Towards Product Avatars Representing Middle-of-Life Information for Improving Design, Development and Manufacturing Processes

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Abstract. In today's globalized world, customers increasingly expect physical products and related information of the highest quality. New developments bring the entire product lifecycle into focus. Accordingly, an emphasis must be placed upon the need to actively manage and share product lifecycle information. The so-called Product Avatar represents an interesting approach to administrate the communication between intelligent products and their stakeholders along the product lifecycle. After its initial introduction as a technical concept, the product avatar now revolves around the idea individualized digital counterparts as targeted digital representations of products enabling stakeholders to benefit from value-added services built on product lifecycle information generated and shared by Intelligent Products. In this paper, first the concept of using a Product Avatar representation of product lifecycle information to improve the first phases, namely design, development and manufacturing will be elaborated on. This will be followed by a real life example of a leisure boat manufacturer incorporating these principles to make the theoretical concept more feasible.

Keywords: PLM, Product Avatar, BOL, Intelligent Products, Digital Representation, Information, Data.

1 Introduction

In today's globalized world, customers increasingly expect physical products and related information of the highest quality. New developments bring the entire product lifecycle into focus, such as an increased sensibility regarding sustainability. Accordingly, an emphasis must be placed upon the need to actively manage and share product lifecycle information.

The so-called Product Avatar [Hribernik, Rabe, Thoben & Schumacher, 2006] represents an interesting approach to administrate the communication between intelligent products and their stakeholders. After its initial introduction as a technical concept, the Product Avatar now revolves around the idea individualized digital counterparts as targeted digital representations of products enabling stakeholders to benefit from value-added services built on product lifecycle information generated and shared by Intelligent Products [Wuest, Hribernik, Thoben, 2012].

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During the middle of life phase (MOL) of a product a broad variety of data and consequently information can be generated, communicated and stored. The ready availability of this item-level information creates potential benefits for processes throughout the product lifecycle. Specifically in the beginning-of-life phase (BOL) of the product lifecycle, opportunities are created to continuously improve future product generations by using item-level MOL information in design, development and manufacturing processes. However, in order to make use of the information, its selection and presentation has to be individualized, customized and presented according to the stakeholders' requirements. For example, in the case of design processes, this means taking the needs of design engineers into account, and during manufacturing, the production planner.

In this paper, first the concept of using a product avatar representation of product lifecycle information to improve the first phases, namely design, development and manufacturing will be elaborated on. This will be followed by a real life example of a leisure boat manufacturer incorporating these principles to make the theoretical concept more feasible.

2 Product Lifecycle Management and Intelligent Products

The theoretical foundation for the Product Avatar concept is on the one hand Product Lifecycle Management. This can be seen as the overarching data and information source from which the product Avatar retrieves the bits and pieces according to the individual needs of a stakeholder. On the other hand, this depends on Intelligent Products being able to gather and communicate data and information during the different lifecycle phases. In the following both areas are introduced as a basis for the following elaboration on the Product Avatar concept.

2.1 Product Lifecycle Management

Every product has a lifecycle. Manufacturers are increasingly becoming aware of the benefits inherent in managing those lifecycles [Sendler, 2009]. Today's products are becoming increasingly complicated. For example, the amount of component parts is increasing. Simultaneously, development, manufacturing and usage cycles are accelerating [Sendler, 2009] and production is being distributed geographically. These trends highlight the need for innovative concepts for structuring and handling product related information efficiently throughout the entire lifecycle. On top that, customer demand for more customisation and variation stresses the need for a PLM at item and not merely type-level [Hribernik, Pille, Jeken, Thoben, Windt & Busse, 2010].

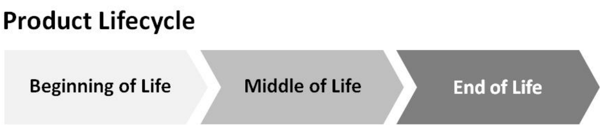

Fig. 1. Phases of the Product Lifecycle

PLM expands on the concept of Product Data Management (PDM) to include information generated and used beyond design and manufacturing [Paul & Paul, 2008; Fasoli, Terzi, Jantunen, Kortelainen, Sääski & Salonen, 2011]. Besides merely handling product and process related data, PLM also has to take into account the interdependencies of information and communication between all of the stakeholders involved in the product lifecycle.

Common graphical representations of the product lifecycle encompass three phases – beginning of life (BOL), Middle of Life (MOL) and End of Life (EOL) –arranged either in a circle or in a linear form (see Figure 1). The linear form represents the product lifecycle “from the cradle to the grave”.

The social web offers a number of opportunities for item-level PLM. For example, Web 2.0-based product information acquisition could contribute to the improvement of the quality of future products [Merali & Bennett, 2011; Gunendran & Young, 2011].

2.2 Intelligent Products

Intelligent Products are physical items, which may be transported, processed or used and which comprise the ability to act in an intelligent manner. McFarlane et al. [McFarlane, Sarma, Chirn, Wong, Ashton, 2003] define the Intelligent Product as “...a physical and information based representation of an item [...] which possesses a unique identification, is capable of communicating effectively with its environment, can retain or store data about itself, deploys a language to display its features, production requirements, etc., and is capable of participating in or making decisions relevant to its own destiny.”

The degree of intelligence an intelligent product may exhibit varies from simple data processing to complex pro-active behaviour. This is the focus of the definitions in [McFarlane, Sarma, Chirn, Wong, Ashton, 2003] and [Kärkkäinen, Holmström, Främling & Artto, 2003]. Three dimensions of characterization of Intelligent Products are suggested by [Meyer, Främling, Holmström, 2009]: Level of Intelligence, Location of Intelligence and Aggregation Level of Intelligence. The first dimension describes whether the Intelligent Product exhibits information handling, problem notification or decision making capabilities. The sec-ond shows whether the intelligence is built into the object, or whether it is located in the network. Finally, the aggregation level describes whether the item itself is intelligent or whether intelligence is aggregated at container level. Intelligent Products have been shown to be applicable to various scenarios and business models. For instance, Kärkkäinen et al. describe the application of the concept to supply network information management problems [Kärkkäinen, Holmström, Främling & Artto, 2003]. Other examples are the application of the Intelligent Products to supply chain [Ventä, 2007], manufacturing control [McFarlane, Sarma, Chirn, Wong, Ashton, 2003], and production, distribution, and warehouse management logistics [Wong, McFarlane, Zaharudin, Agrawal, 2009].

A comprehensive overview of fields of application for Intelligent Products can be found in survey paper by Meyer et al [Meyer, Främling, Holmström, 2009].

Thus, an Intelligent Product is more than just the physical product – it also includes the enabling information infrastructure. Up to now, Intelligent Products are not "socially intelligent" [Erickson, 2009] in that they could create their own infrastructure to communicate with human users over or store information in. However, Intelligent Products could make use of available advanced information infrastructures designed by socially intelligent users, consequently enhancing the quality of information and accessibility for humans who interact with them.

3 Product Avatar

One approach to representing the complex information flows connected to item-level PLM of an intelligent product is the Product Avatar. This concept describes a digital counterpart of the physical Intelligent Product which exposes functionality and information to stakeholders of the product's lifecycle via a user interface [Hribernik, Rabe, Thoben, & Schumacher, 2006; Wuest, Hribernik & Thoben, 2012; Wuest, Hribernik & Thoben, 2013].

3.1 Concept Behind the Product Avatar

The concept of the Product Avatar describes a distributed and de-centralized approach to the management of relevant, item-level information throughout a product's lifecycle [Hribernik, Rabe, Thoben, & Schumacher, 2006]. At its core lies the idea that each product should have a digital counterpart by which it is represented towards the different stakeholders involved in its lifecycle. In the case of Intelligent Products, this may also mean the implementation of digital representations towards other Intelligent Products. Consequently, the Avatar concept deals with establishing suitable interfaces towards different types of stakeholder. For Intelligent Products, the interfaces required might be, for example services, agents or a common messaging interfaces such as QMI. For human stakeholders, such as the owner, producer or designer, these interfaces may take the shape, e.g., of dedicated desktop applications, web pages or mobile "apps" tailored to the specific information and interaction needs. This contribution deals with the latter.

Examples of embryonic Product Avatars are already emerging on the market. For example, each new Smart Fortwo electric drive (Smart ED) car has its own web page, which shows e.g. maximum range capable with current battery charge [N.N., 2012]. The cur-rent charge status or the SmartCharging charge configuration can be controlled and managed via a web portal from a home computer or with any modern smartphone. In the future, several other features will be controlled remotely through a smart drive application for the iPhone [N.N., 2011].

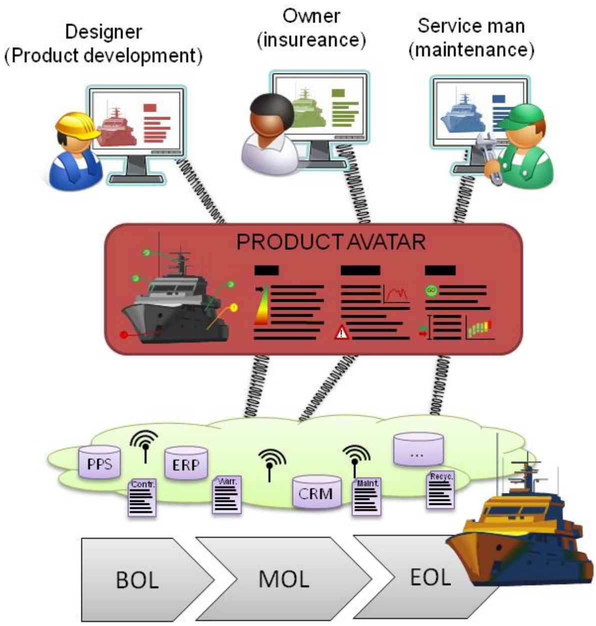

Fig. 2. Digital, Stakeholder specific Representation of a Product through a Product Avatar

3.2 Example for Product Avatar Application during the MOL Phase

In order to make the theoretical concept of a Product Avatar more feasible, a short example based on a real case will be given in this section.

The authors successfully implemented a Product Avatar application for leisure boats in the usage (MOL) phase of the lifecycle for the stakeholder group “owner” by using the channel of the popular Social Network Service (SNS) Facebook. The goal was to create additional benefits for users by providing services (e.g. automatic log-book with location based services). The rationale behind using the popular SNS Facebook was that users are already familiar with the concept and that the inherent functions of the SNS expanded by the PLM based services increase the possibilities for new services around the core product of a leisure boat (see Figure 3).

Fig. 3. Screenshot of the Facebook Product Avatar for the Usage phase (MOL)

The Product Avatars main function in this phase was, to provide pre-defined (information) services to users. The PLM information needed were either based on a common data base where all PLM data and information for the individual product were stored or derived through a mediating layer, e.g. the Semantic Mediator (Hribernik, Kramer, Hans, Thoben, 2010), from various available databases. Among the services implemented was a feature to share the current location of the boat including an automatic update of the weather forecast employing Google maps and Yahoo weather. Additionally, information like the current battery load or fuel level were automatically shared on the profile (adjustable by the user for data security reasons). (see Figure 4)

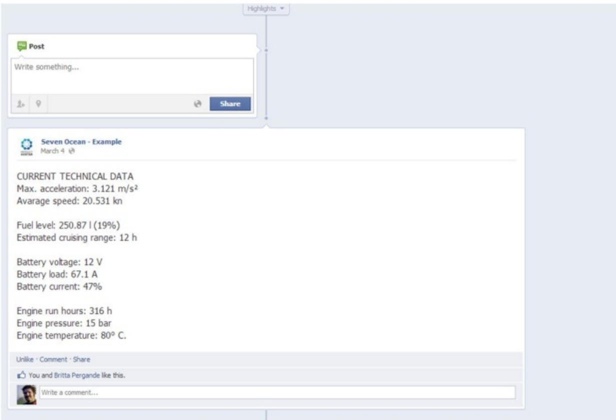

Fig. 4. Screenshot of an excerpt of information provided by the Product Avatar

Throught the digital, stakeholder specific representation of the individual product the available data and information allows the users and their friends, through social features) to benefit from their boating experience even remotely.

4 Product Avatar Application in the Bol Phase

In this section the practical example of a Product Avatar for a leisure boat, shortly introduced with a focus on MOL in the section before, will be described in more detail focusing on the BOL phase. First the stakeholders with an impact on the BOL phase will be presented and discussed briefly. Afterwards, some insights on MOL data capturing through sensor application and the different existing prototypes are introduced. The last sub-section will then give three examples of how MOL data can be applied during the BOL phase in a beneficial way for different stakeholders.

4.1 Stakeholders

The stakeholders having an impact on BOL processes can be clustered in two main groups: data producing (MOL) and data exploiting (BOL).

The group of data producing stakeholders during the MOL phase is fairly large and diverse. The main stakeholders with the biggest impact are:

- Users (owners): This stakeholder controls what data will be communicated (data security). Furthermore, they are responsible for the characteristic of the data captured through the way they use the boat.
- Producers: This group has an impact on updates (software), what sensors are implemented and what services available all influencing the data availability and quality.
- Maintenance: This group on the one hand produces relevant data themselves when repairing the boat but also ensures the operation readiness of the sensors etc.

In the BOL phase, the stakeholders are more homogenious as all have a common interest of building the boat. However, they have different needs towards possible MOL data application. There are two main groups to be identified:

- OEMs: This stakeholder is responsible for the overall planning and production of the boat and later the contact towards the customer. He has the strongest interest in learning about the “real” usage of the boat based on MOL data.
- Suppliers: This group is mostly integrated in the planning process through the OEM. However, even so indirectly included in planning activities, MOL data can be of high value for their operations.

Depending on the Customer Order Decoupling Point, the user might also fall into this category of important stakeholders during the BOL phase. However, the user at this stage is mostly considered not to be directly involved in the product developing activities and has to rely on the OEMs communication.

4.2 Capturing of MOL Data

Today's technological development, especially in the field of sensor technology, presents almost unlimited possibilities of data capturing. Of course this is limited by common sense and economic reasons.

To capture MOL data of a leisure boat, the development included three stages of prototypes.

The first stage of the so called Universal Marine Gateway (UMG) were three sensors (humidity, pressure and temperature) connected to a processing unit (here: BeagleBone) and mounted in an aquarium. In this lab prototype (see Figure 5) first hands on experience was gathered and the software interfaces with PLM data infrastructure was tested.

The next stage, the UMG Prototype MK.II (see Figure 6) incorporated the findings of the first lab prototype on a miniature model of a boat in order to learn about the effects of a mobile application and wireless communication on the data quality and impact on capturing still in a secure environment.

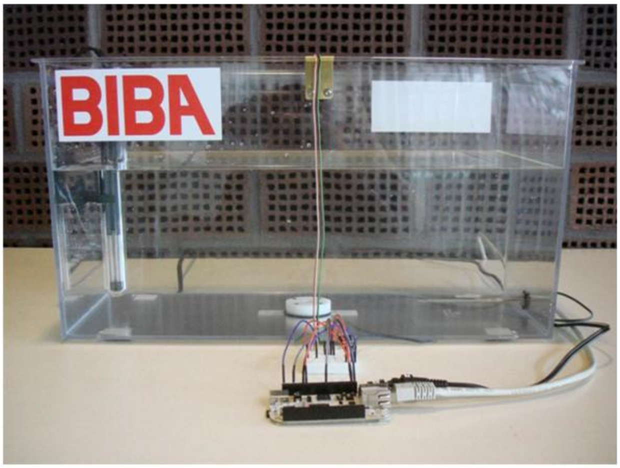

Fig. 5. Lab Prototype "Universal Marine Gateway" (UMG) with Example Sensors

Fig. 6. UMG Prototype Mk. II „in Action“

The final stage,UMG Prototype MK. III (see Figure 7), consists of a fully functional and live size boat where a set of sensors, based on the findings of the earlier stage tests, is implemented. This prototype will be tested under realistic settings and different scenarios.

Fig. 7. Prototype boat for sensor integration and testing

The practical implementation of the sensor equipment implies a series of challenges. E.g. the sensors need to be protected against damage coused by impact when debarking on shore. On the other hand they have to be “open” to the sourrounding environment to measure correctly. Other challenges include how the captured data is communicated “in the wild” to the data base.

4.3 Application, Limitation and Discussion

In this sub-section three exemplary cases of utilization and application of MOL data of a leisure boat by the BOL stakeholders through the Product Avatar are presented below. It is however evident that the use cases are just a short description without going into detail as this would exceed the purpose of this paper.

The first use case of MOL data is based on the Product Avatar supplying data of location, temperature, humidity in combination with a timestamp to boat designers. Ideally they can derive information on not only suitable material (e.g. what kind of wood can withstand high humidity and sun) and dimensioning of certain details (e.g. sunroof more likely to be used in tropical environments) but also on equipment needed under the circumstances (e.g. heating system or air conditioning).

Whereas the benefit of the first use case could also be realized utilizing other methods, the second one is more technical. The Product Avatar provides information directly to the suppliers of the Boat OEM, namely the engine manufacturer. Through aggregated data of, on the one side, the engine itself, e.g. rpm or heat curve and on the other side supplying information about the conditions it is used, e.g frequency, run-time, but also outside temperature etc the engine designers can reduce the risk of over-engineering. When a boat is just used a few times a year, the durability of the engine module might not be as important.

The third use case is in between the former two. Whilst it is unlikely that MOL data can influence manufacturing processes directly, it definiately can influence them indirectly through the process planning. An example is that through location based data and accompanying legal information for that location, both provided by the Product Avatar, the production planner can change the processes. So can it be necessary to e.g. add Shark-Inspired Boat Surface on the hull instead of using toxic paint as for the region the boat is mostly used the toxic paint is illegal. This could also be an application for the MOL phase again, notifying boat users not to enter a certain area (e.g. a coral reef) as they might inflict damage to the environment, which might be valued by environmelntal conscious users.

5 Conclusion and Outlook

This paper presented an introduction on the basic principles of PLM and Intelligent Products as a basis for the concept of a Product Avatar as a digital representation of a physical product. After Introducing the theoretical concept and giving an example of application of PLM data during the MOL phase, the usage of MOL data during the BOL phase was elaborated. To do so, the main stakeholders of both phases were derived and the process towards data capturing on leisure boats was briefly introduced. This was followed by three hypothetical use cases on how MOL data provided by a Product Avatar can be beneficial for the stakeholders.

In conclusion, the Product Avatar can only be as good as the existing data and information and, very importantly, the knowledge on what information and data is needed in what way (e.g. format) through which channel by which individual stakeholder.

In the next steps the Product Avatar concept will be expanded and evaluated further through scenarios as described in the use cases.

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References

1. Hribernik, K.A., Rabe, L., Thoben, K.-D., Schumacher, J.: The product avatar as a product-instance-centric information management concept. International Journal of Product Lifecycle Management 1(4), 367–379 (2006)
2. Wuest, T., Hribernik, K., Thoben, K.-D.: Can a Product Have a Facebook? A New Perspective on Product Avatars in Product Lifecycle Management. In: Rivest, L., Bouras, A., Louhichi, B. (eds.) PLM 2012. IFIP AICT, vol. 388, pp. 400–410. Springer, Heidelberg (2012)
3. Sendler, U.: Das PLM-Kompendium. Referenzbuch des Produkt-Lebenszyklus-Managements. Springer, Heidelberg (2009)
4. Hribernik, K.A., Pille, C., Jeken, O., Thoben, K.-D., Windt, K., Busse, M.: Autonomous Control of Intelligent Products in Beginning of Life Processes. In: International Conference on Product Lifecycle Management (2010)
5. Paul, R., Paul, G.: Engineering Data Management and Product Data Management: Roles and Prospects. In: Proceedings of the Fourth International Bulgarian-Greek Conference Computer Science 2008, Kavala, Greece, pp. 614–619 (September 2008)
6. Fasoli, T., Terzi, S., Jantunen, E., Kortelainen, J., Sääski, J., Salonen, T.: Challenges in Data Management in Product Life Cycle Engineering. In: Hesselbach, J., Herrmann, C. (eds.) Glocalized Solutions for Sustainability in Manufacturing, pp. 525–530. Springer, Heidelberg (2011)
7. Merali, Y., Bennett, Z.: Web 2.0 and Network Intelligence. In: Warren, P., et al. (eds.) Context and Semantics for Knowledge Management, pp. 11–26. Springer, Heidelberg (2011)
8. Gunendran, A.G., Young, R.I.M.: Methods for the capture of manufacture best practice in product lifecycle management. Int. J. of Production Research 48(20), 5885–5904 (2011)
9. Wuest, T., Hribernik, K., Thoben, K.-D.: Digital Representations of Intelligent Products: Product Avatar 2.0. In: Abramovici, M., Stark, R. (eds.) Smart Product Engineering. LNPE, vol. 5, pp. 675–684. Springer, Heidelberg (2013)
10. McFarlane, D., Sarma, S., Chirn, J.L., Wong, C.Y., Ashton, K.: Auto ID systems and intelligent manufacturing control. Eng. Appl. of Artif. Intell. 16, 365–376 (2003)
11. Kärkkäinen, M., Holmström, J., Främling, K., Artto, K.: Intelligent products - a step towards a more effective project delivery chain. Comput. in Ind. 50, 141–151 (2003)
12. Meyer, G.G., Främling, K., Holmström, J.: Intelligent Products: A Survey. Comput. in Ind. 60, 137–148 (2009)
13. Ventä, O.: Intelligent and Systems. Technology Theme - Final Report. VTT, p. 304. VTT Publications, Espoo (2007)
14. Wong, C., McFarlane, D., Zaharudin, A., Agarwal, V.: The Intelligent Product Driven Supply Chain. In: IEEE Int. Conference on Systems, Man and Cybernetics, vol. 4 (2002)
15. Erickson, T.: Social systems: designing digital systems that support social intelligence. AI & Soc. 23, 147–166 (2009)
16. N.N.: Stromer suchen Anschluss. Die ZEIT (2012), http://www.zeit.de/2012/31/Elektroauto-Reichweite-Kosten (received September 15, 2012)

17. N.N.: Third-generation smart fortwo electric drive to launch worldwide in spring 2012. Green Car Congress (2011), http://www.greencarcongress.com/2011/08/smart-20110816.html?cid=6a00d8341c4fbe53ef014e8ab1feeb970d (received August 13, 2012)
18. Hribernik, K.A., Kramer, C., Hans, C., Thoben, K.-D.: A Semantic Mediator for Data Integration in Autonomous Logistics Processes. In: Poppelwell, K., Harding, J., Poler, R., Chalmeta, R. (eds.) Enterprise Interoperability IV - Making the Internet of the Future for the Future of Enterprise, pp. 157–167. Springer Publications, London (2010) ISBN 978-1-84996-256-8