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(54) System and method for failure telemaintenance and expert diagnosis

(57) The present invention is related to a system and method for the telemaintenance of vehicles, namely railway rolling stock, RRS (1), associated to an Intelligent Failure Diagnosis System, IFDS (2), applicable to the universe of the conventional and high-speed train, light rail and potentially comprising all the transport systems.

The invention comprises the railway telemaintenance with a maintenance policy centred in the reliability, *Reliability Centred Maintenance* (RCM), appealing to the technology of maintenance based in the condition, *Condition Based Maintenance* (CBM), in order to improve and intensify the treatment of the RCM tasks, named by tasks on inspection/condition, *on condition tasks,* giving rise to a new support tool to the maintenance of railway rolling stock.

With this new approach and directly influenced by the efficiency of IFDS (2) it's obtained an optimization of the Reliability, Availability, Maintenance and Security settings of the RRS (1) with the optimization of the life potential of the equipments.

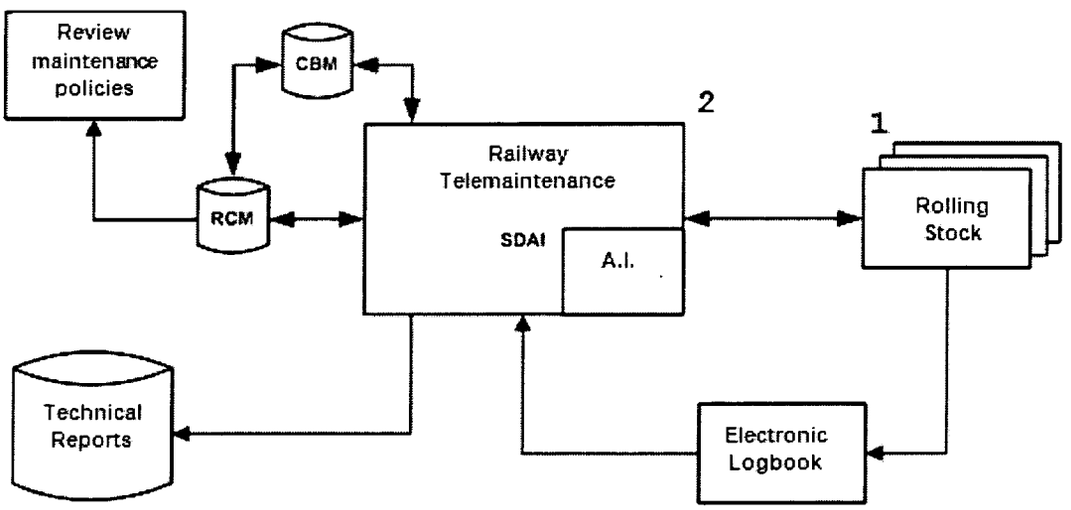

Image 13

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Description

Technical domain of the invention

[0001] The present invention is related to a system and method for the telemaintenance of vehicles, namely railway rolling stock, that comprises an Intelligent Failure Diagnosis System, IFDS (2), applicable to the universe of the conventional and high-speed train, light rail and potentially comprising all the transport systems.

Resume of the invention

[0002] The present invention describes a system for the expert telemaintenance and diagnosis of failures in vehicles characterized by comprising:

- Module of maintenance based in the reliability, *reliability centred maintenance, RCM;*
- Module of maintenance based on the condition, *condition based maintenance, CBM;*
- Intelligent Failure Diagnosis System, IFDS (2);
- System embedded in the vehicle (1).

[0003] In a preferred accomplishment, the embedded system in the vehicle comprises:

- Module of data processing;
- Module of interface with the system of the vehicle.

[0004] In a more preferred accomplishment, the module of interface with the system of the vehicle comprises:

- Settlement of several communication protocols, for various systems;
- Configurable settings in the embedded system itself, of the referred several communication protocols.

[0005] Another preferred accomplishment of the present invention is that the intelligent failure diagnosis system (2), IFDS, comprises:

- A database of knowledge;
- A motor of inference or recognition of patterns, or both.

[0006] Another accomplishment even more preferred of the present invention is that the motor of inference or of recognition of patterns, or both, comprises one or more of the following items:

- Expert system based in cases;
- Expert system based in models;
- Expert system based in rules;
- Expert system based in fuzzy logic;
- Expert system based in neural rules;
- Expert system based in statistics, in Bayes networks;
- Expert system based in genetic algorithms;

[0007] Another preferred accomplishment, even more preferred of the present invention is that the intelligent failure diagnosis system (2), IFDS, comprises additionally:

- Communications module;
- Human interface humane, namely web.

[0008] Another accomplishment equally preferred of the present invention is that the embedded system in the vehicle comprises additionally:

- Communications module;
- Geo-location Module;
- Module of remote reconfiguration and/or update.

[0009] The present invention describes also a method for the telemaintenance and expert diagnosis of failures in vehicles characterized for comprising the steps of gathering, analyzing and producing intelligence of the maintenance policy (2), through:

- The collection of information regarding events relevant to the maintenance by time, condition or both in the embedded system in the vehicle(1);
- The conversion of the information in a specific format and/or protocol and/or inherent to the vehicle in an independent format;
- the maintenance based in the reliability, *reliability centred maintenance, RCM;*
- the maintenance based in the condition, *condition based maintenance, CBM;*
- the suggestion of tasks on condition, *on-condition tasks.*

[0010] A preferred accomplishment of the present invention is that the referred method comprises the gathering, analysis and production of intelligence of the maintenance policy (2), additionally through:

- the classification of each event in a scale of 3 values: notice, warning or alarm;
- The recording of the position of the vehicle (1) through geolocation;
- The real time exhibition of the operational status of one or more vehicles (1);
- The availability and storage of historic data;
- The remote update/reconfiguration of the referred embedded system.

[0011] Another preferred accomplishment of the present invention is the fact that the vehicle (1) is railway.

General Description of the Invention

[0012] The present invention is related to a system and method for the telemaintenance of vehicles, namely railway rolling stock, RRS (1), associated to an Intelligent Failure Diagnosis System, IFDS (2), applicable to the universe of the conventional and high-speed train, light rail and potentially comprising all the transport systems.

[0013] The present invention comprises the railway telemaintenance with a maintenance policy of Maintenance centred in the reliability, *Reliability Centred Maintenance* (RCM), appealing to the technology of Maintenance Based in the Condition, *Condition Based Maintenance* (CBM), in order to improve and intensify the treatment of the RCM tasks, named by tasks on inspection/condition *(on condition tasks),* giving rise to a new decision support tool.

[0014] The telemaintenance/IFDS, lays over a development traineeship, *software deployment,* of the type of *Knowledge Based Systems* (KBS), being targeted to the technical diagnosis using tools of Artificial Intelligence (AI).

[0015] In image 1 is shown the General Structure of the Invention.

[0016] With this new approach and directly influenced by the efficiency of IFDS (2) it's obtained a maximization of the Reliability, Availability, Maintenance and Security settings of the RRS together with the maximization of the life potential of the equipments.

[0017] The described invention replies to an identified necessity by the main transport operators in a wide sense (lad, shipping and air transports), for which the technological offer in the market still doesn't satisfies. The proposed invention allows its users to be able to create an integrated and customized interface between its systems of supervision and support to decision and the several embedded systems, in an independent way with the technology used by the manufacturer.

[0018] The present invention allows to collection, transmission, analysis of different types of intelligence, even multimedia, of several vendors with multiple protocols (including the conversion of protocols) with different systems of physical communication and even with systems of different purposes in order to provide an intelligent, expert integrated support to decision, to the maintenance of rolling stock.

[0019] The end users, having access to this type of intelligence, may maximize the management of their parks of transporting systems, which makes the diffusion of the invention economically feasible.

Description of the Images

[0020] For a easier comprehension of the invention it is attached the images, which, represent the preferred accomplishments of the invention which, yet, don't intend to bound the object of the present invention.

Image 1: Schematic representation of the General Structure of the Invention. **Image 2:** Schematic representation of the physical structure - communications platform embedded.

Image 3: Schematic representation of the interfaces in the Module of Data Processing.

Image 4: Schematic representation of the blocks scheme of the extension Module of E/E.

Image 5: Schematic representation of the general structure of the developed system in the Module of Data Processing.

Image 6: Schematic representation of the scheme of status of the Main sub-process, *thread Main.*

Image 7: Schematic representation of the scheme of status of the sub-process, *thread, GPS*.

Image 8: Schematic representation of the scheme of status of the Module sub-process, *thread Module.*

Image 9: Schematic representation of the scheme of status of the Data Manager Module sub-process, thread *DataManager*.

Image 10: Schematic representation of the data structure created by the sub-process Module, *thread Module,* related to the equipment variables of the RRS.

Image 11: Schematic representation of the scheme of status of the sub-process Sending File, *thread FileSender*.

Image 12: Schematic representation of the proposed Life Cycle for an extraction of knowledge.

Image 13: Schematic representation of the global framework of the invention.

Image 14: Schematic representation of the interaction between the Telemanagement Centre and the embedded system(s).

Detailed Description of the Invention

[0021] The main structural lines of the present invention, in terms of Telemaintenance/IFDS, grant the following features:

- Operate as a Support to Decision System (SDS).
- Integration in the RCM maintenance philosophy.

Operate as a Support to Decision System (SDS)

[0022] The IFDS in order to operate as SDS is directed to the functions of:

- **Maintenance Management (guided to the Maintenance Operator):** Responsible for the different levels of maintenance, making available daily and in real "near" time all the intelligence regarding the operational status of the vehicle fleets involved, enabling at a Short-Term, an effective management of vehicle calling to the factory - human resources, tools and spares, being therefore reduced the stop time of the RRS and at a Medium and Long-Term Period the maximization of the maintenance cycles and the other resources associated to the later;

■ **Commercial Operation (Targeted to the vehicle):** To diagnose *Online* the failures arisen in the course of the operation of the Rolling-stock, suggesting to the driving and in-line maintenance personnel a list of quick straightening actions. To load, Upload, of information to *Passenger Information System* and entertainment in general.

■ **Operations Management:** Provide information on the *"health" condition* of the RRS, supporting the decision to maintain it at the service under a certain set of technical conditions;

■ **Reengineering Project:** Enhance the automatic transmission, *feedback,* of the maintenance and operation data to the manufacturers, originating reengineering actions (ex: remote update of software) in order to increase the inherent reliability of the RRS.

Integration in the RCM maintenance philosophy

[0023] The RCM methodology provides a practical and structured way of achieving optimized results in the maintenance strategy adopted for each target system. The main purpose is to determine the required actions to ensure that the physical assets comply with the required functions within the framing of its operational context.

[0024] One of the major aspects in the settlement of the programmes of maintenance management is the attainment of satisfying information/data about the performance of a certain fleet of RRS, such as co-related glitches, failures and other measures that allow checking the condition of the equipment.

[0025] The assessment, grouping and comparing of an appreciable quantity of information, each more often with the growing automation of the systems/processes embedded in the RRS may not be efficiently managed by a system of general information (not customized) in which importance is only given to standards of global integration.

[0026] In the RCM methodology different types of components and equipments convey inevitably to the development of different maintenance policies that, obviously, involve a great variety of patterns of failure modes. The analysis of these patterns requires, besides the background knowledge of the manufacturers, the knowledge and expert training of the maintenance operation, that should, concordantly, be integrated in the RCM tool that is Computerized Maintenance Management System (CMMS), consisting of the following constituent modules of the TELEMAINTENANCE/IFDS:

■ System of **Database Management** (SDBM).

■ RRS with central structure, *backbone,* of communications and **intelligent network of sensors.**

■ Telemanagement Centre (TMC) of RSS - Server of the **Expert System** with the relevant embedded **Inference Motor** (tools of artificial intelligence).

■ SGI: System of Geographic Information.

■ Architecture **Client-Server,** available in a simple and efficient manner by an Internet browser.

[0027] The SDBM is based in SQLSERVER© or, optionally, for example, an ORACLE© server, in which the tools of the Open Platform of Communications - Communication Standard (OPC - *Communication Standard*), have a prevailing role in order to allow the assumption of the whole system as being the open platform. The REMAIN - OREDA model was followed; in this model the failure modes and the maintenance activities are linked in the SDBM.

[0028] For example, the embedded system has a GPRS communications platform (ready for the evolution to GSM-R), existing the integration with the RSC support. In the embedded equipment there are also the sensors, which aimed to follow the IEEE 1451 standard.

[0029] The TMC of the RRS allows the hosting of the SDBM and has an inference motor of the system.

[0030] The SGI was developed in order to have practical identification capabilities of localization of the RRS, being included in this chapter the dynamic zoom capabilities.

[0031] Finally, the Framework Client-Server supports the whole system. In this scope, the integration of the Expert Systems, of which the IFDS is an example, arises as a value-added tool in different stages of the approach/execution of this management strategy.

[0032] According to the aforementioned it can be concluded that the IFDS is, in fact, a RCM tool, which integration is being implemented under the following aspects:

■ **In the planning and accomplishment phase of the RCM study,** with the experts and facilitators, the TELEMAINTENANCE/IFDS has an important role in the supported localization of the modes/patterns of failure present in each one of the functions/systems studied, allowing the assessment of its importance and its impact in the reliability and maintenance of the railway system in study;

■ **In the following stage of implementing the RCM methodology,** the TELEMAINTENANCE/IFDS is going to use the outputs of the RCM study, namely, the Decision worksheets, so that in the tasks denominated by *on inspection/condition, on condition tasks,* that assert the remote collection of data, using this information for the decision taking about which tasks the maintenance has to accomplish.

In the communications platform embedded in the vehicles

[0033] Each vehicle has a communications platform comprising one embedded processing unit, one *embedded* PC, with routing functions, having a proper Operating System, for example, Linux™, which provides an open framework for the communications with the different communication protocols. Patterns/systems as those previously mentioned are capable of remote monitoring and were extremely useful for the development of the present project:

- Undesirable voltages/Currents.
- Variables of the braking system.
- Doors System.
- Chain of cinematic traction of the transport vehicles.
- Bearings.
- Filters.
- Pressure/temperature: Oil, water, compressed air, etc.
- Different rotating machines.

[0034] The attainment by the communications platform, namely of the embedded PC, of the variables previously referred, occur through a communication with the different systems and equipments present in the vehicles.

[0035] In this communications platform it also exists a GPS receiver that communicates with the embedded PC, forming therefore the data support to the Geographic Information System (SGI) as one of the modules of the TELEMAINTENACE/IFDS.

[0036] Additionally, in this communications platform it's found as well an automaton dedicated exclusively for the entrance/exists extensions, in case of necessity of readings and/or command proper to the requirements of each type of RRS.

[0037] The Exchange of the data collected by this platform and the telemanagement centre is established through a module/device dedicated for the effect, like is the case of the module - modem GSM/GPRS. The developed system enables the integration of communication modules by third parties or commercially available.

In the telemanagement centre

[0038] The TELEMAINTENANCE/IFDS system is supported by a Client-Server Architecture. This framework made available by an internet browser, with the aim of offering to the users (companies using this product) a set of information gathered in interfaces, *front-ends,* developed in a customized way to provide the support to the decision to the set of decision-makers (at different levels) involved in the Management process of the RRS.

[0039] This system is, by default, of the type of *time-trigger* and *event-trigger, in case* it occurs an alarm. It should be stressed that the proactive behaviour of the system, being endowed for each variable of warning levels that allows the anticipation, in the majority of the situations, of the failure.

[0040] Following are highlighted some of the advantages already available by the system:

- An innovative way of rating the severity of the Failure, appealing to a 3 levels of severity (by ascending order) NOTICE, WARNING, ALARM. In applying this rating, it is conferring the system with a predictive behaviour, allowing therefore to the user company to predict the failure of the transport system.

- Possibility of any computer with user intranet to have Access to different interfaces, *front-ends,* of the system.

- Possibility of the users having Access in "real time" to the operational study of a certain fleet of RRS - development of the DRR *Newsletter* (Daily Report of Reliability) - Support to Decision.

- Possibility for the user to see the technical history of the RRS, in order to have access to warnings and alerts (existing links for the viewing of the whole relevant information associated), as well as the trends of evolution of the variables, supporting a decision taking by the Maintenance Area or by the Fleet Manager. Here it is also relevant the clear evidence in graphic form, regarding the warning/alarm points.

- Possibility of searching any variable that is being monitored by the system (under a Cartesian graphic multivariable or table) for the dates already passed or for the present day.

- Access to a System of Geographic Information (SGI).

- Possibility of putting a certain vehicle in the online mode, having the operator an update of the information each 30 seconds. In this situation the framework of the system makes the whole management of the concurrent accesses.

- The Telemaintenance/IFDS also has an internal mode of inherent maintenance allowing among other potentialities, the detection of failures in the networks of intelligent sensors of the vehicles.

- Remote and encrypted collection of data in the "Black-boxes" of the vehicles (by means of authorization of the client company);

- System available by Mobilephone (with SMS service for sending alarms/warnings);

■ Possibility of differed data (e-mail, SMS, ...) collection or by marking in the system, for collection in odds of time in the future.

■ Punctuality Management System - Calculation of the deviation real / predicted time.

■ Possibility for the remote update of the programme, software and the programme in non-volatile memory, firmware, of the system of the communications platform embedded.

Artificial Intelligence (AI) in the development of the railway telemaintenance -IFDS

[0041] The knowledge extraction techniques for supporting decision, available by the AI area are presently varied. These techniques include the expert systems, *case based reasoning* - expert system based in cases, *model-based reasoning* - based in models, neural networks, *fuzzy logic,* etc. These after the accomplishment of the railway I&D within the scope of development of the TELEMAINTENANCE/IFDS, showed to be powerful tools in the enhancement of their performance. The IFDS uses as main tools of AI the expert systems, the case *based reasoning* and the *fuzzy logic* / *clustering.*

[0042] The Telemaintenance/IFDS system reached in a early stage a success rate in the given answers of 67%. With the application of new techniques such as inductive algorithms and neural networks this rate reached the 88% value, with an ascending trend as the Telemaintenance/IFDS system learns with the introduction of information.

Detailed Description of the embedded communication platform

[0043] The communications platform (Image 2) is embedded in the vehicles and due to its robustness and modular character is perfectly adapted to provide support to the acquisition and treatment of the necessary data for the remote monitoring and diagnosis of each series of Railway Rolling stock (RRS).

[0044] This communications platform detaches for being a **data acquisition system clear and transversal,** that is, with its diversity of interfaces (Image 3) and the processing capacity it enables the attainment and Exchange of data between different equipments / systems proceeding from different manufacturers.

[0045] From the developed application in the **Module of Processing Data** (Image 2), with the fundamental feature of managing the whole bidirectional flow of data and the settings of the modules that constitute the communications platform, the following **features** are detached:

■ Treatment and storage of the GPS receiver data.

■ Management of the request, interpretation and storage of the data proceeding from the different systems of the RRS. *(different protocols and physical interfaces)*

■ Sending of the information for the telemanagement centre through the **Communications Module.** *(implemented for example through a GPRS modem under the FTP protocol, being already prepared to integrate the future services made available by GSM-R)*

■ Support to the **remote reconfiguration** of the modules through the reception of a single file.

■ Support for the **remote update** of the system's software.

■ Sending of the data in two modes, time-trigger (default mode) and event-trigger (at the occurrence of alarms), reconfigurable in a customized/adapted form according to the necessities of the user.

[0046] Additionally, in this communications platform it's found as well a module dedicated exclusively for the entrance/exists extensions, **in case of necessity** of readings and/or command proper to the requirements of each type of RRS. Availing therefore the individual and isolated actuation and/or reading of the actuators and/or independent sensors of the command and control system (communication networks) of the RRS.

[0047] Bearing in mind the framework of the communications platform, set up by different modules and by the diversity of communication interfaces existing in the different systems target of remote monitoring and diagnosis of the RRS, it was aimed to make it profitable all these concurrent activities by developing a multi-thread, multi sub-processes application.

[0048] Taking advantage of the fact that the **Module of Data Processing** was developed upon the operating System Linux, the library distributed with this operating system was used to implement the concurrent programming using the Kernel-level threads, sub-processes at the level of the operating system core. With this implementation is guaranteed, for instance, that when a thread, sub-process, conferred to the processing of a certain module blocks, it doesn't corrupt the remaining threads, sub-processes of the process.

[0049] The solution that was developed is therefore structured in different modules, each one with the aim of performing the features previously referred. Following, is described the main modules implemented by the system, namely the five threads, sub-processes that deal individually with the processing of peripherals and that managed the consistency of the generated data. (Image 4)

[0050] From Image 5, where the threads, sub-processes, Main, GPS, DataManager, in a general way are per-

manent part of the application being only configurable some of its patterns.

[0051] The threads *Module - Module* and *FileSender* **are totally configurable in order to be adjusted to the specific requirements of the systems of each RRS,** an innovative feature in the applications used in the railway sector. Thus, in the *Module* it is found the processing and interpretation of the communications protocol(s) of the systems target of remote monitoring and diagnosis. In *FileSender* is set up the way the data will be sent for the telemanagement centre appropriate for the type of the Communications Module being used.

[0052] **Example of implementation** of the communications platform when:

- The system/equipment of the RSS to monitor has a series of interfaces, *(RS232)* of communication of diagnosis data.

- ***(Module:*** *Establish the communication through the serial port with the relevant implementation of the proprietary protocol of this equipment)*

- The ***Communications Module*** is being implemented with the help of a GSM/ GPRS modem. ***(FileSender:*** *Are configured all the necessary patterns to a GPRS connection together with the patterns of a FTP client application for the relevant transfer of data)*

[0053] The thread ***Main*** (Image 5) is the responsible for the creation of the remaining threads of the process, where initially it reads the File ***Settings,*** in order to obtain the settings of the different modules.

[0054] After each module has been configured, it continues to process the local peripherals of the ***Module of Data Processing,*** such as presenting textual information on the LCD, performing keyboard functions until it's pressed the keyboard with the instruction to exit.

[0055] The file ***Settings*** used to obtain the settings is comprised by sections, where the syntax used to indicate the beginning of the settings of each module is:

#<nome_modulo>

Followed by the patterns to configure:

<parâmetro>=<valor>

[0056] The thread, sub-process, ***GPS*** (Image 7) performs cyclically, the communication with the GPS receiver connected to a RS-232 door of the **Module of Data Processing.** In this cycle are stored the data related to the GPS (latitude, longitude, altitude, time and date, number of satellites, quality of the signal and speed) in a structure of data for sharing. Additionally, whenever the system is not configured with the time and date, the time and date given are those received by the GPS receiver.

[0057] The thread, sub-process, ***Module*** (Image 8) is responsible for the management of the communication through the serial port with the RRS equipment. In it, it is found the command code and the relevant interpretation of the necessary information for the extraction of the necessary data for the remote diagnosis. At the beginning of its accomplishment, the list of equipments wherefrom the data are desired to be extracted (list part of the file settings) is loaded and is transformed in a sequence of commands to send. Until the request to terminate is received, this sequence of commands is performed cyclically and the data already interpreted are stored in a structure of data to share.

[0058] The thread, sub-process, ***DataManager*** (Image 9) has as main function the generation of a file comprising the whole information required to send for the telemanagement centre.

[0059] Thus, in order to maintain the consistency of data to send, precedes the reading in a sequential and atomic way of the structure of data shared by the thread, sub-process, ***GPS*** and thread, sub-process, ***Module,*** gathering the identification information of the vehicle. Being a concurrent programming, the consistency and atomicity of the generated data is guaranteed thanks to the use of mutual exclusion mechanisms like the mutex of the pthread.h library.

[0060] Subsequently is created the file, conferring the date and time to the name of the file. Where, by the occurrence of an alarm or having arrived the time for the cycle by default, is moved into the Sending Directory, otherwise is moved into the Storage Directory.

[0061] Before this cycle of readings and creation of the file, the thread, sub-process, allocates a memory space dedicated to the data of the **GPS, Module** and the identification of the vehicle. This has to do with the fact that these data don't occupy always the same space, because in the ***Settings*** file it is made the selection of the equipments allotted for the data collection. Thus, regarding the size of the stored data and subsequently sent, depend of the configuration placed in the ***Settings*** file.

[0062] In Image 5 is represented the mechanism used for the data exchange between the threads, sub-processes. Where an example of how the exchanged information between a ***Module*** thread and a ***DataManager*** thread is represented in the structure of data in Image 10.

[0063] The thread, sub-process, ***FileSender*** (Image 11) verifies continuously the **D*irectory Sending*** waiting for a new file. When a new file arrives to this folder and if it's the first time, establishes a connection to the internet by GPRS, configures the patterns of the **FTP** client account and sends the file together with the information of the connection IP. This procedure is performed cyclically, being also stored a copy of the files in the ***directory Storage.***

[0064] The generated file, with the information of the data proceeding from the GPS, equipments variables and identification of the vehicle, is created similarly to the file ***Settings.***

[0065] This way, there are 3 sessions related to the data of the modules to be send. (GPS, Module, INFO). Where a syntax of the name of the module is:

#<nome_modulo>
And the respective data of this module
<nome_variavel>=<valor>

[0066] It should be highlighted that the described invention replies to an identified necessity by the main transport operators in a wide sense (lad, shipping and air transports), for which the technological offer in the market still doesn't satisfies. The proposed invention allows its users to be able to create an integrated and customized interface between its systems of supervision and support to decision and the several embedded systems, in an independent way with the technology used by the manufacturer.

[0067] The end users, having access to this type of intelligence, may maximize the management of their parks of transporting systems, which makes the diffusion of the invention economically feasible.

Detailed Description of the AI tools in the Telemanagement Centre

INTEGRATION OF ARTIFICIAL INTELLIGENCE TOOLS IN THE ACCOMPLISHMENT OF THE INTELLIGENT DIAGNOSIS (AI) TO THE ANOMALIES VERIFIED IN THE RRS.

[0068] It was developed an expert system using the technology *Case Based Reasoning, using an innovative methodology denominated as System of Intelligent Diagnosis of Failures* (SIDF). This system, before reported situations by the system of remote data collection, generates automatic diagnosis, associating to it a grade of similarity/ trust.

[0069] The pilot system was tested in a computational environment, allowing the building of one of the modules of the *Computer Maintenance Management System* (CMMS), which namely performs the stage of knowledge extraction from a "woof" of variables sent remotely from the universe of vehicles in operation.

[0070] The obtained results were very positive, being the reliability of response of the expert system reaching 65%, with the use of this technology in the railway environment.

Additional tools of knowledge extraction were integrated.

[0071] AI tools available for the integrations in the CBR technology:

- Expert System Based in Models - Reasoning Based in Models - (RBM);
- Expert System Based in Rules - Reasoning Based in Rules - (RBR);
- Methods of inductive Learning.
    - ○ Neural Networks;
    - ○ Statistic Methods - Bayes Networks;
    - ○ *Fuzzy-Logic;*
    - ○ Genetic Algorithms
    - ○ Algorithms of inductive learning.

[0072] As it can be analyzed in Image 11, the CBR technology, *stand-alone,* performed its role in the knowledge extraction and accomplishment of the automated diagnosis.

Expert System Based in Rules

[0073] As a first solution it was developed the Module *Rule Based Reasoning* (RBR), which enabled the increase of the covering/identification of the failure modes of the RRS. This module includes presently 52 rules that cover the failure modes that determine the main systems of the railway vehicle model. The obtained results allowed an improvement in the performance of the diagnosis system

[0074] (success odds ration) in 11,0%, being presently at the 76,0%;

Methods of inductive Learning

[0075] ***FUzzy-CBR clustering***, which applicability aims to the "clusterization" of the base of knowledge of the expert system case-based, accelerating and "tuning" the stages of retrieving/revising/*retaining* of the cycle of reply of the system to the external excitement that is represented by the new failure case presented to the diagnosis system. This methodology is supported in the fact that a knowledge base of the system of important dimensions may be transformed in one of minor dimensions together with a group of fuzzy rules, rules of fuzzy logic, of adaption generated by a *fuzzy decision tree induction.*

[0076] ***Neuro-Fuzzy-CBR pattern matching -*** *recognition of the patterns by fuzzy logic / case-based.* The *Artificial Neural Networks* (ANNs) have the capacity of tolerating the failure, adaptation and generalization, being used in the pre-processing and in learning and recognition of patterns tasks in the diagnosis system object of the doctoral project. The synergy verified with the introduction of the *Fuzzy-set theory,* endows this system with the capacity of treating the uncertainty derived from the "fuzzy" information, filtering the inconsistency as also adapts dynamically the weight of the associated fields, to the records in the databases that represent the global nature of the information collected based on the change of the operational context verified.

[0077] The cases are typically catalogued patterns that represent different regions or features of the knowledge about the technical and expert diagnosis. The inclusion of *Fuzzy-sets* optimizes the selection of the cases from different regions of the knowledge base that deal with uncertainty, ambiguity and overlapping.

[0078] The consistency of the rules extracted from the test model (*trained model)* will be validated by the maintenance experts.

[0079] The application of the Methods of Inductive Learning enabled the improvement of the success rate of replies by the system, achieving 89%. For the failure situations related with the **security aspects,** the grade of certainty verified in the tested systems was 100%.

[0080] It was also performed the integration of the tools of *pattern recognition*, the technologies of *Condition Based Maintenance* (CBM) used for the analyses of the trends for the main physical variables that translate the performance of the train.

[0081] The IFDS is a ***self-learning system,*** feature which detaches it from the existing systems. Performs the **automatic learning,** conducting to the progressive increase of the reliability of its answers in the course of its operation/service time.

[0082] This feature is given, namely by the CBR tools and Neural Networks.

RELIABILITY CENTERED MAINTENANCE (RCM) EXPERT FRAMEWORK

[0083] It can be concluded that the IFDS is, in fact, a RCM tool, which integration is being implemented under the following aspects:

- **In the planning and accomplishment phase of the RCM study,** with the experts and facilitators, the IFDS has an important role in the supported localization of the modes/patterns of failure present in each one of the functions/systems studied, allowing the assessment of its importance and its impact in the reliability and maintenance of the railway system in study;
- **In the following stage of implementing the RCM methodology** the IFDS is going to use the outputs of the RCM study, namely, the Decision worksheets, so that in the tasks denominated by ON CONDITION TASKS, that assert the remote collection of data, using this information for the decision taking about which tasks the maintenance has to accomplish.

Claims

1. System for the expert telemaintenance and diagnosis of failures in vehicles **characterized** for comprising:

a. Module of maintenance based in the reliability, *reliability centred maintenance, RCM;*
b. Module of maintenance based in the condition, *condition based maintenance, CBM;*
c. Intelligent Failure Diagnosis System, IFDS (2);
d. System embedded in the vehicle (1), comprising:

i. Module of data processing;

ii. Module of interface with the system of the vehicle, comprising:

1. Settlement of several communication protocols, for various systems;
2. Configurable settings in the embedded system itself, of the referred several communication protocols.

2. System for the expert telemaintenance and diagnosis of failures in vehicles according to the previous claim **characterized by** the intelligent failure diagnosis system (2), IFDS, comprising:

a. A database of knowledge;
b. A motor of inference or recognition of patterns, or both.

3. System for the expert telemaintenance and diagnosis of failures in vehicles according to the previous claim **characterized by** a motor of inference or the recognition of patterns, or both, comprising one or more of the following:

a. Expert system based in cases;
b. Expert system based in models;
c. Expert system based in rules;
d. Expert system based in fuzzy logic;
e. Expert system based in neural rules;
f. Expert system based in statistics, in Bayes networks;
g. Expert system based in genetic algorithms;

4. System for the expert telemaintenance and diagnosis of failures in vehicles according with any of the previous claims **characterized by** the intelligent failure diagnosis system (2), IFDS, comprising additionally:

a. Communications module;
b. Human interface humane, namely web.

5. System for the expert telemaintenance and diagnosis of failures in vehicles according with any of the previous claims **characterized by** the embedded system in the vehicle (1), comprising additionally:

a. Communications module;
b. Geo-location Module;
c. Module of remote reconfiguration and/or update.

6. System for the expert telemaintenance and diagnosis of failures in vehicles according with any of the previous claims **characterized by** the vehicle (1) being railway.

7. Method for the telemaintenance and expert diagno-

sis of failures in vehicles **characterized by** comprising the steps of collection, analyze and production of information of the maintenance policy (2), through:

a. The collection of information regarding events relevant to the maintenance by time, condition or both in the embedded system in the vehicle (1);
b. The conversion of the information in a specific format and/or protocol and/or inherent to the vehicle in an independent format;
c. the maintenance based in the reliability, *reliability centred maintenance, RCM;*
d. the maintenance based in the condition, *condition based maintenance, CBM;*
e. the suggestion of tasks on condition, on-*condition tasks.*

8. Method for the expert telemaintenance and diagnosis of failures in vehicles **characterized by** comprising the steps of collection, analyze and production of information of the maintenance policy (2), additionally through:

a. the classification of each event in a scale of 3 values: notice, warning or alarm;
b. The recording of the position of the vehicle (1) through geolocation;
c. The real time exhibition of the operational status of one or more vehicles (1);
d. The availability and storage of historic data;
e. The remote update/reconfiguration of the referred embedded system.

9. Method for the expert telemaintenance and diagnosis of failures in vehicles **characterized by** the vehicle (1) being railway.

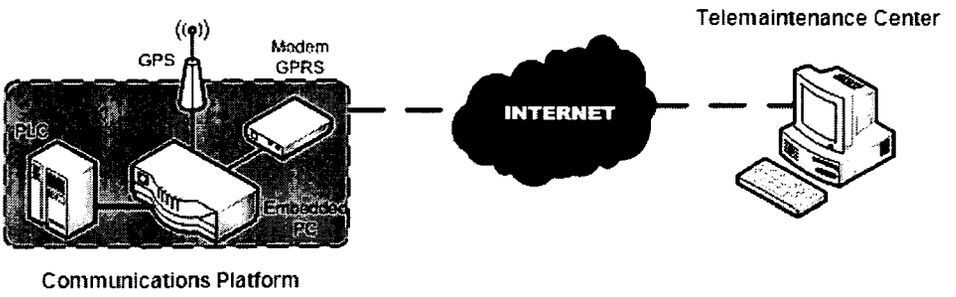
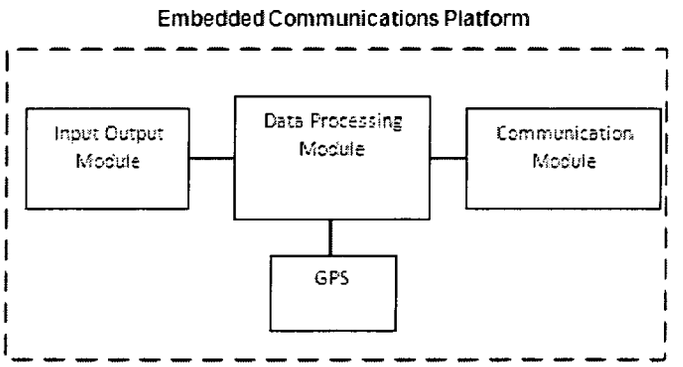


Image 1



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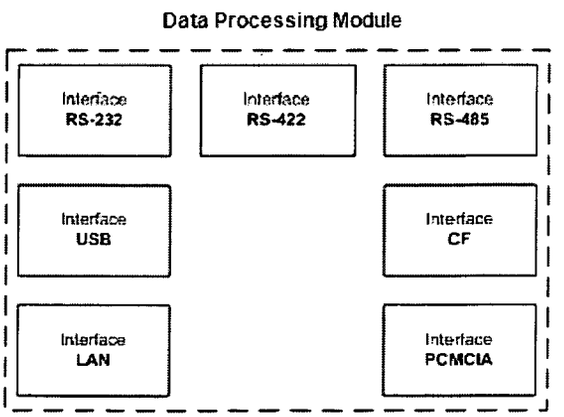

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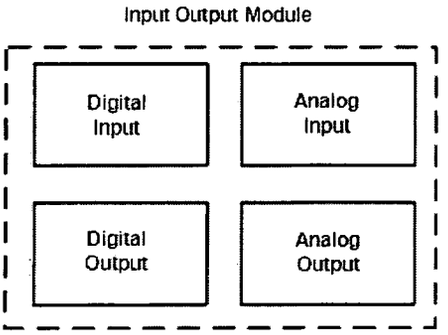

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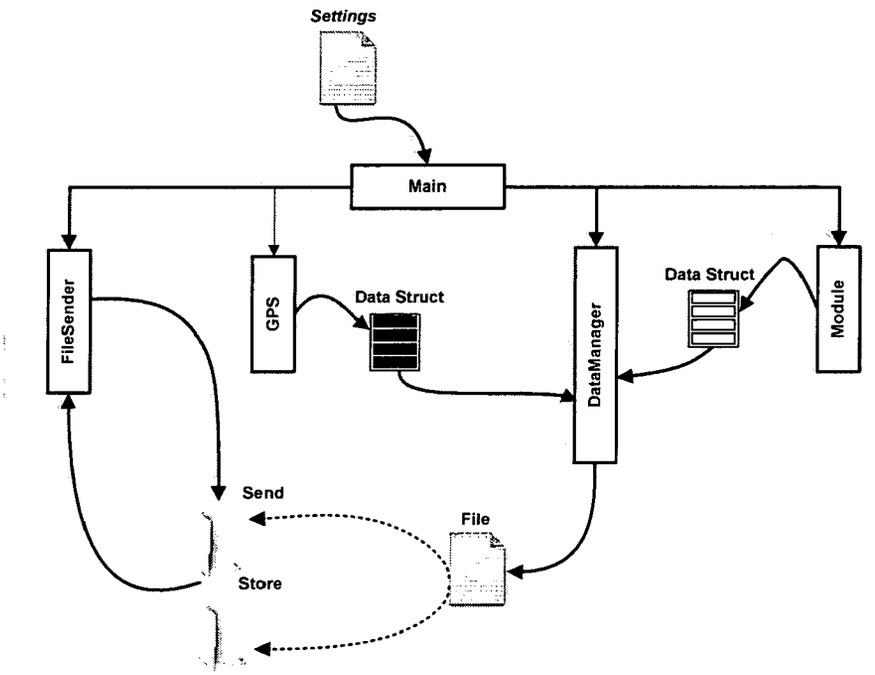

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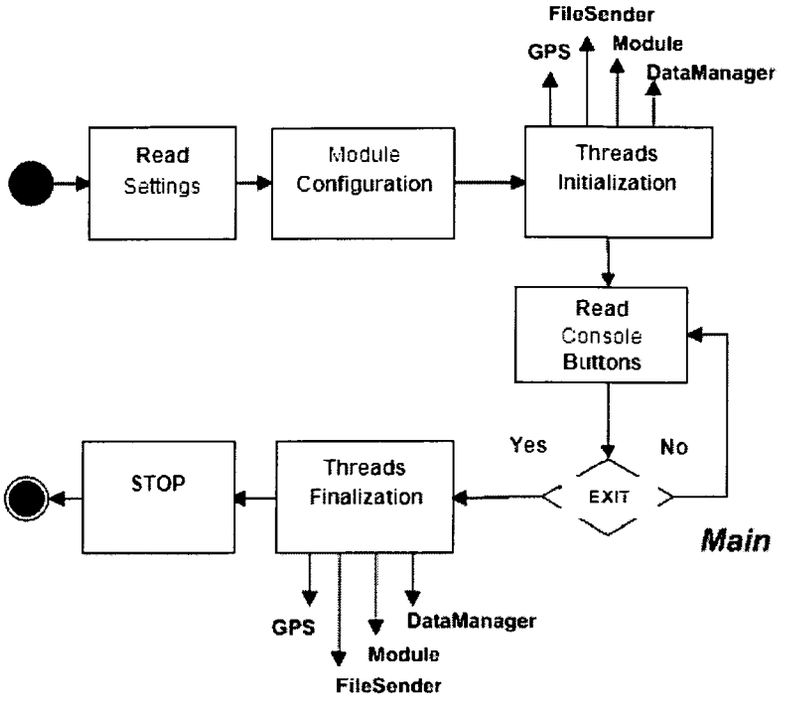

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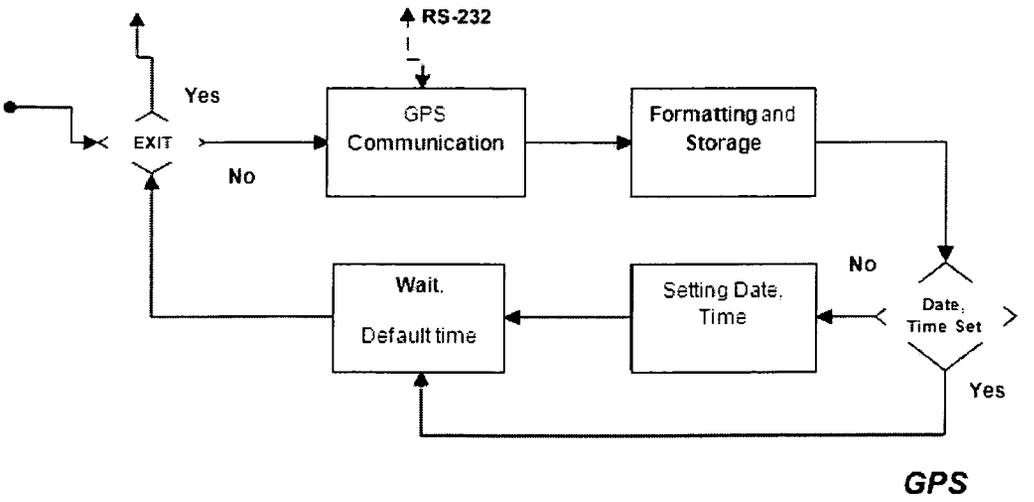

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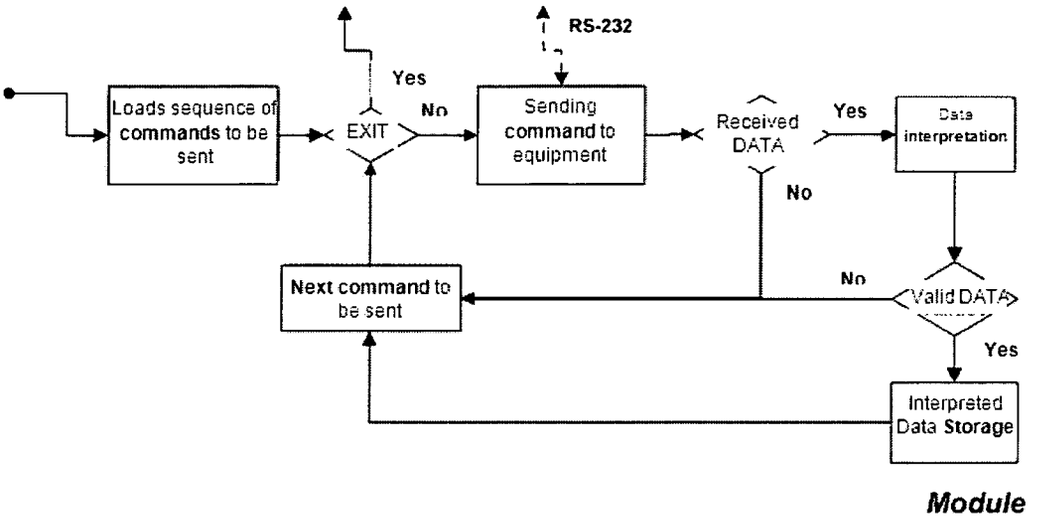

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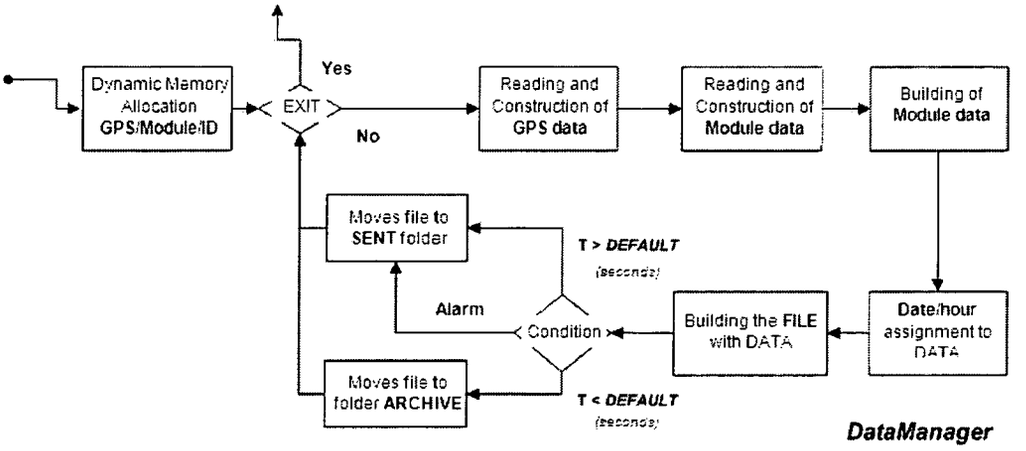

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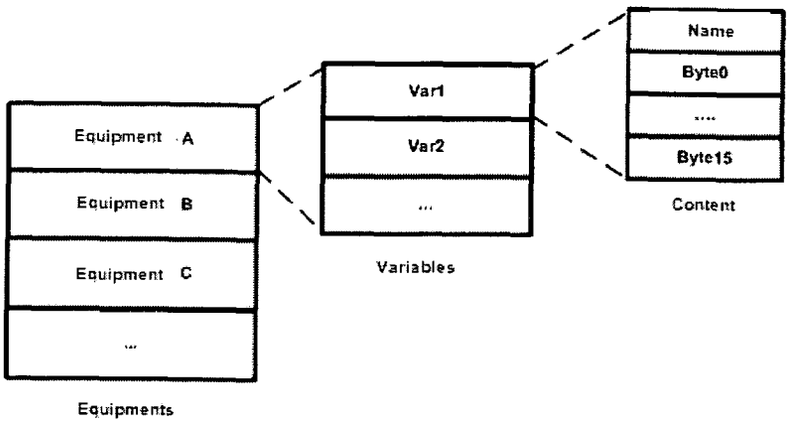

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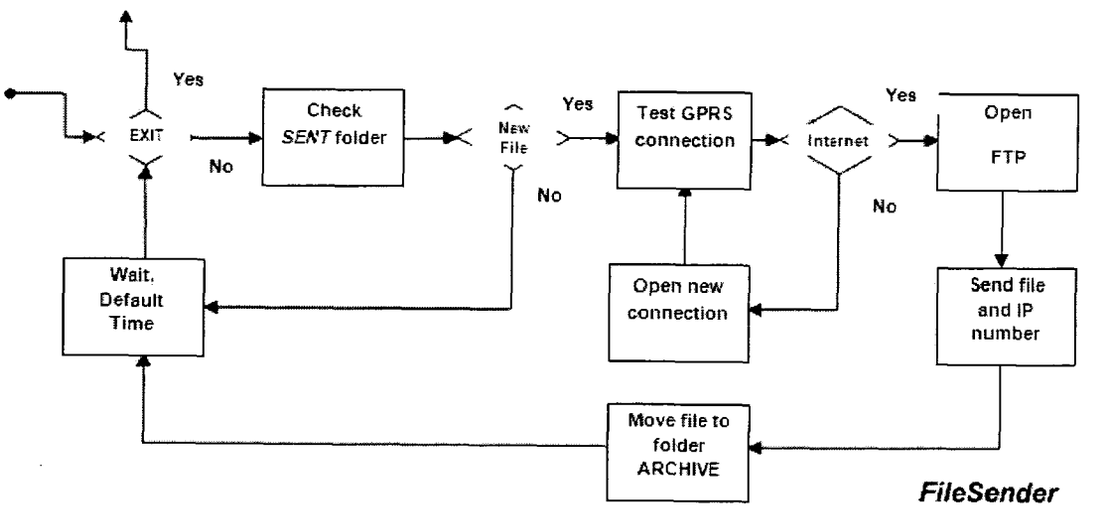

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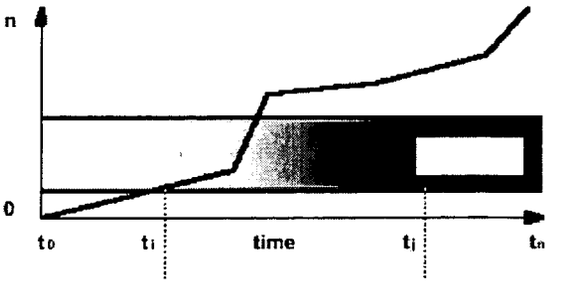

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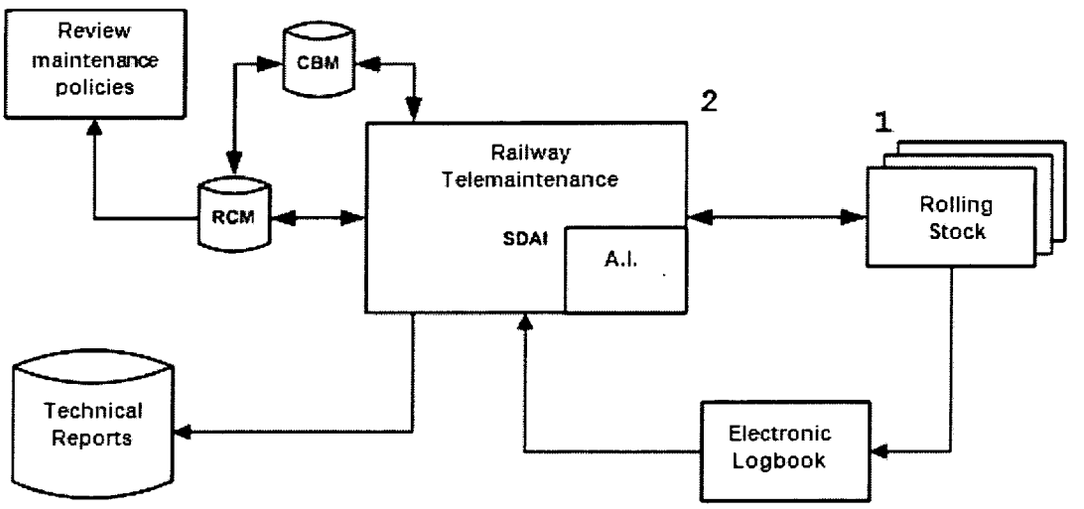

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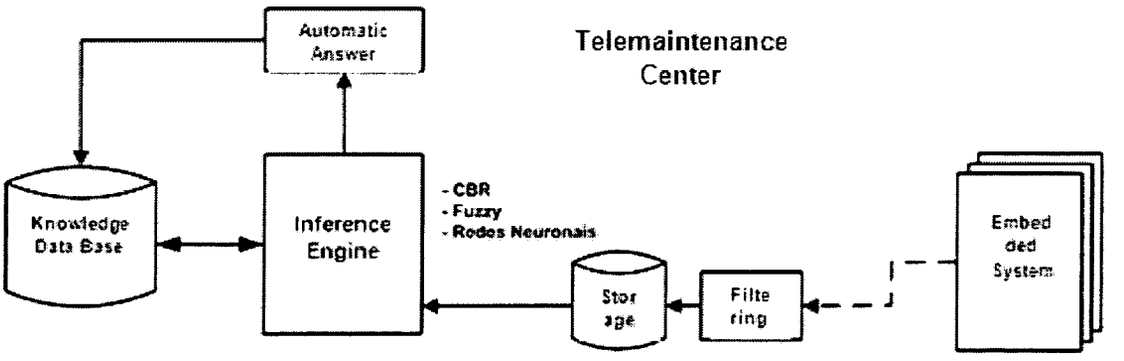

Image 14

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EUROPEAN SEARCH REPORT

Application Number
EP 09 39 8015

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4	Y,P	WO 2009/085476 A1 (SIKORSKY AIRCRAFT CORP [US]; COLBERT SEBASTIAN H [US]; KELL EDWARD T [) 9 July 2009 (2009-07-09) * abstract * * page 6, line 26 - page 7, line 25 * * page 9, line 20 - page 11, line 2 * * page 11, line 18 - page 13, line 2 * * page 15, line 9 - page 17, line 8 *	1-9	INV. G07C5/00 G07C5/08 G06Q10/00
2	Y	US 2007/086482 A1 (PRUZAN BRIAN M [US] ET AL) 19 April 2007 (2007-04-19) * page 2, paragraph 21 - page 4, paragraph 31 * * page 5, paragraph 40 * * page 7, paragraph 51 * * figures 2,4 *	1-9	
2	Y	US 2007/216771 A1 (KUMAR AJITH K [US]) 20 September 2007 (2007-09-20) * page 6, paragraph 58 - page 7, paragraph 61 *	6,9	
				TECHNICAL FIELDS SEARCHED (IPC)
7	A	CARRETERO ET AL: "Applying RCM in large scale systems: a case study with railway networks" RELIABILITY ENGINEERING AND SYSTEM SAFETY, volume 82, issue 3 December 2003 (2003-12), pages 257-273, XP002575438 DOI: 10.1016/S0951-8320(03)00167-4 Retrieved from the Internet: URL:http://www.sciencedirect.com/ [retrieved on 2010-03-26] * abstract * * Section 2, pp.258-259 * * Section 4, pp.266-267 *	1,6,7,9	G07C G06Q

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2 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23 September 2010	Van der Haegen, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number
EP 09 39 8015

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	D'ADDIO G F ET AL: "Optimized reliability centered maintenance of vehicles electrical drives for high speed railway applications" INDUSTRIAL ELECTRONICS, 1997. ISIE '97., PROCEEDINGS OF THE IEEE INTER NATIONAL SYMPOSIUM ON GUIMARAES, PORTUGAL 7-11 JULY 1997, NEW YORK, NY, USA,IEEE, US, vol. 2, 7 July 1997 (1997-07-07), pages 555-560, XP010265085 ISBN: 978-0-7803-3936-1 * the whole document *	1,6,7,9	
A,P	SAE G-11 RCM Subcommittee of the SAE G-11 Supportability Committee: "SAE JA1011, Surface vehicle and aerospace standard : Evaluation criteria for reliability-centered maintenance (RCM) processes" INTERNET CITATION August 2009 (2009-08), XP008121039 [retrieved on 2010-01-01] * the whole document *	1,7	TECHNICAL FIELDS SEARCHED (IPC)
A	SAE G-11 RCM Subcommittee of the SAE G-11 Supportability Committee: "SAE JA1012, Surface vehicle and aerospace recommended practice : A guide to reliability-centered maintenance (RCM) standard" INTERNET CITATION January 2002 (2002-01), XP008121049 [retrieved on 2010-01-01] * the whole document *	1,7	

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