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A critical view on PLM/ALM convergence in practice and research

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Abstract

The Internet of Things (IoT) is the main driver for industrial smart products produced by an increasing number of manufacturers. The overall functionality of smart products is a combination of mechanical, electrical/electronic functions (hardware functions) and software functions. For hardware and software there are different lifecycle models: Product lifecycle management (PLM) focuses on hardware, application lifecycle management (ALM) focuses on software. Smart products force manufacturers to converge both lifecycle models step by step. Although seemingly important, the research community leaves this innovative area mostly up to the PLM tool vendors and the ALM tool vendors, resulting in them driving the convergence. This paper points out the mismatch between industry and academia regarding the PLM/ALM convergence. We encourage academia to increase research activities and we propose potential research topics.

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The Internet of Things is changing the world. More and more physical items are turned into smart products. Smart products are connected to each other creating completely new business scenarios. For example, they can be updated over the air, they can self-diagnose and send repair/replacement alerts before they break down, or they create value to the customer by offering and activating on-demand features. Smart products are intelligent. In order to fulfill all these scenarios smart products are not pure physical items anymore. They have software inside.

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These trends challenge the manufacturers of smart products. Traditionally, they have been and some of them still are, manufacturers of purely physical items. In order to design, develop, produce and service physical items manufacturers implemented hardware related lifecycle models, called product lifecycle management (PLM). PLM is defined as the business activity of managing a company’s products across their entire lifecycles in the most effective way [1]. However, the software within the smart products is not managed by PLM.

The software is managed by a different lifecycle model called application lifecycle management (ALM). ALM “indicates the coordination of activities and the management of artefacts (e.g., requirements, source code, test cases) during the software product’s lifecycle” [2].

It is claimed that PLM and ALM are processes not products [3,4]. It is true that implementing PLM/ALM requires a clear process definition. However, manufacturers can only claim that they have implemented PLM or ALM, if they have a PLM tool or an ALM tool in place and are improving their usage continuously.

Although to some extent similar, ALM and PLM are two different lifecycle models. Therefore, both ALM and PLM are required when developing a smart product. Two lifecycle models, and two different tool chains, are used for the same product. This is inefficient and leads to inconsistent data management, insufficient transparency about results achieved, incomplete documentation and other disadvantageous points [3].

To overcome these drawbacks, both lifecycle models should converged. PLM tool vendors and ALM tool vendors have started this convergence in practice. However, the research community leaves this innovative area to the tool vendors.

In this paper we point out the mismatch between the research activities and the industry activities regarding PLM/ALM convergence. In section 2 we explain briefly PLM and ALM. In section 3 and 4 we summarize related research work and related industry work. We finish with proposals for potential research topics and a concluding discussion.

1. PLM and ALM

The management paths of the hardware development and the software development diverged in the last decades. The hardware path created PLM, the software path created ALM. As both models address the general product engineering process from the idea of a product to its delivery, they are to some extent similar. For example, they consist of dedicated phases, incorporate workflows and link components to each other. Typical phases of both process models are defined in [5] (Table 1 and Table 2).

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conceive</td>
<td>Information is gathered from the marketplace, customer requirements are determined and the product is imagined and technical specifications based on this information are created.</td>
</tr>
<tr>
<td>2. Design</td>
<td>The product’s initial design is created, refined, tested and validated using tools such as CAD. This step involves a number of engineering disciplines including mechanical, electrical, electronic and software (embedded), as well as domain specific expertise i.e., automotive engineering.</td>
</tr>
<tr>
<td>3. Realize</td>
<td>At this stage, the product design is complete and the manufacturing method is determined, with this phase addressing tool design, analysis, simulation, and ergonomic analysis.</td>
</tr>
<tr>
<td>4. Service</td>
<td>In this final phase of the product lifecycle, we enter the service phase, which may involve repair and maintenance, waste management and end of life (disposal, destruction) of the product.</td>
</tr>
</tbody>
</table>
Table 2. ALM Phases [5]

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application project and portfolio management</td>
<td>An investment analysis is performed and business case developed prior to the inception of a software project.</td>
</tr>
<tr>
<td>2. Project inception and requirements gathering</td>
<td>Marketplace information is gathered, potential users/customers of the application are interviewed, and data is gathered to form documented requirements.</td>
</tr>
<tr>
<td>3. Requirements management</td>
<td>As requirements evolve or change, the requirements document also must evolve to analyze impact on development schedules, delivery date, resources, etc.</td>
</tr>
<tr>
<td>4. Design and use-case analysis</td>
<td>The underlying architecture of the software code is set out, and various use-cases are developed to model the user’s possible interactions with the final system.</td>
</tr>
<tr>
<td>5. Coding</td>
<td>Application code is written or, in the case of an enhancement, extended or revised.</td>
</tr>
<tr>
<td>6. Testing &amp; QA</td>
<td>The software is systematically debugged, performance, load and stressed tested, with necessary revisions made to the code.</td>
</tr>
<tr>
<td>7. Build release, deploy</td>
<td>The final release is compiled, the release is finalized, and the application is deployed to production.</td>
</tr>
<tr>
<td>8. Application performance</td>
<td>The ongoing maintenance of the application, including enhancement bug fixing over the application’s lifecycle until the end of life phase.</td>
</tr>
</tbody>
</table>

PLM and ALM are cyclic process models. The first phase starts again whenever a new revision/version of the product/software is created. This is repeated until the end of life of the product.

2. Related research work

We performed a systematic mapping study. The aim of a systematic software mapping is to determine the coverage of a research field [6]. We followed the specific guidelines for software engineering given in [6]. As ALM belongs to software engineering this method is valid for our research question: *What is the research coverage of PLM/ALM convergence?*

We searched in following databases: IEEE Xplore Digital Library, ACM Digital Library (expanded with ACM Guide to Computing Literature), Springer Link and ScienceDirect. For the latter ones, we restricted the search to the disciplines “engineering” and “computer science”. We used the search string: (“ALM” AND “PLM”). As ALM and PLM are well-established abbreviations this search string is precise enough to find papers addressing joined topics of ALM and PLM. As ALM is a new discipline, we limited the search period from 2005 to present. We conducted the search in calendar week 02/2016. Table 3 shows the initial search results.

Table 3. Search results

<table>
<thead>
<tr>
<th>Database</th>
<th>Total number of publications</th>
<th>Number of relevant publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Xplore Digital Library</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>ACM Digital Library</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Springer Link</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>ScienceDirect</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>76</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

After reading the titles and making an overview of the abstracts we excluded many publications, which clearly did not use the abbreviations ALM and PLM according to the meaning in section 2. Furthermore, we excluded all non-English publications and eliminated double entries. This reduced the number of possible relevant publications to 19.

Finally, we studied the publications in detail. We analysed whether they address common issues of PLM/ALM such as configuration management, interfaces or general importance of collaboration. This reduced the number of
relevant publications to 11 [3,16,17,18,19,20,21,22,23,24,25]. Some of them are keynote announcements or workshop descriptions [16,17]. The content of these publications are summarized as follows:

- General importance of PLM/ALM collaboration without detailed suggestions [3,16,19,23,24]
- Collaborative use-cases [22,25]
- Architecture and technology [17,18]
- Using ALM to develop PLM solutions [20,21]

The small number of 11 publications is an indicator that PLM/ALM convergence is hardly covered as a research field. A well covered research field would lead to many more publications, e.g. there have been 167 relevant publications on software product size measurement methods until the year 2014 [7].

3. Related industry activities

A manufacturer of smart products implementing PLM and ALM processes has to deploy at least two different software solutions, one for each lifecycle model. Because ALM and PLM are different process models there are many different vendors selling PLM software solutions and ALM software solutions. As explained before, this parallel and disconnected tool environment is inefficient when managing smart products.

To better meet manufacturer needs, tool vendors have begun the convergence of PLM/ALM. Examples are given from Vector, IBM, Siemens and PTC [3,8,9,10]. The convergence has three dimensions:

- a business dimension
- a technical dimension
- a user dimension

The business dimension addresses the business strategies of the industry. Large tool vendors such as Siemens, PTC and IBM have acquired ALM vendors (Polarion, MKS and Rational, respectively) in order to integrate software engineering know-how and ALM know-how into their product portfolio. Smaller vendors cooperate with partners who implement interfaces.

The technical dimension addresses the implementation of combined PLM/ALM software solutions, e.g. the interface technology. Open Services for Life Cycle (OSLC) is a recent popular attempt to provide a technical framework to implement such interfaces [11]. Originally the IBM internal approach to integrate ALM tools, it is now an open standard and extends the reach of the specification to PLM/ALM. It provides a framework for the integration of lifecycle management [12]. The IT departments of manufacturing companies are responsible for deploying OSLC based solutions. However, the users don’t care about these technical implementations.

The user dimension, of course, addresses the needs of users. The user wants harmonized workflows, an integrated user experience (UX), redundancy-free data, etc. This is the core of PLM/ALM convergence. We pick one concrete example from the industry to demonstrate a practical implementation regarding the user dimension.

Siemens is the vendor of the PLM tool “Teamcenter”. Polarion is the vendor of the ALM tool “Polarion ALM”. As mentioned above, Polarion is now part of Siemens. Although the acquisition has just recently been announced, Polarion and Siemens were already collaborating for some two years to define an approach to PLM/ALM integration. Siemens and Polarion plan to converge their PLM/ALM solutions in several steps. There is no “big bang” solution. In each step, a specific level of integration is reached [13]:

1. Link and Trace
2. Change and Propagate
3. Act and Communicate
4. Align and Unify
5. Collaborate and Report

The integration levels 1 and 2 are already implemented and deployed. Siemens Teamcenter Version 10.1.4 or later, and Polarion ALM Version 2015 or later are required to run them. The companies are now implementing levels 3 and 4. Level 5 is, to some extent, a longer term goal. Table 4 shows the description of these integration levels.
Table 4. Integration levels Siemens Teamcenter and Polarion ALM [13]

<table>
<thead>
<tr>
<th>Integration Level</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Link and Trace</td>
<td>PLM items are linked to software artefacts. Navigation between both systems is possible.</td>
<td>Link a product requirement to a software requirement. Find all software test cases connected to a product test case. Find a product defect to a software defect. Find the product component(s) impacted by a software defect.</td>
</tr>
<tr>
<td>2. Change and Propagate</td>
<td>Impact of changes can be assessed in any direction. Changes can occur at requirements level or at design/production level.</td>
<td>Change a product test case and propagate the change to the software test cases. Change a product requirement and propagate the change to the impacted software user stories. Fix a software bug and update the product BoM.</td>
</tr>
<tr>
<td>3. Act and Communicate</td>
<td>Orchestration of all activities in hardware and software development. Integration of both processes.</td>
<td>Change the status of a software change request to “analyze” when a product change request enters the “evaluate” state. Automatically create a product defect when a software bug is discovered. Assign a test run task to a software tester when a new product testing round starts.</td>
</tr>
<tr>
<td>4. Align and Unify</td>
<td>Unification of user experience with a delegated UI. Alignment of hardware variants and software variants.</td>
<td>Find the software source code running on a specific product version or variant. Find the software variants that can be installed on a product. Navigate the full BoM (with product and software artifacts) in the context of a product configuration, without leaving the PLM environment.</td>
</tr>
<tr>
<td>5. Collaborate and Report</td>
<td>Collaboration of hardware and software engineers. Single user interface for all team members including dashboards.</td>
<td>Define and monitor unified product and software KPIs. Co-engineer a product. Implement and measure product and software process improvements. Software and hardware engineers as part of the same team.</td>
</tr>
</tbody>
</table>

Siemens and Polarion agreed that it has been proven in practice that ALM cannot be used to develop the hardware part of a product, and PLM cannot be used to develop the software part. Their final goal, PLM/ALM convergence, is driven by the desire to deliver a unified user experience, allowing access to dispersed information related to smart product development in one linked and well-managed data structure that, besides supporting collaboration between product engineers, can ensure product maintainability in the long term.

In order to evaluate the announced level of integrations, the Siemens Teamcenter Version 10.1.4 and the Polarion ALM Version 2015 SR2 were installed at the OWL University of Applied Sciences. Additionally, a special connector needed to be installed. After the technical installation, the product development of a USB stick was simulated. The product requirements were entered into Teamcenter. The software related requirements were linked via an OSLC interface from Teamcenter to Polarion. Linking the requirements leads to a UI integration. A user working with Teamcenter can see the linked software requirement, because the Polarion UI of this software requirement is integrated in Teamcenter. The same is possible for a user working with Polarion, he can see the Teamcenter UI in Polarion. When a change is propagated within Teamcenter, it can also be linked with Polarion artefacts. This leads again to integrated UI’s.

The evaluation showed that the integration levels 1 and 2 are implemented in practice. However, there have been issues noticed which need improvement. Most of the issues address the usability when linking items between both tools.
4. Recommendation to the research community

There is a disconnect between activities by industry and research activities regarding PLM/ALM convergence. Is this an issue? We would answer, yes. It is because we are convinced that the future business success of manufacturing companies will, among other things, depend on efficient product lifecycle processes and tool chains. The earlier manufacturers improve on this the better they are prepared for stronger market competition due to digitization. Academia has, among others, the task to support industry to improve its competitiveness.

We see several potential research topics. The following list is considered as an initial set of ideas. We encourage the research community to find many more:

- Design of integrated or common PLM/ALM data models.
- Definition of new approaches, or extension of actual methods (Lean, Agile, Enterprise Agile, etc.) to morph software and hardware teams working on smart product development.
- Design of unified use cases, supporting a better user experience by means of user interfaces and user interactions with PLM/ALM solutions.
- Design of PLM/ALM key performance indicators (KPIs) and measurement systems monitoring quality, efficiency, costs, process improvement, effectiveness, etc.
- Design of meaningful reports, dashboards for KPIs and measurements.
- Create a research foundation to support the development of standards for smart product development, validation, verification, conformance, safety, security etc.
- Design of efficient collaboration between different engineering teams (local, global) with creation of barrier-breakers among cultures, traditions, comfort zones, etc.
- Empirical research on all these topics following clear guidelines [14].

The research community cannot address these topics without the cooperation of PLM/ALM tool vendors and the manufacturing companies. It is hardly promising to investigate purely theoretical solutions. However, such industry-academia collaboration should be planned and performed carefully considering the following success factors [15]:

- Buy-in and support from industry management
- Collaboration champions on site
- Researcher’s attitude and skills

A champion is a person passionately dedicated to a research topic, not just a person assigned the responsibility. Management support implies the genuine commitment by management to a research topic. Academia naturally considers research more important than the industry. In order to create a suitable research environment in companies, management support is needed but researchers must also adapt to the needs of the practitioners.

5. Conclusion

Nowadays, software and hardware are colliding into the “Things” of IoT. This requires PLM/ALM convergence as ALM cannot be used to develop the hardware part of a product, and PLM cannot be used to develop software. Convergence includes the definition of integration approaches and product roadmaps, the design of data-linking structures, open standards for interfaces and the investigation of use cases for the integrations.

This paper addresses the state-of-the-art of PLM/ALM convergence in research and practice. First, the terms ALM and PLM were defined. A systematic literature review was conducted to find relevant research publication. The industry activities were presented with details of the activities of Siemens and Polarion. The paper finishes with recommendations to the research community.

PLM/ALM convergence, as a research field, is hardly covered at all. We found 11 relevant publications, some of which only address this topic very generally. PLM and ALM vendors are much more active than academia. They drive the PLM/ALM convergence, creating solutions for the customer.

We recommend that academia increase its research activities on PLM/ALM convergence, as it is a critical business success factor for manufacturing companies. We also encourage manufacturing companies to seek support from academia when designing PLM/ALM solutions. When both parties collaborate, efficient solutions can be created.
However, success factors for industry-academia collaboration such as management support and champions on site must take place.

Admittedly, there can be challenges to the validity of our findings. We searched in four scientific databases. There are others. Consequently, we may have missed relevant publications. Furthermore, we used the terms “PLM” and “ALM” as search strings. There may be publications addressing our research issue but not using these terms. However, given that we found so few publications in four leading scientific databases, and that PLM/ALM are widely-used terms, it is unlikely that there are many other relevant publications with a scientific context.

We did not ask manufacturing companies if they have already installed solutions for PLM/ALM convergence. Therefore, in order to evaluate the industry statements, the PLM tool “Siemens Teamcenter” and the ALM tool “Polarion ALM” were installed at the OWL University of Applied Sciences. It was proven that first levels of PLM/ALM integrations are implemented and can be used by manufacturing companies. Therefore, even if PLM/ALM convergence is not broadly deployed in the industry yet, it will be soon. It is time for academia to cover this innovative research field. This paper names the reasons and proposes detailed research topics.

References


