PART 1

Traceability of Information and Knowledge Management

1

Intelligent Traceability of Equipment

1.1. Introduction

Over the last few decades, the business awareness of companies has been based on their intangible capital, the knowledge and expertise of their employees. Many works have been dedicated to creating, sharing and capitalizing on this expert knowledge.

However, just like expertise and practical skills, data also contributes to the intangible capital of companies and it is carefully recorded. Banks jealously guard their databases. Companies distrust the cloud due to security issues related to data, which may fall into the wrong hands and be exploited by competitors or harm data owners. In the age of connected objects, of easy data harvesting and instantaneous remote access, it is evident that well-exploited data represents a gold mine. Indeed, data is becoming a resource which can be exploited by the economy. Data must be secured and exploited and this is the basis of informed decision-making within a domain.

The process of knowledge capitalization corresponds to the notion of knowledge management, which was defined by Davenport as the process of collecting, distributing and effectively using knowledge [DAV 94], an approach developed by [DUH 98]. Traceability is an essential element of the capitalization of knowledge related to different stages of a product's evolution [BIS 08]. Several works have highlighted the notion of the growth of products' lifecycle management as one of knowledge management [AME 05] and [STA 15]. In fact, the research consortium of the project FP6 IP 507 100

PROMISE (PROduct lifecycle Management and Information tracking using Smart Embedded systems) has remarked that traditional PLM systems lack product knowledge and visibility in the two MOL and EOL phases, and has recommended developing traceability and knowledge capitalization during the lifecycle.

The aim of our work is to design and develop a solution for processing and capitalizing knowledge related to industrial equipment throughout its lifecycle and for making it available for operators to easily access this equipment in an understandable way and at the required moment.

New PLM possibilities [RAN 11] are being introduced, thanks to continuous developments in the domain of information systems regarding radio-frequency identification (RFID), sensor network technology and, more generally, in product embedded information devices (PEID). A new generation of products called smart or intelligent products is being developed [KIR 11]. According to [YAN 09], it makes the information easily accessible for designers, users or disassemblers of the product or equipment. However, although these intelligent products are capable of gathering data during their lifecycle, they lack the means of extracting information and acquiring knowledge from this data. To reach this goal, we have tackled three challenges:

– Creation of a so-called intelligent product which allows users access to reliable information capable of being read or manipulated, as well as an available deduction related to the current health state of the product;

– Transformation of data in knowledge in a memory that stores all the information concerning the product during its lifecycle and which can be accessed from the product;

– Proposition for decision support services, online prognostics and monitoring of the health state of equipment and support services for maintenance and recycling of products. These services should be available via an information system which can be easily accessed through the product.

We will address these challenges in three stages: (i) after having defined what intelligent equipment is and having considered the work in this domain, we will orient ourselves toward the data exchange infrastructure CL2M, featuring RFID tags connected to an e-maintenance platform and equipped with deduction tools. (ii) We have developed a knowledge capitalization process that stores the knowledge in an operating memory which is distributed on the equipment and the e-maintenance platform. The knowledge is formalized according to the maintenance ontology IMAMO_RFID and made is available by means of an intelligent product infrastructure that ensures knowledge sharing. (iii) We have developed web services that require the availability of information regarding the state of (mal)functioning of the equipment along its lifecycle. In this way, we propose different decision support services:

– a support service for recycling components (products), in which data is indispensable in order to provide such a service [SIM 00];

– a support service for the monitoring and prognostic processes of the health state of the component;

– a support service for maintenance action planning.

As a result, this chapter will begin by outlining some state-of-the-art intelligent products followed in section 1.3 by a presentation of a knowledge capitalization process that monitors a component's health state along its lifecycle, and the proposition of an ontology called IMAMO_RFID, defined for intelligent products. Section 1.4 will be dedicated to the infrastructure of an intelligent product with the exchange of data and information and the implementation of decision support services.

1.2. State-of-the-art intelligent products

1.2.1. *Definition of intelligent products*

In order to monitor a product during its MOL phase, this product has to be intelligent in McFarlane's sense. [MCF 03] defines the product via a physical and informational representation stored in a database, which is associated with an intelligence provided by a decision support agent. An intelligent product is characterized by five main properties: possession of a unique identify, a capability to communicate effectively with its environment, ability to retain or store data about itself, and a potential to participating in or making decisions relevant to its own destiny. Other definitions of intelligent products exist [MEY 09, MCF 03] as listed [KIR 11] by Kiritsis, who synthesized them by defining an intelligent product as a system containing sensing, memory, data processing, reasoning and communication capabilities. He listed four intelligence levels ranging from a physical product without any embedded system to products with product embedded information devices (PIED).

1.2.2. *Research on intelligent products*

Research on intelligent products suggests integrating the product within an infrastructure of processed data sharing and lifecycle management. Ranasinghe *et al.* [RAN 11] have studied three Product Lifecycle Information Management architectures (PLIM) for collecting and accessing product data, both industrial and academic ones: (i) the EPC network architecture (Electronic Product Code), (ii) the DIALOG system (Distributed Information Architectures for collaborative logistics) and (iii) the WWAI network (World Wide Article Information). These architectures show some weaknesses regarding data synchronization when network disturbances occur. In other words, without a network connection there is no access to databases and the update cannot take place. Xiaoyu [YAN 09] remarks that the intelligent product should have some kind of mechanism that could use the collected lifecycle data to provide services. He suggests that an intelligent product should contain at least three fundamental elements: (i) an intelligent data unit (IDU), (ii) an access service and (iii) a communication infrastructure (CSI).

Z.Y. Wu *et al.* [WU 14] provide a software platform for lifecycle knowledge management that allows systematic assistance for the development of a product, in particular for new heating valves in nuclear power plants. For this purpose, record data has been exploited in order to support the design of the products (fault types, causes and recommendations regarding the actions to be undertaken).

Kiritsis proposes a closed-loop infrastructure for product lifecycle management, the CL2M (Closed-Loop Product Lifecycle Management), which was developed during the European project PROMISE [KIR 11]. The available technology (such as wireless sensors, telecommunications and product identification technology) makes it possible to connect the intelligent products with other information systems during an exchange request for information regarding the lifecycle. This closed-loop architecture enables the inclusion of the different users of the product in the information sharing, ranging from the designer to the constructors and the maintenance operators.

In this way, the designers are able to access real-time data of the product that they have designed, they can observe its usage conditions during the MOL phase and even have a look at recycling data (EOL phase). This is an important step for improving the product design. Furthermore, it enables collaborative tasks to be performed among the users, together with the analysis of information gathered during the lifecycle in order to extract new knowledge about the products. Moreover, Sylvain Kubler *et al.* [KUB 15] propose associating the CL2M concept with a new kind of hardware capable of communicating (for example, an RFID tag), which would make the component capable of undergoing physical transformations without losing either its ability to communicate or its stored data.

1.2.3. *Infrastructure of an intelligent product and RFID*

Recently, several different studies focusing on the usage of RFID technology within the domain of lifecycle management have been undertaken [KIR 03, MOT 11, MOT 13, WAN 10]. RFID technology uses radio waves for the automatic collection of data and is used for storing and transmitting information as well as identifying objects in several domains such as healthcare, military logistics, transport, clothing, food, construction, maintenance, and the logistics of the cold chain [ZAC 11, KAN 12].

Today, thanks to the existence of the RFID tag, intelligent products can provide a network oriented to the creation both of databases and decision support software services [RAN 11] 8 [MEY 09] 19 and [MCF 13].

Sylvain Kubler *et al.* [KUB 14] propose an information diffusion process in order to select information that is relevant to the usage context of the product: this information is stored directly on the product thanks to the RFID tag.

Sarac [SAR 10] underlines the fact that RFID improves both the traceability and the visibility of the products and processes information with accuracy. Mohamed *et al.* [MOT 11] use tags placed on the product to share lifecycle information. They illustrate twelve lifecycle stages such as production, installation and reuse/recycling/dismantlement. An information model is proposed for interacting with the different users along the different lifecycle phases and for providing them with access to data. The authors highlight the limited memory of the tags. Wang *et al.* [WAN 10] propose a usage of RFID technology for supporting disassembly decisions for products at their end of life, and they suggest a model for planning the dismantlement and sequencing based on fuzzy logic.

Kiritsis *et al.* [KIR 03] propose using RFID technology to implement a closed-loop system for PLM systems. The authors illustrate as well a concept for the e-transformation of information into knowledge. However, a lack of formal comprehension about the way of constructing lifecycle information still persists.

These works inspire us to present a piece of intelligent equipment implemented by a CL2M architecture that uses the RFID technology based on an e-maintenance platform. Our contribution concerns the transformation of data into knowledge and, in particular, the formalization of the knowledge that will be capitalized by a distributed memory. This formalization will be obtained from a knowledge capitalization process based on the maintenance ontology adapted for the lifecycle, which we shall call IMAMO_RFID.

1.3. Knowledge management approach

1.3.1. *Knowledge capitalization process*

In order to ensure information traceability during the whole lifecycle of the equipment, we have used a knowledge capitalization approach developed by our team [RAS 08]. It is based on the four phases of the Grundstein capitalization cycle [GRU 96, GRU 00]: the detection of strategic information, preservation of knowledge, its capitalization and its actualization (see Figure 1.1).

1) The detection of strategic information is done via an analysis of maintenance strategies developed in a company by observing the maintenance actions performed at each event. The events may be caused by failures, diagnostic tasks or systematic maintenance planning. This may concern the monitoring of the equipment's operating state, detection of the fault mode and prognostics of its state.

2) Knowledge preservation is achieved through the construction of an operational memory, which can be done via three existing approaches: bottom-up (collection of verbal data), top-down (model-driven) or mixed approach. We have chosen the top-down approach to formalize knowledge via

a maintenance ontology based on IMAMO [NEZ 06], which we have adapted to the intelligent product IMAMO_RFID.

3) Knowledge exploitation is implemented thanks to the infrastructure of the intelligent product and to an e-maintenance platform hosting the IMAMO_RFID ontology which ensures the exchange and diffusion of knowledge.

4) The actualization of knowledge is done via decision support services provided to the equipment's users. These web services can be of different kinds, depending on the information and knowledge data, its traceability, exploitation and maintenance support services.

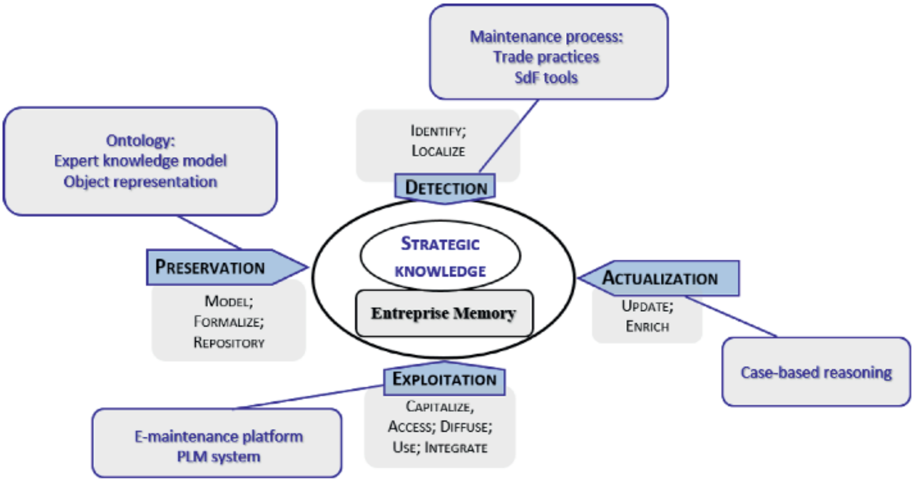

Figure 1.1. *Knowledge capitalization cycle*

We dedicate section 1.3.2 to a survey of the ontologies developed in PLM in order to propose an IMAMO_RFID in this work.

1.3.2. *PLM ontologies*

Ontology-based approaches are being developed to facilitate the communication and the exchange of information among various systems. This reasoning allows an inductive way of solving problems.

Several works regarding PLM ontologies exist. An ontology related to assembly (OAM - Open Assembly Model) is proposed in [FIO 07] and it is integrated into the models of existing products. In the BOL phase, design support ontologies have been developed in a unique environment [SUH 08] and in a distributed design environment [ZHA 08], as well as for the purposes of sharing product knowledge on a network [LEE 07].

An ontology dedicated to engineers working with knowledge management in design processes and implemented in a comprehensible way is proposed in [BRA 08]. Borsato proposes an ontology that is related to the data of the product and its process in terms of durability through semantic links.

Matsokis and Kiritsis [MAT 10] transformed the semantic object model of the European project Promise (PROMISE_SOM (Semantic Object Model)) into an ontology by adding temporal events. Karray proposed a first version of a maintenance ontology [KAR 10] and Matsokitis and Karray combined their ontologies to propose the SMAC (Semantic Maintenance and Lifecycle) model [MAT 10], which takes into account maintenance and different PLM phases. Karray created the IMAMO ontology by bringing together the models of MIMOSA CRIS (reference of the maintenance domain), the SMAC model and PROMISE-SMO. IMAMO incorporates the concepts of the SMAC model, which are related to the equipment's lifecycle in such a way as to take into account: (1) the lifetime, starting from the design phase; (2) the life environment, by monitoring all the events and the health states of the equipment; (3) the end of life, by calculating indicators that support the decisions of reuse and disassembly.

1.3.3. *Proposition of IMAMO_RFID*

In this work, we propose an ontology called IMAMO-RFID. We have created an evolution of the IMAMO ontology [KAR 10] with the purpose of managing the RFID tags associated with an equipment and their content. We have integrated the concept of distributed memory and determined the minimal necessary knowledge that has to be stored in an e-maintenance platform in order to guarantee the monitoring of an equipment during its whole lifecycle.

This package of memory card management, the “LifeRecordManagement” package, ensures the monitoring of the equipment during its whole exploitation phase.

The memory card management model ensures the monitoring of the equipment during its whole exploitation phase. It creates indicators that represent the equipment’s health state. These indicators, mainly statistical ones, are calculated from the stored record of data regarding the various operating state modes of the equipment, the sensor measurements and of different interventions performed on the equipment.

This ontology associates a memory card with each component or piece of equipment by using the LifeRecord management system, “the LifeRecordManagement package”. This package is directly linked to five other packages:

– InterventionManagement: a package that allows the usage and storage of data originating in maintenance interventions, both from systematic preventive and corrective interventions and/or palliative ones;

– MaintenanceStrategy: a package that includes technical indicators calculated via the function “Generate indicator” and the function “Validate control” which updates the counter indicator of the control operations that are performed or generated by prognostic functions;

– EquipmentManagement: a package that stores the equipment’s characteristics;

– MonitoringManagement: a package that allows the acquisition of data from sensors. It stores the collected data in a technical database created according to the notion of measure. This information model will be implemented in an intelligent product;

– RFIDManagement: management of the RFID tag, a new package in IMAMO. It enables reading and writing onto the RFID memory by using an RFID reader.

The class diagram in Figure 1.2 illustrates the objects of the various packages that define the links with the different classes associated with the distributed memory, which is composed of the LifeRecord and the RFID tag. We will describe only those classes that are involved in the management of this distributed memory.

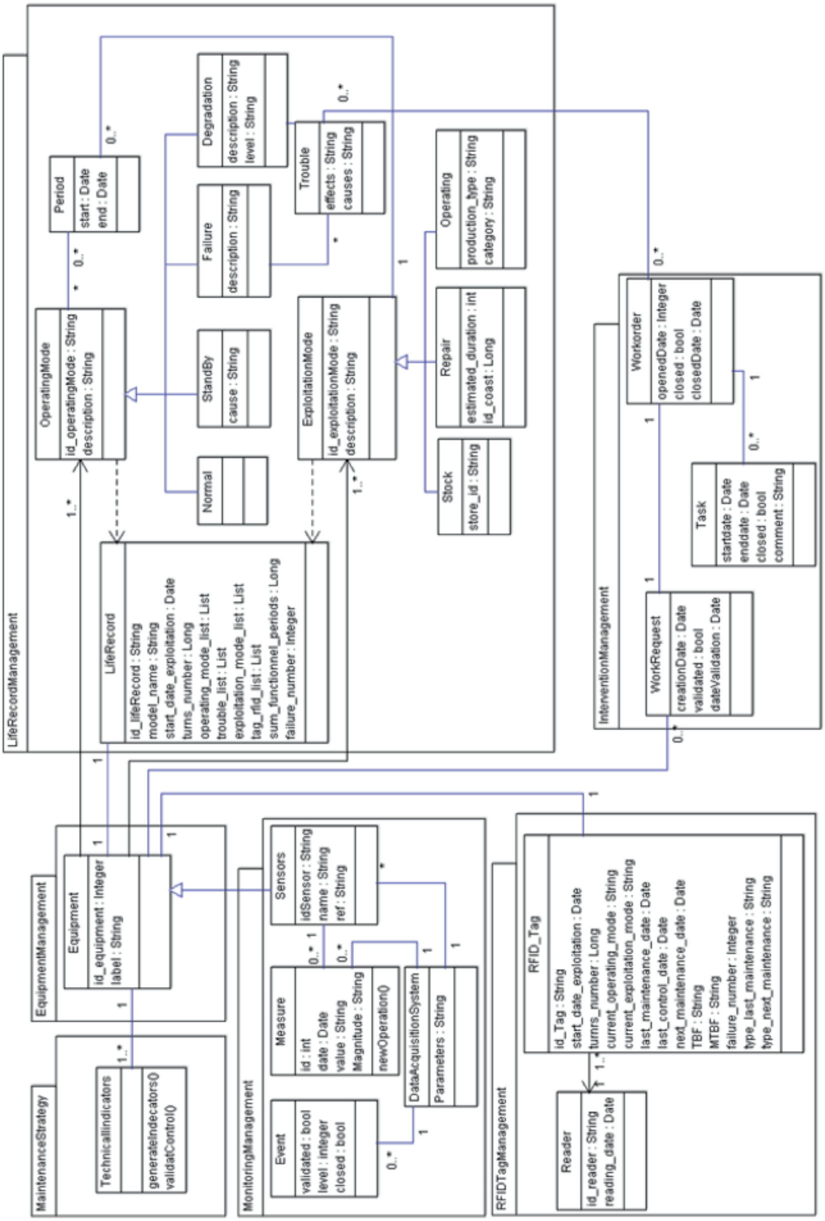

Figure 1.2. *Class diagram of the memory concept*

The latter comprises a set of operating and exploitation modes which are related to intervals of time defined by a start and an end date. Data regarding the equipment's usage has to be put in relation with the operation and exploitation modes, in order to guarantee the monitoring of the equipment during its whole lifecycle.

The operating mode (OperatingMode class in Figure 1.2) is related to the location of the component. It is quite important to be able to localize the component at any moment. We take into consideration the component's location, which is directly related to its operating state. For example, in the case of a component, the exploitation mode can be in stock (the location during a temporary suspension) or in repair in a maintenance workshop. Three exploitation modes are defined:

– Operational: in this case, besides the production duration, it is necessary to indicate the location of the equipment in order to localize its operating place;

– Stock: the component is in a normal state, ready to be used, although it is temporarily unused. It is placed in a storage location. For example, ski cabins are not used all the time. They can be parked in an appropriate place when they are not used;

– Repair: the component can be located in a workshop during the repair.

The operating mode of the equipment can be defined as the ability to perform a required function in particular conditions at a given moment or during an interval of time, supposing that the required exterior results are provided. The different possible modes are normal, degraded and failure states.

LifeRecord is a virtual memory that records data about the equipment's lifecycle. This data is synthetic, being composed of maintenance indicators calculated from the data record. These indicators, mainly statistical ones, may include (i) a reliability coefficient such as the MTBF (Mean Time Between Failures), which represents the average duration of correct operations between consecutive failures, (ii) a maintainability coefficient, MTTR (Mean Time To Repair), which is the average repair duration, (iii) the availability rate of the equipment, which is the ratio between the actual time of availability and the required time, and (iv) a health state indicator modeled by prognostic methods.

The variation over time of these indicators constitutes a characterization of the operating state of the component or equipment.

The RFID tag contains the minimal memory used for data storage associated with the component or equipment during its whole lifecycle. The equipment has several operating and exploitation modes during the MOL phase of its lifecycle. An operating mode involves several components, which are involved in the operating mode during a certain amount of time. A malfunction is associated with each fault or degradation. For a given malfunction, several interventions are possible.

1.4. Intelligent product: data flow and distributed memory

1.4.1. *Architecture of an intelligent product*

The proposed infrastructure is a closed-loop model of product lifecycle management (CL2M), shown in Figure 1.3.

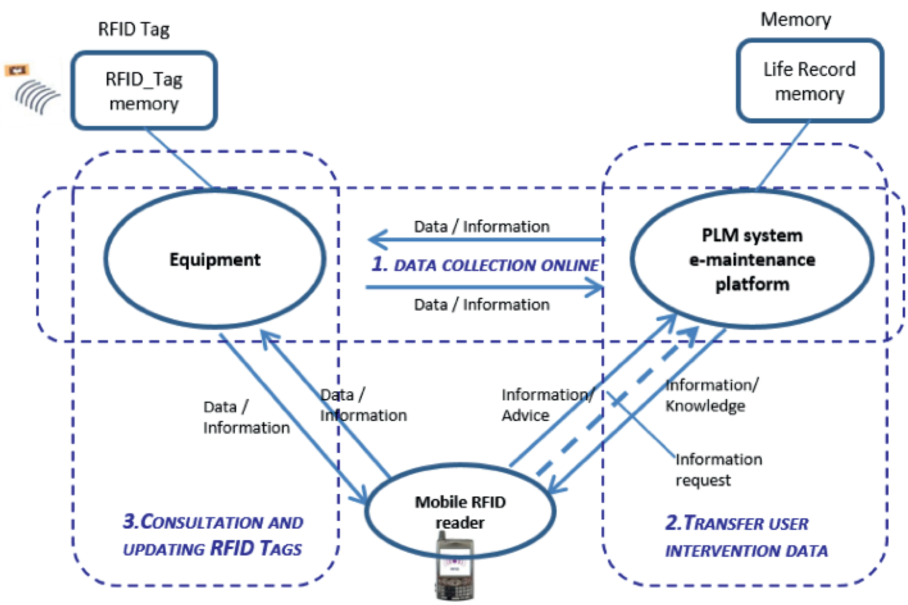

Figure 1.3. *CL2M infrastructure of an intelligent product*

To each critical component of a monitored equipment, we associate:

– an RFID tag with a unique identifier containing enough memory to record essential data and to communicate between the component and the PLM system;

– an additional feature consisting in the identification and communication capabilities that are now added to the product characteristics, thanks to RFID and NFC (near-field communication) technology;

– access via a mobile agent (mobile RFID reader) to the PLM system and to the memory, which we shall call the "vital card";

– a PLM system that controls the knowledge capitalization.

1.4.2. *Stream of data and information in the MOL phase*

There exist three types of data transfer related to the various kinds of maintenance:

1) Online data collection that allows the acquisition of maintenance data via a remote platform and makes predictive maintenance possible. In fact, conditional maintenance planning is done depending on the wear state, which is controlled by the sensors, and the predictive maintenance monitors the variation of the sensors' indicators via experimental measurements. The monitoring service is provided by the platform;

2) Transmission of data related to systematic maintenance, which schedules periodic interventions as a function of time or consumed units, and corrective maintenance, which focuses on an effective repair or replacement of the component or equipment after the failure occurs. Different kinds of services can be provided by the platform;

3) Information consultation and/or updates by the operator requesting information about the component's health. The platform offers a decision support service regarding recycling or maintenance actions according to the component's health state.

1.4.3. *Distributed memory: RFID tag and LIFE RECORD*

In order to gather knowledge about the health state of a component or piece of equipment during its lifecycle and to make this knowledge available, we propose to create a corporate memory of a company specialized in maintenance services. This memory is constructed by means of a knowledge capitalization process and it evolves during the lifecycle.

The corporate memory consists of two distributed memories:

– an RFID tag, which can be read with a mobile reader thanks to the NFC technology; we can thus read locally the tag identifier and the content of its memory, a “short term memory”. The equipment is capable of providing a minimum of information about its health state: for example, if the information regarding its maintenance plan is updated, then the dates of its last and next maintenance are automatically updated. This memory is equivalent to a health record for this equipment;

– LIFE RECORD: we can access this remote memory, located in an e-maintenance platform, at a later step. Thus, it is possible to obtain all the information concerning the equipment model, its failures, effective usage time, degradation and past interventions.

1.4.4. *Stream of information during the MOL phase*

Data transmission during the whole lifecycle of the equipment is implemented by means of an e-maintenance platform. Information is collected, capitalized and stored in a memory. Figure 1.4 describes the data flow between the equipment and the platform. It corresponds to loop number 1 in Figure 1.3, “data collection online”, whereas Figure 1.5 corresponds to loop number 2, “transfer of systematic maintenance data”. The transmission of the intervention data corresponds to the data flow between the tag reader and the platform, which is related to control operations (systematic maintenance) and corrective maintenance.

Figure 1.4 shows that the sensor data originating on the component or equipment is collected (data acquisition, DAS) at regular intervals of time by means of events.

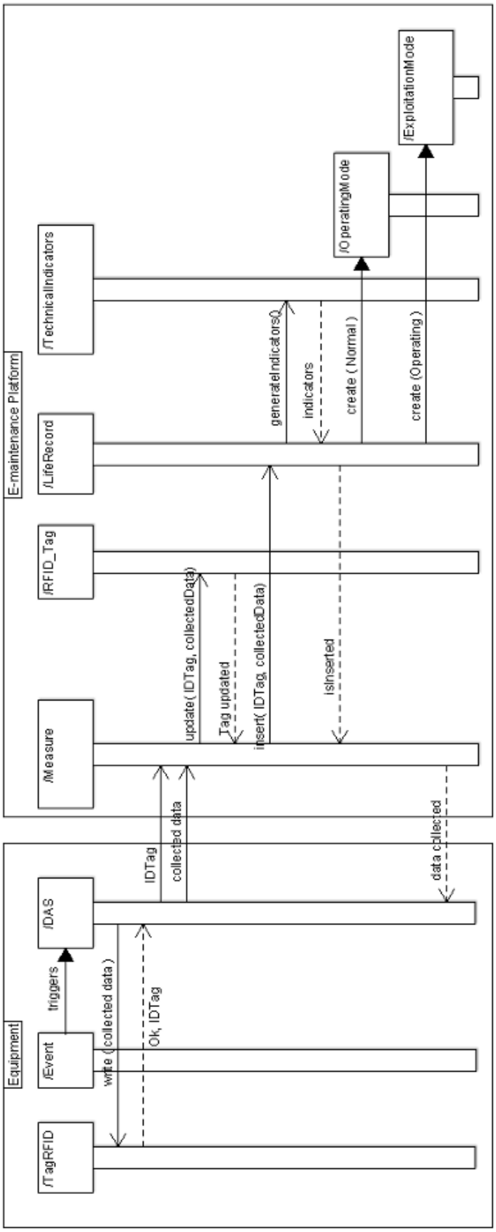

Figure 1.4. *Data flow during the transfer of intervention data*

The */Event* command prompts the data acquisition system, DAS, to collect data and to send it to the platform. A web service sends a message to the platform with one or more measurements. This message is recorded in the technical database. The data is stored in the RFID tag that contains the most recent data and in the LifeRecord in order to keep a record of all the measurements. From this record, the function "Generate indicators" calculates the indicators and updates the health state according to the lifecycle data. As long as data is collected, the equipment is in a normal "OperatingMode" and it is working.

This data stream is used to detect the occurrence of a fault and to generate an event concerning the control operations to be performed during the systematic maintenance. In the case of a failure, the platform creates a "failure mode" in cooperation with the associated perturbation. In the case of a control operation, the platform validates the control of the equipment via the function "validateControl" of the "TechnicalIndicators", then the function "GenerateIndicator()" of the "Class TechnicalIndicators" is called.

This approach allows the creation and transmission of indicators to the RFID tag, as represented in Figure 1.5. When an equipment failure is detected on the site, the maintenance operator uses an RFID reader to scan the tag that is associated with the faulty component, thus retrieving the maintenance data stored in the component, so that this data is eventually modified and updated. This data is used to describe the health state of the equipment, as well as its operation and its (mal)functioning modes. After the maintenance operator has updated the data within the tag, the mobile reader sends its content to the platform via a web service. The characteristics of the equipment are identified by means of the tag identifier.

The operational mode changes to "Failure" mode. This entails the creation of a "WorkRequest", validated by a maintenance supervisor who plans a "WorkOrder" that contains all the tasks to be performed during an intervention on this equipment. The timestamped data recovered via the web service will be inserted into the "LifeRecord". From the content of the "LifeRecord", the function "GenerateIndicators" of the Maintenance Strategy package of the "TechnicalIndicator" class calculates a set of indicators that are associated with this equipment, such as the number of failures, its MTBF, TBF and the type of the most recent maintenance (control, systematic upkeep or corrective) and sends them to the "RFIDTag".

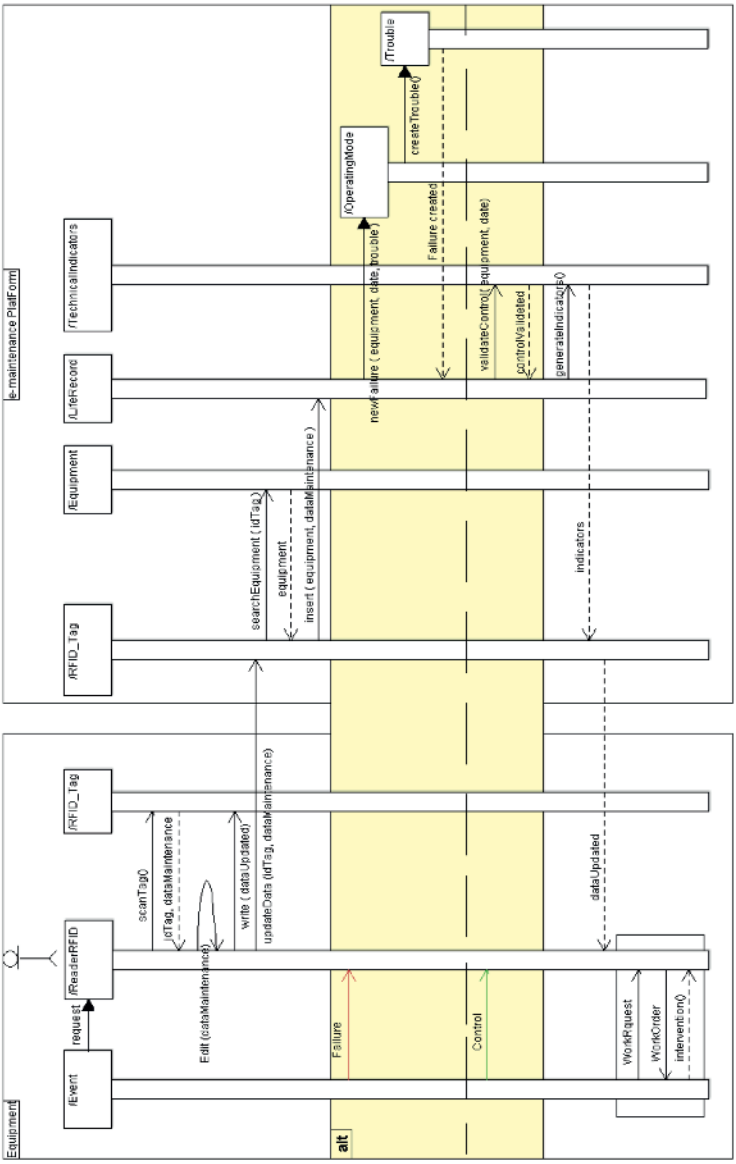

Figure 1.5. *Data stream during the transmission of intervention data*

1.5. Support service for component's recycling

The usage of the IMAMO_RFID ontology provides us with an access to all the information about the critical component or equipment. The indicators of correct operation rate calculation and of the number of failures undergone by this item are updated at each data collection interval. Thanks to these indicators, which synthesize the component's behavior and health state, it is possible to make decisions regarding the possibility of recycling the component.

We will identify these states by using specific scores, which are obtained from the calculation of the indicators and are updated during the whole lifecycle of the component. These indicators are stored in the memory of the RFID tag and they can be accessed without a prior connection to the platform.

If the number of failures N is greater than a default threshold $N_{threshold}$, the equipment is scrapped. In the opposite case, we consider the score defined as $score = MTBF * TM$.

The interval of time measurement is defined by $S \pm \Delta S$, where S $=$ threshold of MTBF, ΔS $=$ measurement error, and MTBF $=$ Mean time between failures.

If ($score < S \pm \Delta S$), then the equipment can be reused.

For the systematic maintenance, we calculate:

$$TM = \frac{\text{number of performed systematic maintenance interventions}}{\text{number of planned systematic maintenance interventions}}.$$

In this way, we take into account the maintenance performed on this equipment. If this rate is not good enough, MTBF can be penalized by multiplying it by the maintenance ratio. This may lead to a rejection of reuse for this equipment.

If the obtained score value is within the interval, LifeRecord has to be consulted.

On the other hand, if the score is slightly lower than the limit value, the component can be connected to the platform and its complete record can be consulted in order to access the characteristics of the component, on which basis the expert can make decisions.

1.5.1. *Implementation of an intelligent equipment and decision support service*

In order to create an intelligent system, we have implemented a closed-loop model architecture shown in Figure 1.4. The techniques employed, various components and some new intelligent services are described. These services allow knowledge capitalization during the MOL phase of the lifecycle and the calculation of indicators for decision support regarding the possible reuse of the component.

Component:

1) The e-maintenance platform provides some maintenance applications. It is based on J2EE specifications. The client is a light browser enabling access to the platform. The application server is a JBOSS server. The persistence level uses PostgreSQL as an object-relational database management system (ORDBMS);

2) The RFID tag has a unique identifier and contains a small memory which allows the storage of vital information and communication between the component and the PLM system;

3) The RFID reader: a smartphone or a tablet with applications developed under Android. It allows, on the one hand, reading and writing in the RFID tag by using the NFC technology and, on the other hand, communication with the platform via web services;

4) Web service: the communication is performed by means of the web service technology, which is a widely used technology for implementing service-oriented architectures (SOA). These architectures simplify the interoperability and the integration of applications on the platform;

5) NFC protocol: in order to ensure the equipment's monitoring, the RFID (Radio Frequency IDentification) tag technology is used and the NFC technology facilitates the reading and writing of information in the RFID tag.

1.6. Conclusion

Sharing information about a product and its lifecycle processes is vital to ensure its durability. The new possibilities of PLM afforded by technological advancements enable the creation of a new generation of intelligent products, which is the subject of this chapter. We proposed an approach that makes a product intelligent; in other words, we integrated the product in CL2M, a closed-loop infrastructure for data exchange equipped with an RFID tag.

To endow this equipment with the capabilities to manage the knowledge that concerns it, we developed a knowledge capitalization process that records the knowledge concerning the whole product's lifecycle in a corporate memory. This memory is distributed in two memories, one embedded on the product in an RFID tag (capable of identifying the product) and another that stores remotely all the events undergone by the product.

The implemented CL2M architecture allows the connection of the product to a remote maintenance platform that ensures the product's health state monitoring. This monitoring is performed using three types of data transfer: (i) online data collection via an acquisition system, with a transfer to the platform via a web service, (ii) local reading of the RFID tag embedded on the product via the NFC technology (its usage facilitates reading and writing within the RFID tag) and (iii) the acquisition of data related to user interventions by means of a questionnaire on a mobile RFID reader, which thus sends information to the tag and to the platform where the information is capitalized.

The knowledge capitalization approach, which we proposed and implemented, is based on the construction of IMAMO-RFID, an ontology from the maintenance domain adapted for intelligent equipment. This ontology stems from different ontologies within this domain, combining the concepts of maintenance, lifecycle and distributed corporate memories. This model associated with the intelligent equipment offers different services such as (i) making the product's lifecycle information available at any moment, (ii) allowing the decision of whether the product can be recycled or not according to a calculation of indicators performed on reliable information and (iii) proposing decision support systems based on constructed indicators such as MTBF or RUL and the information available thanks to the integration of the detection, diagnostic and prognostic applications in the maintenance platform.

This intelligent product can provide different services by means of its CL2M architecture, ranging from local or remote information retrieval to support services for traditional maintenance, such as systematic, corrective and conditional maintenance, and for predictive maintenance, which anticipates the failures. Some examples of these services will be described in Chapter 3.