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ONTOLOGY BASED TOOL FOR TASK TRACKING AND DECISION SUPPORT IN AN AUTOMOTIVE COLLABORATIVE WORKING ENVIRONMENT

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1. Introduction

Virtual product development in automotive industry reduced the production time. At the same time the number of product variants multiplied over time. Nowadays, product development is a distributed process which involves a variety of participants with different roles. Intensive changes on product need a high communication effort [Mueler et al. 2012], which is still carried out in face to face meetings and does not interact directly with engineering artifacts affected by these decisions. Our work aims to overcome this problem by offering a collaborative working tool which enables flexible management of information about collaboration in product development. Together with "TU Graz Racing Team" [TUG Racing Team 2013], which participates each year in the FSAE Formula Student [2013] competitions, and produces for these purposes a new racing car, we defined an use case which served as starting point for specification of a basic collaboration model that we integrated into our tool. Our solution allows capturing and tracking of data about tasks, depending requirements and goals, persons involved, components and resources used, particularly during the planning and development phase of the product. We used semantic technologies such as RDF (Resource Description Framework) [RDF Core Working Group 2004], OWL (Ontology Web Language) [OWL Working Group 2004] and SPARQL [SPARQL Working Group 2008] as well as a specific domain ontology PROTARES (PROject TAsks RESources) [2013] to model the collaboration processes on the task level. As collaborative editor for the model we integrated modified OntoWiki [2013] in our solution as generic editor for ontology instances. This adaptation enabled us to run SPARQL queries over semantic structured data and generate flexible visualisations for our interactive browser named "PLM Cockpit", enabling in this way better task tracking for managers and engineers. With our tool we show, how semantically driven application can support tracking of engineering tasks and support decision-making within collaborative working environment of the automotive product development.

2. Related work

In following subsections as part of the related work we discuss about open issues and challenges in Product Lifecycle Management (PLM) on collaboration and decision-making. Furthermore, we address the potentials of application of semantic technologies and tools to model and manipulate over such information context and review some existent models and methodologies applied so far for these purposes. At the end of the section, we report briefly about already existing relevant prototypes from recent research.

2.1 Decision making and collaboration processes in Product Lifecycle Management

Product Lifecycle Management (PLM) is a concept for integration of information about activities, persons and artifacts of product in different phases of the product lifecycle. This approach includes adequate tools, standards and technologies for collaborative product development involved into product lifecycle. Several studies have shown already that this approach leads to remarkable improvements [Dubois et al. 2012], [Mueler et al. 2012]. A PLM system requires a high level of co-ordination and integration as stated in [Jun et al. 2007a]. However, the key enabler in PLM are stake holders, as well as the communication and relations between them [Denger and Unzeitig 2012]. Formalising these relations contributes to data reuse and optimisation as reported in [Hani et al. 2012]. Main challenge for a PLM system is: how to offer stake holders adequate information to support their decisions without increasing the administrative effort. Functionally such an approach must enable an overview on time, stakeholders, components and resources they use in processes where involved. As already shown in recent research [Bruun and Mortensen 2012], context based approaches in collaborative environment contribute to the better understanding of the product and to improvement of decision-making process. Further they lead to more formal access to the knowledge within the design and development process as already noticed in [Patil et al. 2005] and [Chartier et al. 2006]. The problem stated here implies a high demand on the context transparency, which includes a wide range of influencing entities, relations, and actions between them. Modelling collaboration and decision making process is especially beneficial for the early phases of project planning to optimise the process and prevent the unforeseen risks, as well it increases quality of collaboration [Jankovic et al. 2006]. As reported in [Rizutti et al. 2006], a graph based approach to seize this problem is valid and enables the participants to focus to the center of activity. However, this approach lacks of the availability of proper technologies. New technologies like Semantic Web could fill the gap. Moreover, they offer better overview, and operation over participants [Ponn et al. 2006].

2.2 Semantic technologies as enabler for modelling the collaboration

Semantic Web technologies suite well for designing complex models and relations. Their flexibility regarding changes in information model as well inference potentials are outlined earlier in research efforts like [Wache et al. 2001]. The Semantic Web technology stack is well-defined and standardized [Berners-Lee et al. 2001]. The OWL (Ontology Web Language) as part of it offers the flexibility for description and restrictions of data schema. The RDF Schema (RDFS) [RDF Interest Group 2004] allows definition of lightweight ontologies as well combination of different ontologies and vocabularies at once. Ontology instances use Resource Description Framework (RDF) data model. RDF provides machine as well human readable notations (e.g. RDF/XML, N3). The SPARQL retrieval and query technology uses the RDF instances as query base. SPARQL endpoints (SPARQL query interfaces) deliver results of queries in different standardized data formats (XML, JSON etc.). Therefore, applying semantic technologies to describe collaboration context and its artifacts like tasks, involved actors and related items allows creation of flexible views on data using the queries, based upon standardised technologies and formats, as support for activities tracking and decision-making.

2.2.1 Overview over existing ontology models for collaboration tracking and decision making

Recent research [Jun et al. 2007], [Matsokis et al. 2010], [Matsokis and Kiritsis 2010] has shown that ontology based approach of modelling information in product design and development offers more flexibility on context changes than any other method applied so far. Those benefits, in particular for the segments of product lifecycle, outlined the work by Young et al. [2007]. The efforts in this field so far, focused on modelling partial aspects of product life cycle like maintenance [Matsokis and Kiritsis 2010] or product description [Matsokis et al. 2010]. However, to explore serendipity and contribute to real lifecycle improvement, aspects of organisation, communication and interaction which include actions, time constraints, persons, artifacts, processes as well as relations among them play a crucial role. Review of existent work on use of ontologies [Mostefei and Bouras 2006], [Styles and Shabir 2006] and formal approaches [Patil 2005], [Matsokis et al. 2010], [Matsokis and Kiritsis 2010], [Fortineau 2012] in this field, has shown that none of the existent ontologies or vocabularies offer adequate model with sufficient properties and restrictions specific for the needs of the task level.

Although some work on ontologies for tasks exists like for instance TOVE Ontology project [Fox 1992], [Fox et al. 1996], [TOVE Ontology 2013], unfortunately with its upper level approach, it still lacks on the granularity needed for the intended context.

2.2.2 OntoWiki – a semantic collaborative tool

Currently there are very few useful operative semantic collaborative tools that overcame the experimental state. Mostly interesting for sure is OntoWiki [Frischmuth et al. 2013]. OntoWiki is a wiki based collaborative environment application for maintenance and creation of semantically modelled data, originally developed to support distributed knowledge engineering scenarios [Frischmuth et al. 2012]. It is extensible and it may also serve as development framework for knowledge based applications, as well as user interface for arbitrary RDF knowledge graphs. OntoWiki supports the navigation through RDF knowledge bases through SPARQL queries generated lists, tables and trees e.g. class trees and taxonomies. All resources are automatically represented as links. Backlinks are automatically created whenever possible. In this way users can easily traverse entire knowledge graphs. All collections of resources displayed in OntoWiki result from SPARQL queries. Further refined views are manageable by applying queries via provided SPARQL interface which is also exposed as API (Application Programmable Interface). Beside API, the OntoWiki, offers a well-defined and flexible plug-in mechanism to integrate customized functionalities if needed.

2.3 Existing research on sematically based modeling collaboration tracking and decision making

Solutions provided by recent research on activities tracking and decision-making only partly cover the range of artefacts like: persons, tasks, requirements, goals, resources and components. First prototype of web based solution on tracking project results introduced Sauer et al. [2006]. Maletz et al. [2008] implemented infrastructure which uses ontology based model of PLM data to relate simple described tasks and persons representing them in a specific project portfolio. The OntoNavi application presented by [Ulbrich et al. 2010] uses ontology to relate participating persons with a project goals according to their roles in project. [Krima et al. 2012] used an Ontology derived from STEP (Standard for Product Data Exchange) and SPIN (SPARQL Inferencing Notation) enhancement to verify the changes of requirements of product data . None of the solutions treated the “on the fly” generation of results combined with a flexible visualisation supported by backend editor to edit and create context data. The data in referenced works is generated only once and the tools are using it only as viewer or feedback interfaces of the static context.

3. Approach and implementation

Designing tools for agile processes requires definition of use cases [Selhorst et al. 2008]. In following subsection we introduce our use case together with implementation architecture and derived context ontology model based upon it.

3.1 Use case

To define the requirements for the system architecture and collaboration model, we used data, experience and knowledge of "TU Graz Racing Team" as well observations we made for the period of design and development. As result we defined simplified “Task Tracking and Decision Making” use case shown in Figure 1. which includes two simple scenario views: The first scenario view is the one of a “Project Manager”. “Project Manager” needs to know about actuality and state of the tasks. In this way Project Manager” gets an overview of the project, to make decisions and influence the development process. “Project Manager” needs to know which persons relates to which tasks and which persons can support him for the case to that some other person needs help or when a responsible person is missing for some reasons. The second view is the one from the perspective of “Engineer”. “Engineer” has to know tasks assigned to him and which requirements describe them, which components and persons related to these tasks affect his work, what are the goals and deadlines, and which components and resources to use to solve the task.

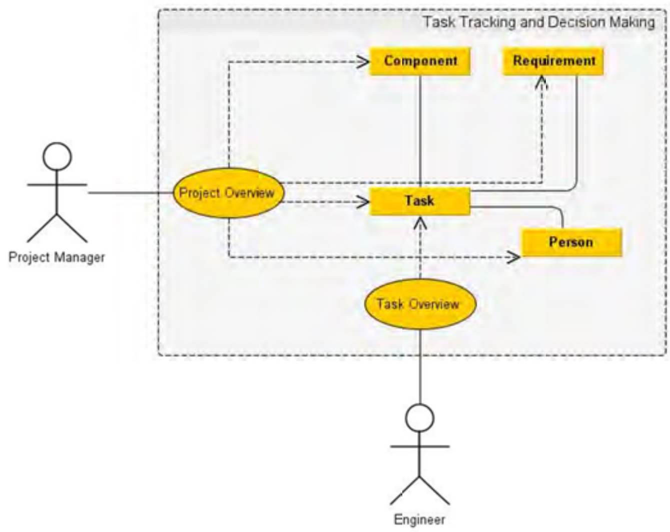

Figure 1. "Task Tracking and Decision Making" use case diagram

3.2 Ontology model for "Task Tracking and Decision Making"

Our use case required very precise modelling of targeted context which includes artifacts like: projects, tasks, requirements, (design) components, goals, time constraints and resources necessary for this work. As stated in related work none of the existing models or tools covered that high precision for the task level. Therefore, we decided to define a new domain ontology named PROTARES (PROject TAsks RESources) (presented in Figure 2). The ontology combines own concepts and FOAF (Friend of A Friend) [Brickley and Miller 2010] which purpose is to describe persons and information about them and Requirements Management Ontology [OSLC Requirement Working Group 2012] defined by the OSLC (Open Services for Lifecycle Collaboration) initiative which specifies the standard attributes of a requirement.

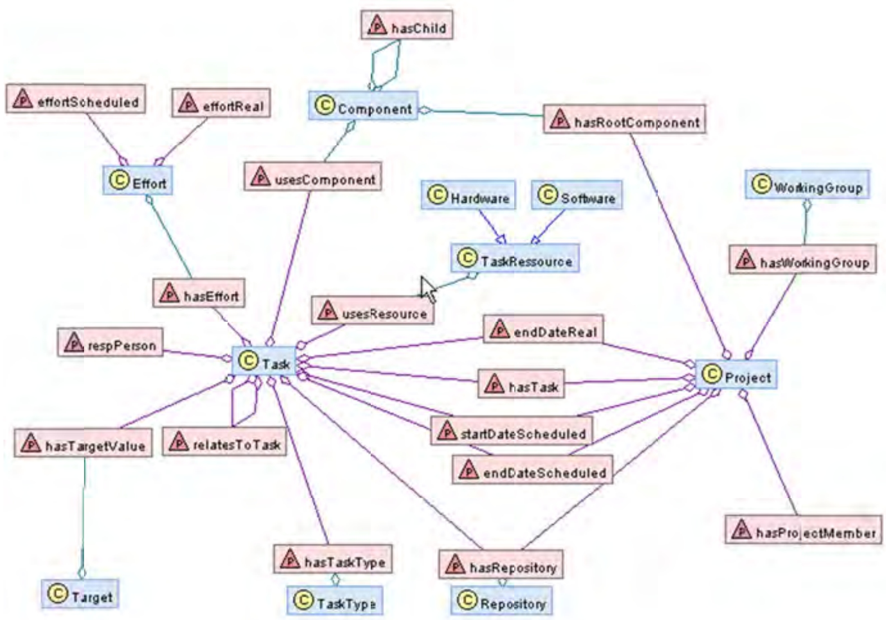

Figure 2. PROTARES Ontology context model

3.3 Architecture

Figure 3 represents implementation architecture for the "Task Tracking and Decision Making" use case. Generally there are three different layers distinguished: *data*, *context* and *view* or *visualisation* layer. The *data* layer covers the collection and relating of information about components, persons, requirements and related tasks manually using the OntoWiki with PROTARES Ontology as underlying domain model for instance creation. After creation in OntoWiki, editor saves instances (entries) as RDF data into knowledge base. This repository allows flexible querying via integrated SPARQL endpoint, which delivers JSON (Javascript Object Notation) or XML (Extensible Markup Language) as retrieval formats for query results. *Context* layer reflects this functional part of the architecture. At the top of the technology stack resides the *view* layer with *visualisation* interface. The *view* layer consumes the pre-structured data from the underlying *context* layer and presents it to the user. User interaction with the system is twofold: first by creating and editing instances (via OntoWiki) and second by the selecting concepts (context based information) using visualisation interface. Each selection via interface means restrictions and filtering options for the *context* layer and SPARQL endpoint which generates results for visualisation.

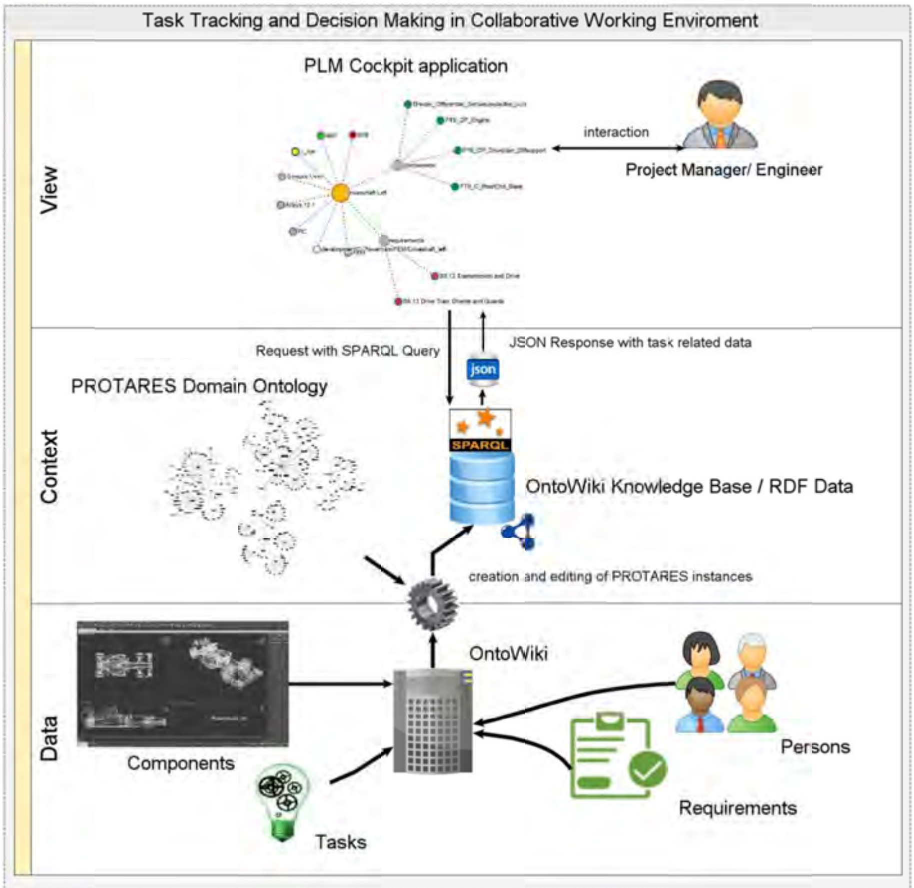

Figure 3. Design of architecture for task tracking and decision making support tool

3.4 Creation and editing of instances with OntoWiki

Context instances in OntoWiki represent concepts (classes) from PROTARES Ontology. Figure 4 depicts creation of a single task instance named "Drivesshaft Left". As shown in Figure 4, requirement "rq00_B8.12" relevant for this task was linked using the auto-complete function. In general, descriptions and linkages for the task properties are either entered manually or assisted by auto-complete function. In the background the system generates representation of the instance as RDF data.

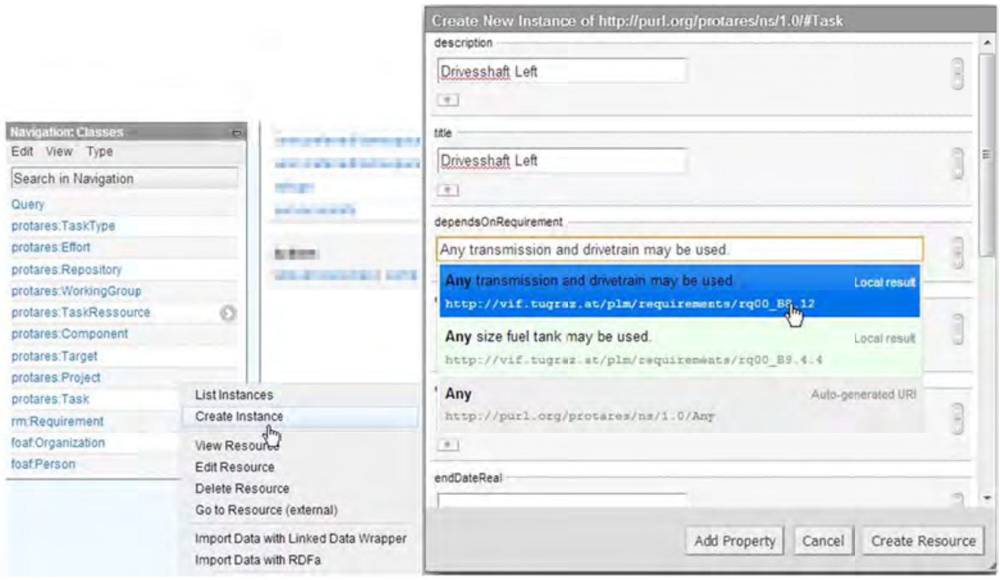

Figure 4. Creation of "Drivesshaft Left" task

After creation, instances can be edited either all at once or separately (fieldwise) as shown in Figure 5 where a component named "PT9_CP_Engine" is newly linked using the auto-complete to the current task named "Drivesshaft Left". Moreover, Figure 5 also shows the set of all relevant information that is usually assigned created for task instances like: requirements on which this task depends, resources and components that are used to solve this task, responsible person for this task, estimated start and end date and many other aspects.

Figure 5. Editing properties the "Drivesshaft Left" task

3.5 Querying and retrieval of context views

Instances saved into local OntoWiki knowledge base as RDF data (triples) are queryable using the SPARQL language. OntoWiki provides a SPARQL interface out of the box and exposes it to the docking applications as so-called endpoint. Figure 6 shows a SPARQL query which retrieves names of all related components for a certain task entitled “Drivesshaft left”. Retrieval of all other related aspects of the task like persons, requirements, resources and the like happens in similar way.

```
SELECT ?component_name WHERE
{
  ?s rdf:type protares:Task ;
     dct:title ?title ;
     protares:usesComponent ?component .
  ?component dct:title ?component_name .
  FILTER(?title = 'Drivesshaft Left')
}
```

Figure 6. Example of querying all component names related to the “Drivesshaft Left” task

As response to the query as the one in Figure 6, the OntoWiki endpoint delivers results in JSON (Javascript Object Notation) and forwards it for the visualisation front end of “PLM Cockpit”. Figure 7 represents the JSON response for query in Figure 6.

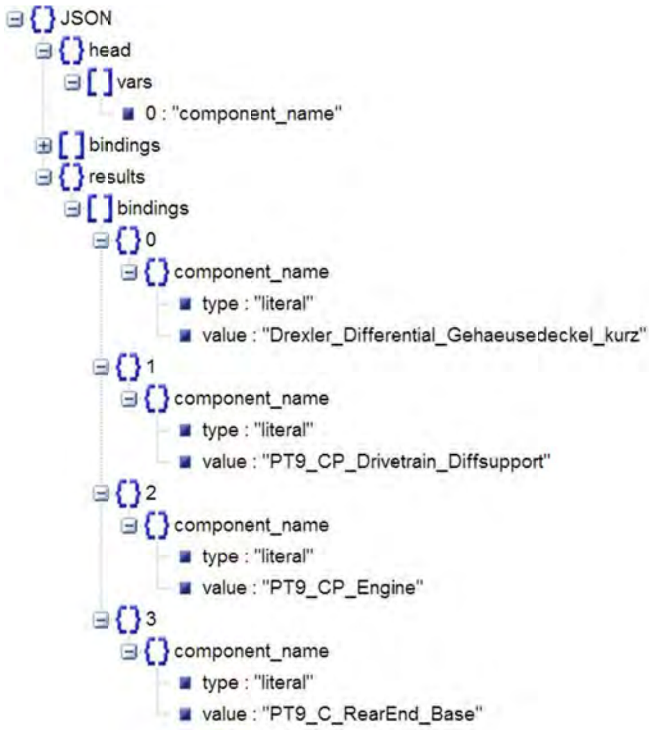

Figure 7. JSON Response for “Drivesshaft Left” task query

3.6 Visualisation interface

Figure 8 depicts the current state of “PLM Cockpit” visualisation interface. This tool was developed HTML5 and JavaScript library D3 (http://d3js.org/). Visualisation in the main window represents the task. Additionally, all related entries about selected task (here in Figure 8 as example “Drivesshaft Left”) are opened and marked in the tree views on the left side of “PLM Cockpit”. The “PLM Cockpit” enables the user to browse visually through the development project and retrieve desired information. Different circle colors represent different types of data: orange color represents tasks, red colored circles with blue border represents requirements, also other entities have their own symbols.

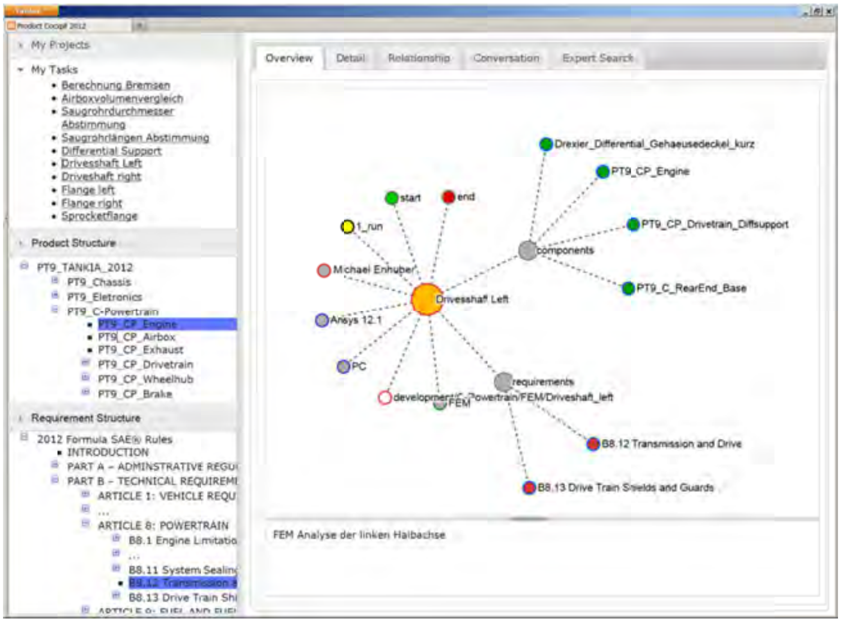

Figure 8. "PLM Cockpit" interface

4. Preliminary results and outlook

The reference system works with a data set which includes 700 requirements, 60 tasks, 358 related components, 24 resources and 21 persons involved into production and development process. In this preliminary stage our tool supports acquisition, editing and querying of this information with two different focuses on provided context. The described approach allows the members of the team (project manager and engineers) to analyse dependencies between product components, requirements, used tools, involved persons and tasks. Documented start and end times allow a reverse engineering of the project plan and focused querying. In this way at any certain point of time in product lifecycle the project manager has an overview on collaboration issues. Further, visual task analysis contributes better co-ordination and shortens the iteration cycles in development and planning, since an engineer can always recall the progress and person responsible for certain part of work. In the case of absence of a certain team member the team is still able to react and get an overview on the current development state. The project manager is also able to check whether certain tasks will take longer as planned and adjust the project plan according to the current state of the progress. We conducted a short pilot survey on "PLM Cockpit" consisting from only one question for the test users: "What is the main aim of the tool"? Hereby we offered following answers: "to explore", "to discover", "to search", "to analyse" and "to explain". Each answer was rated on the Likert scala containing possible values: strongly disagree, disagree, not sure, agree, strongly agree. Our test sample consisted from 11 test persons 4 with manager roles and 7 with engineering roles. Overall perceived usefulness shows that the tool was made to discover (82%), to search (71%) and to explore (55%) and less to analyse (45%) and to explain (9%). In the future, we will extend te survey to capture more precisely the "usefulness" and "ease of use" using the TAM (Technology Acceptance Model) [Davis 1986] in order to gain more insight on the usability of the system. Automotive OEMs and suppliers use in their management processes requirement management systems and tools like IBM Doors, HP Quality or PTC Integrity. We also aim on integration of requirements of these systems into out tool as some of the next steps in the future to test the concept validity for real production use cases with a bigger amount of requirements.

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