Onboard electronic library supporting railway operations

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Abstract: - A new telematics solution is presented to solve the problems derived from the huge amounts of necessary documentation that locomotive engineers currently have to carry printed on papers during railway operations. This thesis is inspired on a case study analyzed at Euskotren, a basque railway operator. The functional characteristics of the solution are related and some technical aspects of its implementation are introduced. In the experiments carried out with the railway operator, this innovative solution has proved to improve the efficiency of railway operations what implies improvements in the safety of the operations.

Key-Words: - railway telematics library software application HMI train

1 Introduction
On railway operation, the train driver requires having available several kinds of information. The sources of this information vary. This information can be learnt by all the actors involved in the operation, and this is the case of the most fundamental types of information, e.g. information regarding train driving. However, this kind of support: human learning, is only reliable when the information is used very often. On the contrary, when these data are not commonly used the information tends to be forgotten or corrupted [1]. That is why, instead of relying on human capabilities, some types of information are usually provided printed on a certain support, so that it is accessible in the case of being required [2].

Currently, the only support available for some types of information is printed paper. This is the case of the company Euskotren and other railway operators. And actually it seems not to be any other immediate solution and that is why the solution explained next has been developed. This, not only has been claimed by the railway operator mentioned: Euskotren, but by other authors as in [3] and [4].

2 Documentation on paper onboard
It is common to see the locomotive engineer carrying a big bag when coming into the train. What that bag contains, why and what are the problems derived from that? And the most important question: can this be improved so that the operation becomes safer and more efficient?

2.1 About this documentation
It is not the purpose of this paper being an exhaustive reference (see [3]) about the description of the documentation carried onboard, but it is necessary to justify the necessity of this documentation as a support mechanism of the activities undertaken by the train driver. In consequence, the main documents that are carried out by a train driver at Euskotren are exposed next. However, in other companies with different contexts and regulations other kind of documents may be carried. Basically, three types of information have been identified: manuals, maps and regulations or protocols.

Manuals of the operation of infrastructure devices. For instance, a manual that explains how to operate an interlocking manually in the event of automatic operation failing; or a manual that explains what the relays on board are and which ones should be reviewed in case a certain functionality (e.g. gates control) fails.

Maps of the route. Synoptics that contain traffic indications to help the driver know how to conduct the train at a given location; or how to accurately refer to a signal (what the signal number is) when a message about it has to be reported to the control room, i.e. these maps are used as an absolute means to identify the infrastructure elements by the operators in the control room, by the train drivers and by the supervisors.
Regulations that establish how to deal with certain protocols in railway operations. For example, oral communications are accurately regulated [5] and certain verbal messages in a certain form are exchanged between the train driver and the control room. How these messages are formulated and interpreted is codified and contained in the documentation carried by the train driver. Obviously, it is expected that the locomotive engineer knows by heart how to use these messages; but, sometimes some doubts may arise and the purpose of these documents is to help him clarify these doubts.

2.2 Characteristics of the information
An analysis of this information has been made. It has been concluded that there are some characteristics that must be taken into consideration in any approach that intends to organize the management of it.

Position related information. The information contained in the documentation may or may not be related to the position of the train in the rail network. For instance, most of the regulations of railway operations are not position dependant; however, the synoptics of the railtracks are obviously related to a position. The relevance of this characteristic relies on the fact that, most of the times, position related information will be required exactly when the current train position is near the position associated with that information.

Vehicle related information. A similar situation occurs when it comes to the train vehicle that is driven. Usually, the fleet of an operator consists of several series of trains, each of which belongs to a different manufacturer and has different onboard equipment. In consequence, some documentation is tightly related to the vehicle, e.g. which relays need restoring when an specific onboard mechanism fails.

Dynamicity and granularity. Data require being updated depending on the aspect of the railway operation they depend on. And this dynamicity is not homogeneously distributed for every set of information. For example, maps may change frequently on a daily basis when there is an area in which some maintenance tasks are being undertaken; but it is probable that they will not change in months once these tasks have been finished. In consequence, it is important to determine different levels of hierarchized granularity of the information that ensure the consistency of the whole documentation when updates are due; and, at the same time, support selective updates at different levels.

Format. The information currently used includes images (vector graphics), schemes and plain text. The sources of this information are very diverse. Manufacturers will provide the manuals to operate their devices; although, these manuals may be updated by the maintenance department of the company when an improvement or a repair is needed. The network operator will create and maintain its own documentation about internal regulations. The owner of the railway infrastructure will provide the information about the infrastructure and its elements. In summary, heterogeneous sources for this documentation exist, and therefore the support for this information has to be as loosely coupled as possible.

2.3 Problems derived from this situation.
Once the baseline of the content and the characteristics of the documentation carried by train drivers has been established and considering the framework that supports it: printed paper, several problems and disadvantages are easily observed. The next are the main ones that motivated at Euskotren the promotion of a new electronic framework in his railway operations.

Accessibility: searchability. Handling loads of papers is not an easy task. Even though these papers may be ordered and classified and the train driver may be familiar to this order, looking for a certain solution associated to a specific rail station may be difficult. It is even more difficult if the information is not classified by rail station but by manufacturer or by the owner of the infrastructure, i.e. only one single criterion is possible for classifying. Regardless this classification, turning pages is not the quickest way to search information.

Accessibility: readability. The way in which printed information is shown and read is not customizable. The way it is printed directly conditions how the train driver reads it. Therefore, different handicaps affecting the reading process become important, for example, the light available, the distance from the eyes to the paper, the clarity of the printing, etc.

Loss of attention. As a consequence of the previous two inconveniences: poor searchability and readability of the information; the driver is required to focus a significant percentage of his attention in tasks different to main railway operations, such as, train driving, passenger control, communication with the control room, onboard device control, etc. This results in a higher probability of failure on performing these tasks [6].
Distribution management. Train drivers change very often the routes in which they work. It is frequent that a driver has to work in several routes during a single shift. Moreover, a driver will drive different models of vehicles during his shift. Equally, a certain model will be used at different routes depending on the availability of vehicles and the demand of the operation. As it has been exposed, the information is sometimes position and vehicle dependant. This means that the driver will have to be changing continuously the documents he handles because of changes in the routes and the vehicle. A complete distribution system is required to ensure that at a given route with a certain vehicle the information available is the right one. This is usually addressed by including the information for every route and every vehicle in the documentation package provided to the driver. An approach that, in turn, makes readability and searchability even poorer.

Update management. When the information has to be updated, it has to be reprinted and redistributed. This process has inherently some costs that make it only justifiable when a significant number of updates are due. In the mean time, the updates are usually reported in the form of annexes that break the order of the documentation. This fact implies that the documentation will not always be as up to date or, at least, as coherently ordered as it would be desired.

Environmental issues. Environmentally speaking the current framework is not a scalable solution. The more the activity of the railway operator grows, the greater is the number of train drivers employed and the larger is the area covered by the offered routes, and consequently the more paper will be printed. Along the same line, for each update that becomes necessary, these papers have to be reprinted again. Obviously, this is an expensive, non scalable, framework both economically and environmentally.

3 An electronic library onboard

A project consisting of several telematics solutions to improve safety in railway operations has been developed in a joint effort of the University of the Basque Country and the railway company Euskotren. This project has resulted in the development of an infrastructure for implementing these telematics solutions as well as the solutions themselves. One of these solutions is the onboard electronic library which is part of an integrated train driver information system. The onboard electronic library addresses all the problems motivated by the current documentation framework for train drivers.

The next lines describe the foundations of these infrastructure required for the implementation of an onboard electronic library. The functional description of this solution follows next and, finally, some technical guidelines concerning the implementation of it are enumerated.

3.1 IT infrastructure

To implement a telematics solution the very basic requirement is an IT infrastructure. In railways this infrastructure is not commonly deployed in the rolling stock. Therefore, the first step is to deploy it.

Two aspects have to be solved by this infrastructure: processing capabilities and communication networks. They have to be deployed both in the control room and in the rolling stock. The latter is rarely fully available, whereas some processing equipment may be installed; it is rarely interconnected with the control room.

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Figure 1 outlines the infrastructure deployed in the case studied in this paper.

In each train, the legacy control network (N1) is interconnected to the new processing devices (PD) by means of a gateway that transforms legacy control protocols (e.g. TCN) into the protocols used in the
new network (N2). N2 interconnects new PDs such as the HMIs interacting with the train driver and the Onboard Communication Router (OCR) that forwards traffic from the elements at N2 to the control room N3 and vice versa. This requires the so-called virtualized network, consisting of those mechanisms that wirelessly connect the OCR to the entry routers at the control room (e.g., a VPN over a PPP link with GPRS/HSDPA + Internet; or a proprietary WLAN). N3 is an already existing office network to which configuration and control devices are attached.

The implementation of each of these processing and interconnecting elements may differ. In [7], [8], [9] and [10] alternative implementations are discussed.

### 3.2 Functional description

Three main functionalities have to be addressed by the solution: the library data model, the configuration application and the visualization application.

#### 3.2.1 The library data model

The data model determines how the information described in 2.1 is going to be logically handled by the applications. Two aspects of the information are distinguished:

- **Railway Operation Information (ROI):** involves the digitalized representation of the aforementioned information.
- **Visualization Information (VI):** includes the information required to represent how the ROI is going to be visualized by the visualization application.

The main requirement for the data model is that it must be as flexible as possible in two senses:

- To support a portable format of digitalized information for the ROI.
- To provide the capability to customize the way in which the information is visualized to the train driver according to different evolving circumstances.

![Figure 2 - Electronic Library functionalities](image)

![Figure 3 – Library data model](image)

Figure 3 illustrates the UML data model that caters for the flexibility due. It shows the relationship between the VI and the ROI. It can be seen that VI is a layered hierarchy of nodes containing the information used by the application to implement the user navigation through information. Some of these nodes will render the content at the ROI repository pointed by a URI.

Note that the way in which VI and ROI persistency is implemented is not determined here to let this solution be as platform independent as possible and highlight the fact that this is not a constraint for the validity of the solution. However, in 3.3 some guidelines corresponding to the actual implementation of this case study are introduced.

#### 3.2.2 Configuration application

The configuration application is responsible for three tasks:

- Building the ROI repository that is distributed to each train unit, i.e., creating the digitalized pieces of information and uniformly persist them at a
given storage system (e.g. a database or a file system)

- Creating the VI that marshals the ROI units in a way suitable to the train driver. It is suggested that the visualization component used in the visualization application is jointly used in the process of creating the VI so that the user that builds the VI can predict how the information will be shown to the train driver.

- Scheduling the distribution of updated VI and ROI to specific train units. The actual implementation of this information distribution is out of the scope of this paper. But it can be outlined that it is an Uploads Management System (UMS) that according to some metadata intelligently distributes the given payload (VI and ROI) to the selected train units. The UMS provides incremental distribution of persistent elements (a file system element), what in turn improves the scalability of the distribution system.

![Figure 4 - Configuration application snapshot](image1)

This application is executed at the control room in a desktop machine by a user with knowledge about the data contained in ROI and about ergonomic aspects affecting the train driver during railway operation.

### 3.2.3 Visualization application

The visualization application is executed in an onboard HMI and is integrated within a more complex software system implementing additional safety solutions. Two are the main tasks that are executed by this application:

- Rendering the information contained in the ROI according to the information described in VI and to some characteristics that are particular to the HMI in which the application is implemented (i.e. the implementation for a touch screen will be different to that for a button based HMI) Equally, very specific requirements for this application may be raised by ergonomic experts [11] and they must be considered (e.g. the combination of colors used, the controls provided to browse the information, facilities to zoom the documents) In overall, the requirement is making information accessible: readable and searchable.

- Coordination of the railway operation and the rendering of the information. This coordination consists of implementing the policies for the integration of this application with the train driver’s operations. For example, in the case of position related information being accessed, the application will automatically show those ROI elements that refer to positions nearer to the current train position. Another example, the application will restrict the access to some low importance information while the train is moving and it will only allow the train driver to access it when the train is fully stopped to prevent him from losing attention on train driving.

![Figure 5 - Visualization application snapshot](image2)

### 3.3 Technical aspects

The functionalities just explained can be implemented in several manners. Next some technical considerations regarding the experience at the case study motivating this paper are enumerated.

- ROI persistency: the pieces of information contained in the ROI come from several sources and a flexible mechanism for their digitalization must be used. Printing documents into PDF formatted files has proved to be an adequate (loosely coupled) mechanism for persisting the documentation. These files are structured in a file system hierarchy as desired by the final user. Another option would be to store them in a database but this alternative requires a DBMS which otherwise is not required.

- VI persistency: the implementation of the data model visualization persistency has been achieved by means of an XMI file. This proves to be the best alternative when it comes to interoperability and potential reuse by other systems in the future.
Non-mechanic storage elements are required onboard due to the intolerance of these elements to vibrations. In consequence, solid state Compact Flash memory has been used. It has to be taken into consideration that the number of writing operations is limited and this is a factor the UMS accounts for by minimizing the number of writings.

.NET framework has been used both in the configuration and the visualization system. The HMI was running an XP Embedded operating system. The performance of this environment has proved to be excellent.

The rendering functionality has been implemented as a .NET component (any other encapsulation mechanism available at other platforms is valid as well) so that it can be reused both in the visualization application and in the configuration application.

The communications protocol used for the distribution of the library repository was both FTP and SMB/NetBIOS.

4 Conclusions
A solution to the problems motivated by the use of printed paper for the documentation carried by train drivers during railway operations has been proposed. This solution has been proved in a real case study with the railway operator Euskotren in the Basque Country.

This paper focuses mainly on the functional description of the solution, because the technical aspects of its implementation are not a condition to attain the benefits of it.

This solution eases the process of updating and distributing the information required by locomotive engineers. At the same time, it allows for an ergonomic integration of the information with the train operation. The safety of the operation is consequently improved because the driver does not have to deal with the inconveniences of printed paper and the information is more accessible.

References: