solutions retained. The specification depends on the type of the solution:

1- For procedural solutions:
   a) Justification:
      - according to the results of accidents/incidents statistics
      - return on experience: this concerns the solutions already implemented elsewhere (state of the art), and consists in detailing the results obtained by setting the new procedures
      - appraisal of road and railway experts: RFF and CERTU partners who are respectively Infrastructure Managers and road managers will analyze the procedural changes and give their opinion both on the efficiency and the convenience of the solution to the French context.
   b) Functional description: this consists in integrating the retained solution into the global LX functional model
   c) Awaited gains, cost/benefit analysis
      - Analysis of the impact on the LX functional model
      - Cost assessment
      - Benefit expected: from REX, etc.

2- For technical solutions: A technical solution consists in introducing a new service in such a way to improve services rendered to some actors in the LX environment, for instance by providing additional information, etc.
   a) Justification:
      - based on the functional model, the functions which will be impacted (improved) will be detailed
      - appraisal of technical experts: Experts on the technology used will assess the feasibility of the solution as well as its technical convenience for the LX environment
      - appraisal of railway/road managers: Railway and road managers will analyze the global impact of the new solution on the railway operation and road traffic, while taking into account human factors.
   b) Functional description:
      - integration of the solution into the global LX functional model
      - requirements: in terms of performance and Reliability, Availability, Maintainability and Security (RAMS)
   c) Specification of use scenario
      - use cases: by determining the situations in which the new solution will be involved
      - interaction with the other elements in the LX environment

III. Technological solutions

III.1. Video Surveillance system

Today, high technology systems are developed to avoid collisions between trains and road vehicles. Nevertheless, high safety requirements may mean a costly system which will hinder their actual use. Systems having unacceptable levels of false/missed detection have adverse effects and should not be implemented either.
Several conventional object detection systems have been tested on level crossings, and provide more or less significant information. Referring to the literature, little research has focused on passive vision to solve the problems at LXs. Among the existing systems, two of them based on CCTV cameras are to be distinguished:

- A system using a single camera [3]. It uses a single CCD camera placed on a high pole in a corner of the LC, classifying objects as cars, bikes, trucks, pedestrians, dogs, papers, etc., and localizing them according to the camera calibration, assuming a planar model of the road and railroad. This system is prone to false and missed alarms caused by fast illumination changes or shadows.

- A system using stereo cameras [4], with a stereo matching algorithm and 3D background removal. This system correctly detects vehicles and pedestrians by day and night under usual weather conditions, but is extremely sensitive to adverse weather conditions, like heavy rain, fog or snow.

### III.1.1 Overview of the system

Our research aims at developing an Automatic Video-Surveillance (AVS) system using the passive stereo vision principle. The proposed imaging system uses two cameras to detect and localize any kind of object lying on a railway level crossing. The system supervises and estimates automatically the critical situations by detecting objects in the hazardous zone defined as the crossing zone of a railway line by a road or path. The AVS system is used to monitor dynamic scenes where interactions take place among objects of interest (people or vehicles).

After a classical image grabbing and digitizing step, this architecture is composed of the two following modules:

- **Motion detection module**: the first step consists in separating the motion regions from the background. It is performed using Independent Component Analysis (ICA) technique [5] for high-quality motion detection. The color information is introduced in the ICA algorithm that models the background and the foreground as statistically independent signals in space and time. Although many relatively effective motion estimation methods exist, ICA is retained for two reasons: first, it is less sensitive to noise caused by the continuously environment changes over time, such as swaying branches, sensor noise, illumination changes, etc. Second, this method provides clearcut separation of the objects from the background, and can detect objects that remain motionless for a long period of time. Foreground extraction is performed separately on both cameras. The motion detection step allows focusing on the areas of interest, in which 3-D localization is applied.

- **3-D localization module**: this process applies a specific stereo matching algorithm to obtain a 3D localization of the detected objects. In order to deal with poor quality images, a selective stereo matching algorithm is developed and applied to the moving regions. First, a disparity map is computed for all moving pixels according to a dissimilarity function entitled Weighted Average Color Difference (WACD) [5]. An unsupervised classification technique is then applied to the initial set of matching pixels. This allows to automatically select only well-matched pixels. The classification is performed applying the Confidence Measure technique described in [6]. It consists in evaluating the result of the likelihood function, based on the "winner-take-all" strategy.

### III.1.2 Experimental Results

Several evaluations of our algorithms have been carried out in real world situations. For this purpose, data sets have been acquired, composed of a hundred real scenarios of cars, pedestrians, objects, etc., crossing different
LXs in France and Switzerland. These scenarios are either real events, or played by actors in order to increase the number and variety of cases, and allow evaluating in depth the accuracy of our obstacle detection system in terms of objects extraction and 3D localization (Figure 2).

![Figure 2. (a) Left-hand image (b) Moving car extracted by ICA (c) Disparity map obtained by WACD likelihood function. The red pixels are false matches (d) Improved disparity map using Confidence Measure.](image)

The different steps described in the previous sections are illustrated in Figure 2, showing a car crossing a LX in Lausans (Switzerland). ICA is applied to the left-hand image. The segmentation results are used as motion constraints to the stereo matching process, yielding quite often several disparity values for each detected foreground point. The false matches corresponding to wrong disparity values are detected automatically using the confidence measure as described in [6]. However, the final disparity map obtained for each object allows locating very precisely each object at the LX. The foreground extraction method based on ICA has already been evaluated in terms of Recall (95%) and Precision (98%), on a set of several hundreds images with manually elaborated ground truth.

The introduction of the confidence measure in the matching process improves the accuracy of the disparity of each segmented object. The disparity allows estimating the 3-D position and spatial occupancy rate of each segmented object.
III.1.3 Summary and Discussions

In this section we have proposed a processing chain addressing safety at level crossings composed of a foreground extraction based on ICA, followed by a robust 3D localization taking advantage of a novel hierarchical belief propagation algorithm based on Confidence Measure. Although the processing time is further increased by the stereo matching, the localization results are more accurate. Experimentations show the effectiveness of our method in level crossing applications. For this purpose, real-world data sets have been shot at four different level crossings, including a hundred scenarios per level crossing under different illumination and different weather conditions. The global chain still needs to be evaluated in a comprehensive sampling of weather conditions.

The main output of the proposed system is an accurate localization of any kind of object in and around a level crossing. For safety purposes, the proposed system will be coupled with the already existing devices in each level crossing. The states of the traffic light and the barriers will be taken as input in our vision based system. The level of an alarm depends on the configuration of the different parameters. For instance, the presence of an obstacle in the crossing zone when the barriers are lowering is a dangerous situation and the triggered alarm must be of high importance. A Preliminary Risk Analysis (PRA) seems an interesting way to categorize all levels of alarms. In the frame of PANsafer, these different parameters will be combined transmitted to those allowed to interact with given such situation. The communication tools and the type of information to be transmitted are described in the next section.

III.2 LX advanced driver information system

III.2.1 Introduction

Communications are vital for seamless and safe railway operations. Using both Vehicle to Vehicle communications (V2V) and Vehicle to Infrastructure (V2I) communications, they are also becoming vital on the road side with many different concerned users. In the project PANsafer, we decided to develop and evaluate an infrastructure to vehicle (I2V) communication system with the goal of improving safety at LX. To illustrate the problem, at Britain’s level crossings only, between January and September 2008 there were nearly 900 incidents involving a vehicle. These figures show also that vehicle drivers are very much concerned and that an advanced driver information system delivering warning information inside the vehicles can most likely increase safety at LX.

As far as railways are concerned, Communication Based Train Control (CBTC) systems, also known as Positive Train Control (PTC) systems, provide positive train separation, speed enforcement, and road worker protection utilizing wireless communications to exchange control information. As far as roads are concerned, based also on wireless communications, VANETs - the Vehicular Ad-hoc NETworks could provide a broadcasting facility between vehicles and the infrastructure, within radio line of sight, to deliver real time information on traffic, road conditions and hazards [7].

Therefore, at rail road crossings, these wireless communication systems could be used to reduce road-rail intersection collisions by transmitting train movement information to road users. In PANsafer, a reliable, safe and high data communication link from the infrastructure to vehicles is currently developed. For these V2V and V2I
applications, frequency allocations are available in most regions of the world, below 1 GHz in Japan, between 5 and 6 GHz in the US and Europe.

III.2.2 PANsafer studied scenario

To deliver real time LX warning information to the driver, we decided to use the existing vehicle or personal navigation devices (PND). These navigation devices have the capability to receive real time traffic information by means of the Radio Data System (RDS) in Europe, the DAta Radio Channel (DARC) in Japan and the cellular phone, generally using the General Packet Radio Service (GPRS). Figure 3 shows the selected PANsafer scenario. An I2V communication system working as a beacon is installed at the LX. It is connected to the LX control command system and receives the LX status. The beacon broadcast periodically this status, up to a few hundred meters range, all around the LX. This information is received in the vehicle using the corresponding V2I equipment. A short range personal area network communication system (Bluetooth™) is used to transfer this information from the vehicle receiver to the PND also located in the vehicle [8]. The PND selectively displays the LX real time information to the users who are effectively going to cross the LX.

Figure 3: PANsafer Infrastructure to vehicle communication scenario.
To broadcast the information, we selected the following parameters [9]:

<table>
<thead>
<tr>
<th>LX Warning</th>
<th>Communication</th>
<th>Messaging type</th>
<th>Message period</th>
<th>Latency</th>
<th>Other requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon mode,</td>
<td>Ad hoc - I2V</td>
<td>Periodic permanent broadcast</td>
<td>500 ms</td>
<td>100 ms</td>
<td>High priority</td>
</tr>
<tr>
<td>non connected</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 1: LX infrastructure to vehicle communication parameters.

In Europe, at 5.9 GHz, a constant 23 dBm/MHz Equivalent Isotropic Radiated Power (EIRP) over the whole bandwidth is currently allocated. This provides an expected useful range of several hundred meters. To simulate transmission from a LX to a vehicle, a propagation model was used. The model considered signals reflecting off the ground. The LX communication system antenna height was set at 5 m and the receiving antenna height was set to 1.7 m. Using a 10 MHz band channel, the transmitter power was set to 23 dBm. To achieve the requested I2V 6-7 Mbps bit rate objective, a -72 dBm reference input power level was considered as a receiving threshold. Figure 4 represents the simulation results obtained using these parameters and the -72 dBm reference input power.

![Figure 4: Received power at 5.9 GHz, along the LX to vehicle radio link.](image)

We obtain a communication range in excess of 500 m. Over this simple communication channel, fast fading affects communication mainly over the first 100 m, received signals drop several times below the -72 dBm selected reference level at farthest distances.
III.2.3 Conclusion

This type of LX to vehicle wireless communication could provide vehicles with the duplication and the enhancement of the LX status information across a significant transmission range. The communication range means that the driver of a vehicle driving at an average speed of 60 kph would receive warning information 30 seconds before crossing the LX. This definitely broadens the warning triangle obtained from direct visual information, which is often situated 150 m ahead of the LX in a rural environment and 50 m ahead in an urban environment. The PANsafer project will now explore more deeply this scenario.

IV Conclusions and Perspectives

The work described in this paper has addressed a French project PANsafer: Towards safer level crossings.

The paper has mainly addressed possible technological solutions to improve level crossing safety. A new generation of level crossing fitted with equipment was described, made up of three main parts: LX modelling, sensing and communication. A case study was presented with the aim to explore the potential of automatic detection technologies using intelligent cameras in level crossing safety applications. The conclusion has been that the detection of stopped vehicles or other kind of obstacles provide part of the solution to the problem of accidents/incidents at level crossings. However, further tests and improvements to the video system are needed. These include: testing on a larger video data set, increasing robustness in terms of shadow and headlight detection in order to limit the number of false detection incidents, improving the reliability of the system in adverse weather conditions. In addition, a transmission system is provided in order to transmit the status of the system as well as updates to road users in the LX area and relevant decision making centres. It also provides triggers and signals for alarms in potentially dangerous situations, or in case of a system failure. With respect to the case study presented earlier, the transmission system presented in this paper is needed to deal with video sequences which generally require high transmission bandwidth.

Beside the technological solutions, further work is planned for the near future in this project. Among the goals of this project, we can list the analysis of user behaviour and the behaviour linked to the infrastructure and its mode of operation.

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V REFERENCES