18 THE APPLICATION OF THE CLOSED-LOOP LIFECYCLE MANAGEMENT IN VIRTUAL ORGANIZATION

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In this paper we propose the implementation of a distributed architecture for product lifecycle management in Virtual Organization created to manage the Middle-of-Life phase. After a short introduction of the innovative Promise-PLM system which support decision making process based on dynamic creation of knowledge, the application of the system to a case study for maintenance management demonstrates how the system can be customized to change process organization guarantying better integration between the actors. The system is studied to be easily accessible and usable by different kind of companies in different industrial sectors.

1. INTRODUCTION

Manufacturing industry is shifting production from pure physical products towards knowledge intensive and service oriented solutions to answer to new market requests. This goes in the direction of lifecycle management view to offer solutions which are reliable and controllable in any phase of their life, solutions which have innovative approach to solve and prevent customer's problems. Smart tags, tracking systems, RFID devices are some of the available systems in the market which can be embedded in the product in order to collect information and data useful in different lifecycle phases.

The development of an integrated solution where it is possible to retrieve, use, manage data and information to obtain knowledge useful for supporting and taking decisions along the product lifecycle is one important issue which is held in many different research projects. Such integrated systems for Product Lifecycle Management (PLM) have a strong impact in the improvement of the Virtual Organizations management since they permit to easily merge and share information and knowledge necessary for many different actors.

In particular the breakthrough contribution of PROMISE project (EU, IST-507100) allows information flow management to go beyond organizational barriers effectively closing the product lifecycle information loop using the latest ICT, and seamlessly transforming that information into knowledge (Kiritsis et al., 2003).

In the present work we describe how the implementation and integration of these technologies have been applied to the case of a company producing milling machine. After a short description of the Promise-PLM technologies we will show the advantages of implementing such a system in a company producing durable equipment and in particular we will show how the implementation of 2 components have been carried on customizing their generic structure for the specific application scenario. Virtual Organization here is intended as the temporary relationship which is established between the customer and the service provider in order to manage maintenance in an innovative way according to data collected along the whole lifecycle. Also other actors like designers of the milling machine can be part of the Virtual Organization and have benefits from sharing information of the product status and usage.

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2. THE APPLICATION OF PROMISE-PLM SYSTEM IN THE VIRTUAL ORGANIZATION

The Promise-PLM system is based on many different modules interacting each other to improve the capability of the companies to manage product along its lifecycle. In particular the system is composed of:

- PEID (Product Embedded Information Device), a data storage device to identify the unique product and which can be read or written to (mainly active and passive RFID tags). On board devices capture lifecycle events or specific conditions that can impact the product performance.
- Middleware: Promise-PLM middleware enables both device management and communication between one or more PEIDs and existing enterprise backend software. Middleware also acts as the networking layer of the Promise-PLM systems, enabling different players in the Virtual Organizations to have controlled and secure access to relevant information.
- PDKM (Product Data Knowledge Manageme) integrates and manages information from all lifecycle phases of the product.
- DSS (Decision Support System) provides algorithms for decision management in different industrial applications for predictive maintenance, diagnosis and analysis of use patterns.

The innovation of PROMISE-PLM system is in its capability to manage and optimize knowledge on product lifecycle thanks to up-to-date and accurate collection and retrieval of related information which can have significant influence on residual life decisions regarding individual sub-assemblies or components and positively impact the usage, the environment, the production through improved and more efficient decisions (Cao et al., 2007).

The Promise-PLM system has been developed to provide integrated and innovative technologies to help companies to manage the Beginning-, the Middle- and the End-of-Life phases (respectively BOL, MOL, EOL) allowing many actors to create and manage Virtual Organizations integrating the product's lifecycle where they are involved (managers, designers, service and maintenance operators, recyclers, etc.) to track, manage and control product information at any phase of the product and process lifecycle.

During the project the Promise-PLM system has been applied to many different applications which have adapted and used some of the components according to the specific needs.

The virtual enterprise is a relatively consolidated approach in modern company organizations. It means that there is a stable and continuous link between a company and, from one side its customers and from the other side its providers. This allows a seamless production flow along the whole process chain. This model is guided by the effort of reaching a greater efficiency in a extremely competitive market characterized by globalization, technological development and differentiation of client requires.

Virtual enterprises are based on reliance between the companies involved. From such a flexible, but coordinated, organization several advantages can be retrieved. Time and costs reduction in service, manufacturing, supplying processes for instance.

In this large context the closed loop lifecycle management of an industrial product has its important part. In fact an integrated solution (hardware architecture and information flows) where it is possible to retrieve, use, manage data and information to obtain knowledge useful for supporting and taking decisions along the product lifecycle is an one important issue that makes things from virtual (that means it exists as potentiality, but not yet in things/acts) to real.

In particular the company under study represents one of the MOL cases on predictive maintenance for milling machines. The company expects the benefits of exploiting PLM functionalities enriched with Promise-PLM technology implementing a closer integration both in terms of information and material flows between maintenance staff and machine owners: the system will allow organization of maintenance activities mainly between these two actors optimising the number and the typology of intervention. Moreover the system will allow an enriched information feedback loop from MOL on certain parameters selected for BOL phase in order to improve the performance of the design phase.

3. THE IMPLEMENTATION OF THE PDKM

The PDKM (Product Data and Knowledge Management) module is responsible for the integration and management of both product data and knowledge from all lifecycle phases from different sources and to the creation, update and management of knowledge, in order to improve future generations of products, starting from data on the current products collected directly from the field.

Starting from the semantic object model of the PDKM developed within the project (Cassina et al., 2006) the Product Data Structure for this application scenario was formalized according to pre-defined categories for each product instance and related characteristics of each product lifecycle phase. The product structure of milling machine has been analysed and studied together with the company in order to create the related class diagram. The information collected from the company have been used to create the objects and the structure and then have been inputted in the PDKM. An example of the structure of one component is here given (Fig. 1).

Milling machine is a complex product with many different components. For each component measuring points have been foreseen in order to collect field data on the performance of the components themselves during MOL phase and are used by the DSS module to plan maintenance actions.

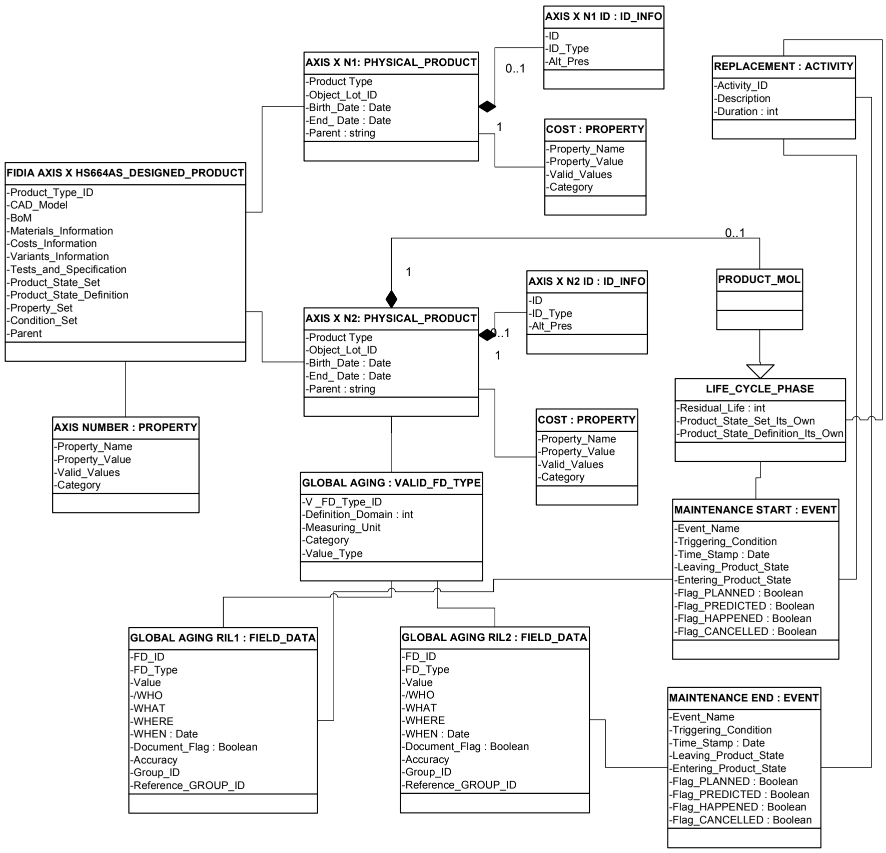


Figure 1: Product data structure

4. THE IMPLEMENTATION OF THE DSS

The DSS of the Promise-PLM system offers a set of functions which are important for a variety of actors in the Virtual Organization.

The Promise-PLM DSS is based on a set of strategies defined in the project which are thought to support companies in strategic and operational tasks and which can be used for a variety of different optimization problems according to the specific lifecycle phase under analysis and to the actions the company wants to undertake. In the Promise-PLM DSS some of the most important strategies considered are linked to data mining and pattern search based on field-, diagnosis- and environmental data, evaluation and measurement of the efficiency of a set of products compared to their design target values, predictive-maintenance management to evaluate the status of deterioration or upcoming breakdowns, etc

Each of these strategies has been designed with lifecycle perspective and has been applied to some application scenarios for test and validation.

The integrated Decision Support System developed for the milling machines producer goes in the direction of predictive maintenance strategy as suggested in many approaches proposed in literature (Swanson, 2001; Pinjalaa et al. 2006; Takta et al., 2004; Yam et al.2001) and is the results of the merging of 3 different modules of the overall Promise DSS interacting each other in order to reduce the number of unexpected stops for maintenance and to minimize the overall lifecycle costs of the product avoiding component breakdowns (Fornasiero et al.,2007).

In the figure below the Use Case for the MOL phase shows the sequence of events when participants to the Virtual Organization at any lifecycle phase wishes to interrogate the machine status. The creation of a new collaborative environment is based on technological development and improvement which have been carried out both at customer and service provider site. Sensors measures the relevant parameters related to the components and to their usage and send this information to the onboard computer where a first module of the DSS has been installed to filter, analyse and store data. The customer (machine user) can activate the modules of the DSS (diagnostic and ageing module) on the on-board computer of the milling machine in order to evaluate the status of the parameters and to calculate the residual life of the components. With the companies it was defined which are the most critical parameters to be sent to the central server of maintenance Service. Data are stored in the PDKM and can be used to monitor the status of the machines around the world. This data is used to activate another module of the DSS which has been developed for maintenance cost management with which the service staff can plan the maintenance interventions around the world.

The DSS evaluates maintenance costs with an iterative process on each machine for components exceeding a given threshold value of “criticality”. Once the machine user has verified the status of the components with the testing module, an alarm on aging is sent to the Maintenance Service which collects the alarms from all the machine tools under maintenance and calculate the economic value of different maintenance actions according to residual life costs estimation. Risk of failure are evaluated and are used to weight the costs.

The system is meant to provide a list of suggested interventions that can be performed on the machine when the monitored mechanical components are expected to fail according to alarms from the aging module which gives in input the residual lifespan of the machine and components through the PDKM where these information are stored.

Data are collected from all the machines and LCRC (Life Cycle Residual Cost) for each maintenance action is computed (see fig.3). The system minimizes the LCRC according the residual life of the machine and of the components taking into consideration a long term view on the impact of maintenance. Forecasting future intervention and probability of failure are based on historical data collected along the life of the machine.

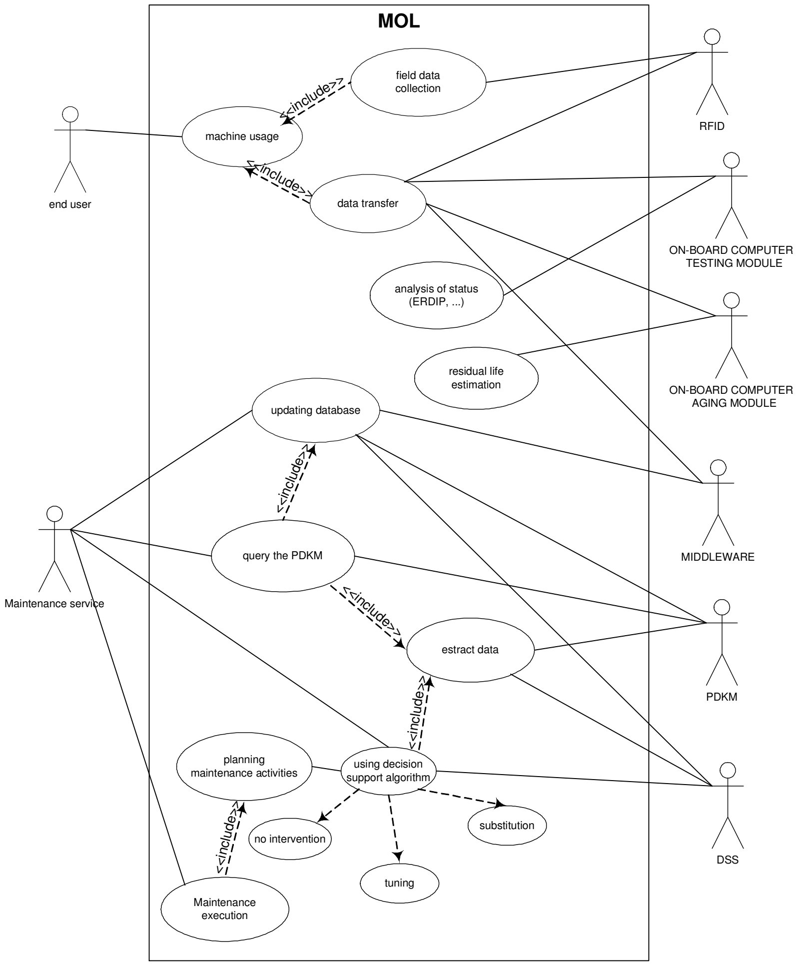


Figure 2: Use case for the MOL

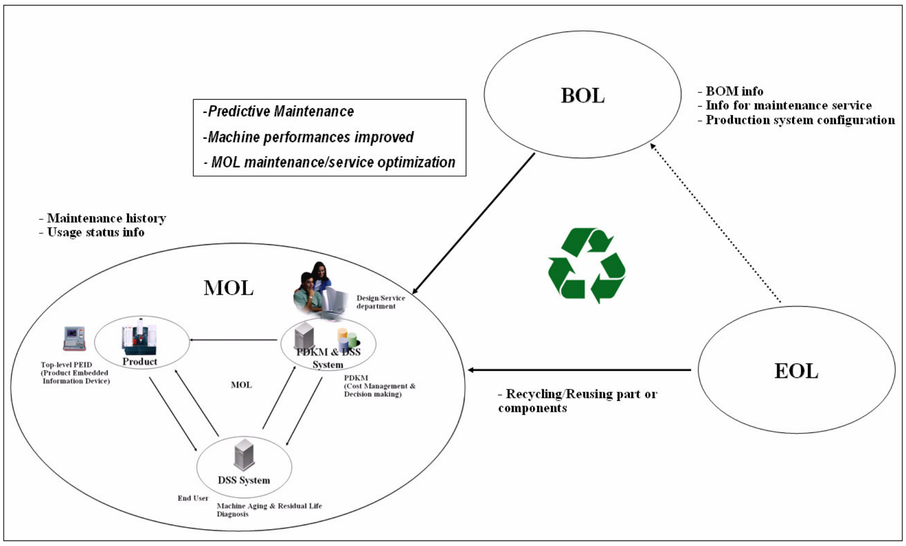
5. IMPACT ON THE COLLABORATIVE ENVIRONMENT OF THE COMPANY

The implementation of the Promise-PLM solution in the specific case under consideration has been critically evaluated according to assessment criteria defined within the project and shared with the other partners. The integration between the various components of the Promise-PLM system have been tested so that the sensors on the machine, the PDKM and the DSS communicate via middleware system. The system can manage a multiple number of machines according to security and reliability criteria. The most important functionalities which have been tested are:

- the link to active PDKM (real data filled-in database), to retrieve cost elements, residual life, historical data, etc.

- import/export functionalities with the Computerized Numerical Control
- adequacy of the models by refinement of algorithms implemented
- DSS capability to manage to variable multiple-axis machines

The overall implemented system covers most of the functionalities required by the company like assessment of the residual life of machine components, classification of maintenance actions, evaluation of costs associated to maintenance actions, evaluation of the life cycle residual costs.



The business model for the company is based on reliable relationship established with the customer in order to provide an after-sale service which is based on updated and shared data. The milling machine builder strictly collaborates with the milling machine user. The PDKM can be used both in the BOL and EOL phase according to data needed by the specific phase.

The advantage of implementing such a system overcome the problem met by the company of collecting data based on the experience and sensibility of technicians that set the thresholds and analyse great quantity of historical data to be affordable. Therefore model based algorithm requires a start-up period in which continuous refinements could be done during first years due to the interpretation of data coming from the field. On one hand the application of fuzzy logic algorithms for the DSS are more flexible and can be programmed so that self-improvements are possible in the future when enough field data will be available, gathered through the maintenance crews, or the centralized data management infrastructure (PDKM). On the other hand the application of maintenance cost minimization is based on evaluation of actions postponement and of the cost all along the residual lifecycle is taken into consideration.

6. CONCLUSIONS

The MOL phase of a product expands the value-added processes after the delivery of the product to the customer; indeed, this phase of the lifecycle is experiencing rapid growth. After-sales market sizes is increasing because service provision and high quality performance of product is essential to keep customers.

In the implementation of Promise-PLM system, the overall structure has been matched with the industrial requirements derived from the company analysis and have been customized using the modules of the system necessary for the specific case. The PDKM gives the company the possibility to manage and formalize data on the product and its components updating them according to periodically collected field data. The DSS gives the company the possibility to optimise and manage maintenance delegating to the machine user the capability to easily control and monitor some parameters and to the maintenance provider to plan the intervention all over the world.

Rules of behaviour and process flow have been defined at different level of detail to use the Promise-PLM system in different steps of the product lifecycle for the establishment of a collaborative environment based on Virtual Organization principles between machine user and maintenance provider to optimise the performance of the machine and the cost of maintenance. The overall decision support system can have a double impact on maintenance management. In fact it may support the machine user who can monitor machine performance and ageing of the components and the maintenance service provider who can plan and forecast interventions needed and optimise maintenance costs.

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