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DATA MANAGEMENT BASED ON INTERNET TECHNOLOGY USING RESTFUL WEB SERVICES

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ABSTRACT

Shorter product lifecycles and increasing complexity of products, processes and information technology (IT) systems require efficient, computer-aided methods and tools to support product development. In product lifecycle management the world wide access to data stored in different systems is a key challenge in order to realize a holistic information integration. New internet technologies enable the provision of information in a suitable format and the application on mobile devices.

In this paper the concept for data management based on modern internet technologies using RESTful (Representational State Transfer) web services is introduced. The concept enables the access to product data, simulation data and factory data stored in different data management systems by using URIs (Uniform Resource Identifiers). The concept is validated by two use cases, demonstrating its potentials by the use of mobile devices for a review of simulation data and for the building process of prototypes in manufacturing.

1 INTRODUCTION

Increasing complexity of software systems and production processes, the need to reduce costs and time to market as well as the world wide access of information through mobile devices require new methods and tools. Today’s manufacturing companies use several xDM (x Data Management) systems, e. g. PDM (Product Data Management), SDM (Simulation Data Management) and FDM (Factory Data Management) in combinations, because the xDM systems work very efficiently in their application domains. Modern internet technologies like SOAP (Simple Object Access Protocol) and REST allow the world wide access to data and the interlinking of data management systems. Due to the continuous improvement of information and communication technologies (ICT), the increasing usage of mobile devices and advanced information integration, manufacturing companies expect improvements in time to market, product and process quality and costs reduction. A fundamental issue, however, is the fast availability of product information whenever and wherever needed. The REST technology provides a promising and an appropriate approach for retrieving and accessing product information stored in various data management systems.

In this paper, a concept for the retrieval of information from xDM with a RESTful web service is introduced. The application of a RESTful web service enables the world wide access of data, especially by using mobile devices. After the specification of the concept, two use cases are presented to demonstrate the potentials of the concept under practical conditions: The first use case describes a scenario for an access of product and simulation data on a business trip using a mobile device, while the second use case is about the building process of prototypes in manufacturing.

2 DATA MANAGEMENT SYSTEMS

The development of products is mostly based on computer aided systems. Several systems are used for an efficient support throughout the entire product lifecycle, but an integrated and continuous virtual product development is rarely achieved. An integrated information logistics throughout the entire product development process is becoming increasingly important. The virtual representation of products, concerning processes as well as organizational and operational business structures is necessary. Data and structures between data is mapped into data management systems. CAD (Computer Aided Design) systems in particular as authoring systems and PDM systems as central storage platform play a major role in today's product development process. Besides, highly-customized systems have been developed for the domains of the product lifecycle [ARV+12], [VWB+09].

Conventional PDM systems aim at the central storage, management and provision of data. They are mostly used in product development. In other engineering areas like simulation and manufacturing, systems have to fulfil additional requirements. In computer aided engineering simulation data management systems are used, in manufacturing methods of the digital factory based on a federative data management are applied [ARV+12]. These different systems will be described hereafter.

2.1 Product Data Management

Product data management contains the administration of product data and the control of product data flows in all phases of the product lifecycle. Major goals are the reduction of cost and development time as well as an enhancement of the product quality. PDM systems contain product, project and document data for the provision of necessary information. The key challenge is to ensure and to automate the flow of information across organizational and system boundaries. Thus, PDM systems serve as central systems for information management and distribution as well as an integration hub for all systems involved, see Figure 1 [AT00], [ES09].

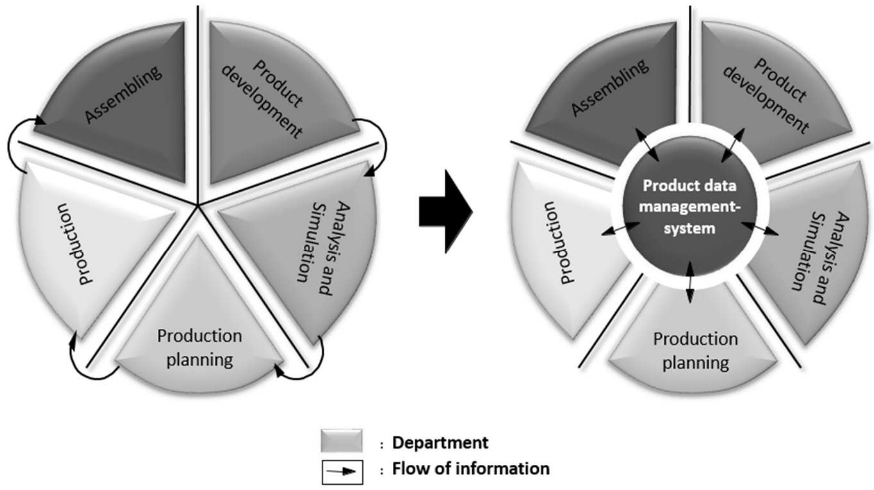

Figure 10: PDM system as central integration hub [AT00]

For the efficient processing of orders it is necessary to integrate the domains of product development, production planning and manufacturing to ensure an appropriate flow of information. In manufacturing companies production documents like technical drawings, parts lists, work schedules and test specifications form the basis for the exchange of information. For each of those documents a virtual representation has to be stored in the PDM system with a linkage to the corresponding IT system [AT00]. Besides the management of objects, the operational and organizational structures are represented in PDM systems. This enables an effective computer-aided automation of workflows [WI10].

PDM systems are knowledge repositories which offer a wide range of functions for the management of data throughout the entire product lifecycle. The most important functions are element management, privilege management, file management and workflow management, see Figure 2. The storage and management of information in element management serve as basis for PDM systems. This includes the description of individual elements (master data), the creation and management of relations between master data (structural data) [AT00].

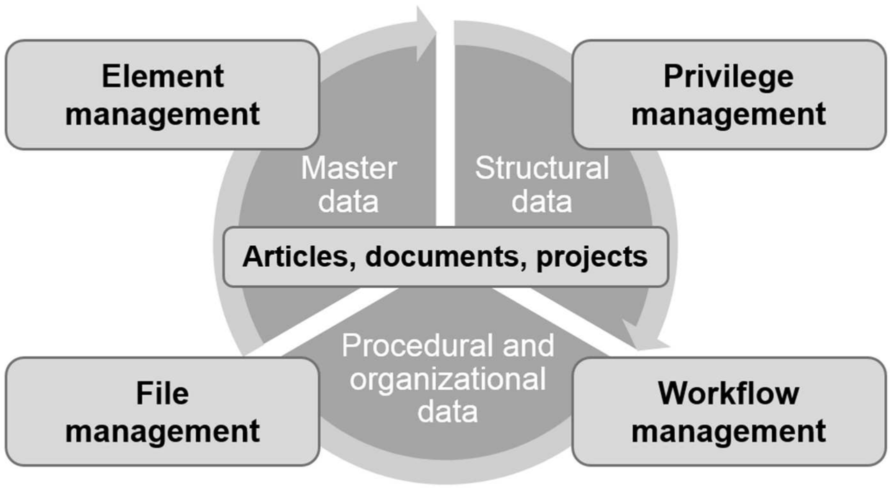

Figure 11: Layout of PDM systems [ARV+12]

2.2 Simulation Data Management

Simulation data management (SDM) focuses on the integration of simulation data into the workflows of virtual product development. For this purpose simulation data is embedded in a data management environment [AB14].

At the interface of PDM and SDM operational and organizational data ensure a suitable flow of information, see Figure 3. On the PDM side articles, documents and projects are the basic elements, on the SDM side these are input decks, output decks and reports. For the integration an unambiguous identification and classification combined with item versions and current status is applied [ARV+12].

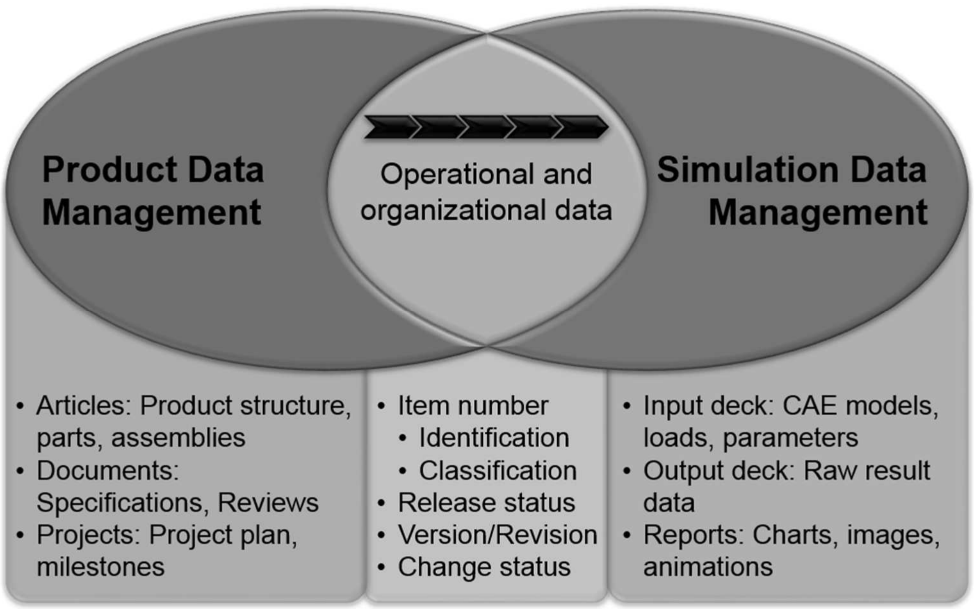

Figure 12: Integration of PDM and SDM concepts [ARV+12]

For the appropriate integration of product and simulation data in a data management environment specific data models have been developed. They enable the implementation of different instances of computer aided engineering (CAE) models with revisions and the definition of relations between these revisions and the associated CAD master. Therefore, source and target relations with different cardinalities are used [AB14].

The ProSTEP iViP Association and VDA (Verband der Automobilindustrie) have developed recommendations for the integration of simulation and computation data in a product management environment (SimPDM). In these recommendations processes, relations and use cases for crossenterprise and cross-domain scenarios are defined as well as the integration of CAE process modules into SDM systems. Therefore, a modular meta data model is used [PR08], [PV12], [VDA08].

2.3 Factory Data Management

In factory data management (FDM) multiple, usually proprietary systems are applied. For each domain a separate, independent information technology tool is used to fulfil a specific task within the production process. This leads to a diversification of data formats and the number of interfaces. To reduce the complexity in factory data management the integration of the systems involved is needed [PAS14].

Integration strategies can be divided into three groups: direct coupling, indirect coupling and loose coupling. The differences result from degree of flexibility, integration and distribution. Direct coupling aims at the complete integration of all information tools. Through the creation of a neutral interface, the number of specific translation software is reduced to a minimum. Every information tool has a direct link to the neutral interface. Hence, the autonomy of each information tool is limited as well as the degree of flexibility. Indirect coupling also uses a common data model, but each information tool is responsible for the linkage. As each information tool stays independent, a high degree of distribution can be achieved. The drawback of this approach becomes apparent during data management processes involving several information tools [MAM+11], [PAS14], [SMA+13].

The loose coupling of information tools is called federation. Federation aims at an encapsulated integration while information tools remain partial autonomously with a maximum degree of flexibility. A standardized communication between the information tools enables a suitable collaboration and ensures the data consistence. Since factory data management usually is based on a federative strategy, it is also referred as federative factory data management (FFDM) [MAM+11], [PAS14], [SMA+13].

3 MODERN INTERNET TECHNOLOGIES

Nowadays modern internet technologies like the World Wide Web are ubiquitously used as source for information retrieval. Almost every mobile device (e. g. smartphones) has a web browser which can be used to navigate through the World Wide Web. Web services like search engines simplify the retrieval of information by providing only keywords. They can be used by humans as well as by machines.

3.1 Uniform Resource Identifier (URI)

An URI is an unique identifier, which identifies a resource. It can be classified into URL (Uniform Resource Locator) and URN (Uniform Resource Number) [BFM05]. While URL locates a resource by its access mechanism (e. g. *http://tools.ietf.org/html/rfc3986*), an URN denominates a resource (e. g. *ISO/IEC:18004:2006*). The resource, which is identified by an URI, may be static (e. g. *http://www.omg.org/spec/PLM/1.0*) or dynamic (e. g. *http://www.omg.org/spec/PLM/Current*).

URIs are not limited to address only web services as they also enable the access to product related information. A concept for the URI-based assignment of product related information to 3D product models has been introduced by Sprenger [SP14].

3.2 Hypertext Transfer Protocol (HTTP)

The main technology for browsing through the World Wide Web is the Hypertext Transfer Protocol (HTTP), which is specified in [BL92]. A HTTP request consists among others of a HTTP method (e. g. GET, POST), a location given by an URI, specified in [BFM05], and the transmitted data. The transmitted data can be in any format, for websites mostly Hypertext Markup Language (HTML) is used. The HTML language allows the usage of hyperlinks, which results in an easy navigation for users.

While sending HTTP request and response, the transmitted data are sent as cleartext. Everybody with access to the used network is able to comprehend the transmitted data. In case of confidential data, this is a major issue in knowledge protection. In order to resolve this issue, HTTPS (Hypertext Transfer Protocol Secure) has been developed [RE00]. It provides a TLS (Transport Layer Security) encryption of the transmitted HTTP data. The schemes of HTTP and HTTPS are identitical, but HTTPS provides an encryption.

3.3 Web Services

Web services allow the human-to-machine communication as well as the machine-to-machine communication. Clients are able to call methods on a web service, which is called Remote Procedure Call (RPC). From a technical point of view, web services use the HTTP technology and URIs to access the resources. For confidential data, web services also support the communication over HTTPS. In order to allow a machine-to-machine communication, the interface of a web service must be well-known. There are two main approaches for web services: SOAP and REST.

3.3.1 SOAP

Simple Object Access Protocol (SOAP) [W3C07a] is a W3C (World Wide Web Consortium)-Standard for RPC on the basis of the Extensible Markup Language (XML). Both, the request and the response use XML. The focus of SOAP is to provide a well-defined interface for communicating with web services. The specification of the interface is expressed in the Web Service Description Language (WSDL) [W3C07b]. This implies that algorithms are able to communicate with the web service automatically, given only by a specification of the web service in WSDL.

3.3.2 RESTful Web Services

Representational state transfer (REST) is an architectural style for a web service whose interface is given by the hierarchy of URIs. RESTful web services must fulfil five constraints [FI00]:

1. Client-server (Separation of user interface concerns and data storage concerns to improve scalability)
2. Stateless (Each request must contain all information for understanding the request)
3. Cache (Data in a response maybe marked as cacheable or non-cacheable to improve network efficiency)
4. Uniform interface (identification of resources, manipulation of resources through representations, self-descriptive messages and hypermedia as the engine of application state)
5. Layered system (clients cannot access layers behind the immediate layer directly)

An URI addresses a certain resource in the web service, which is a method for performing an action, e.g. retrieval or creation of data. In order to read, create, modify or delete a resource, the client has to use the HTTP methods GET, POST, PUT and DELETE. The contents of the response may be in an arbitrary format (e. g. HTML, XML, images, etc.). The client is capable of the choosing the best-suited format out of a number of different formats.

3.4 PLM in combination with Web Services

In 2006, the Object Management Group (OMG) has released the version 1.0 of the PLM Services specification [OMG06]. It enables the access of PLM data through web services using SOAP. Currently, PLM Services is in version 2.1, using Unified Modeling Language (UML) notation as specification language [OMG11].

Some of the newer product lifecycle management systems have yet an integrated web service. Teamcenter 8 has a service-oriented architecture based on SOA [SI10], [ER11]. AutoDesk [AU14] offers a cloud-based PLM system named AutoDesk PLM 360, which has an integrated REST API (Application Programming Interface).

Further applications with integrated web services are listed in [ER11]. All recent integrations of web services in PLM software have in common, that they are proprietary. AutoDesks PLM 360 stores the data in a cloud outside of the company. This implies a reduction of maintenance costs but also the issue that data may be temporarily unavailable. A possible scenario may be a breakdown of the cloud infrastructure. In this case, documents stored in the cloud are not accessible. A federative approach would be more reliable than a cloud-based solution. Furthermore, if the data are stored outside of the company, the knowledge base of the company could be unprotected to unauthorized access.

First approaches for a REST-based access to manufacturing data have been developed by Picard, Anderl and Schützer. But their approach is limited to data stored in federative FDM systems [PAS14].

In this paper, a concept for the application of RESTful web services in data management in general is specified. This includes all xDM (PDM, SDM, FDM, etc.) systems and incorporates complete virtual product development.

4 CONCEPT FOR THE APPLICATION OF RESTFUL WEB SERVICES IN DATA MANAGEMENT

The implementation of efficient methods and tools for information integration in data management is a major challenge. While systems internally often use an integrated data model, the connection of different systems like SDM and PDM is realized by a federative approach. For this cross-linking a number of information models has been developed. These information models enable the definition of relations between items and item revisions from different data management systems. Source and target relations with fixed cardinalities serve as basis.

In this paper the concept for the application of RESTful web services in data management is introduced. Three data management systems (SDM, PDM and FDM) serve as data repositories and they are connected in a federation. The PDM system contains data about products, assemblies and parts, parts lists, materials as well as associated documents. Simulation data like input decks, result files, images and animations for the visualization of stresses and deformations are stored in the SDM system. In the FDM system production data about products, processes and resources are stored, e. g. machine data, tool data, available capacity, etc.

4.1 Architecture based on a RESTful Web Service

The concept is divided into five layers: devices, user interface, RESTful web service, queries/RPC and data repositories, see Figure 4. As devices stationary workstations, portable laptops and mobile devices like tablet computers and smart phones can be used. Users operate the hardware via the user interface. The user interface accesses the RESTful web service via a browser.

The RESTful web service is divided into multiple xDM services containing a number of resources. Each xDM service has an individual task and can be addressed by a HTTP call. In order to retrieve all information related to pneumatic_cylinder_002, the HTTP call is *GET /pneumatic_cylinder_002*. The xDM service itself collects the requested information provided by the involved resources. This can be implemented by the use of HTTP calls (*e. g. GET /SDM/pneumatic_cylinder_002*). Additionally, the resources can also be addressed directly from outside the xDM services.

The resources build queries in order to retrieve data from the data repositories. The protocol type of each query depends on the software used by the data management systems. Possible protocol types are SOAP, SQL (Structured Query Language), RMI (Remote Method Invocation), HTTP and others. The query for the requested information of the pneumatic cylinder from the SDM system, expressed in SQL, is *SELECT * FROM simulations WHERE item=”pneumatic_cylinder_002”*.

Resources can retrieve data from several xDM systems. For file systems the resources can directly access the requested data by file accessing methods. The advantage of using a RESTful web service is, that the data is always accessible in the same manner, independent of the type and structure of data management system. The interlinking of requested data stored in different xDM systems can be realized by the integration of the data within the xDM service or by relations between the xDM systems based on data models.

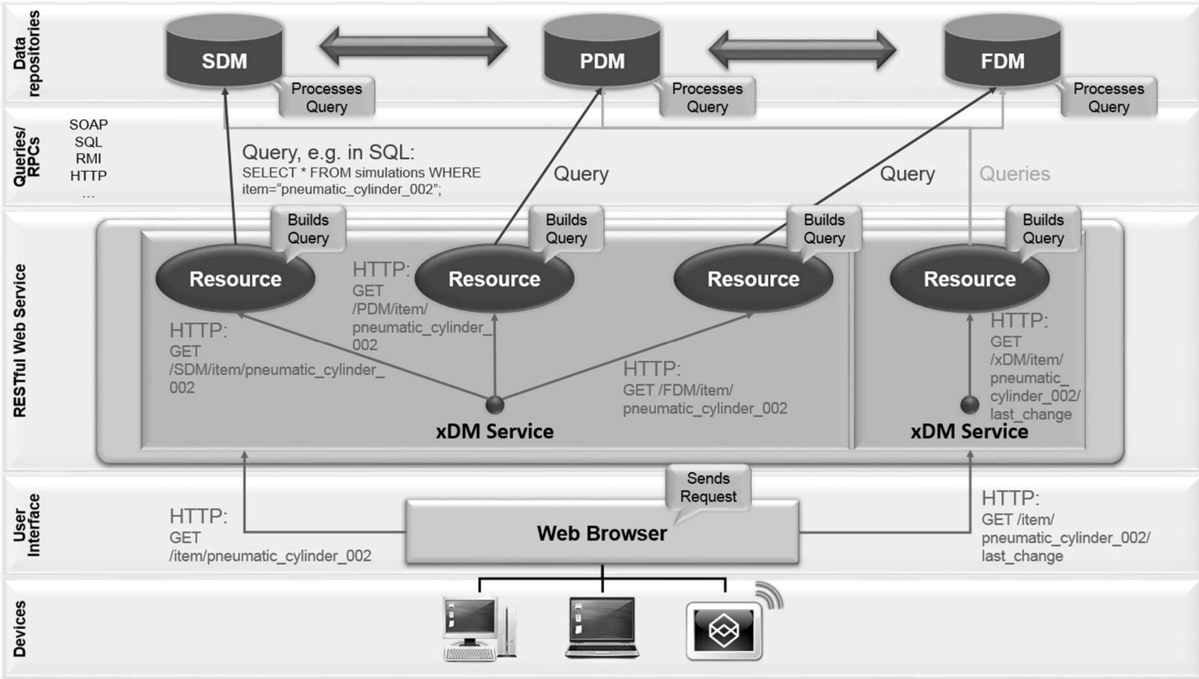

Figure 13: Concept for data management based on RESTful web services

The concept enables the retrieval of information for single items as well as for products. The HTTP call for the example described above in order to retrieve all information related to pneumatic_cylinder_002 is *GET /pneumatic_cylinder_002*. The system response for this call is:

PDM
1x 3D assembly model
8x part models
8x part technical drawings
1x assembly technical drawing
1x product structure
3x parts lists

SDM
25x finite element analyses
5x multi body simulations

FDM
6x production plans
1x assembly schedule
3x test specifications

Another request shown in Figure 4 is the latest change status. The system response would be:

Version 3.5 has been changed on July 26, 2014
1x 3D assembly model
8x part models
8x part technical drawings
1x assembly technical drawing
1x product structure
3x parts lists

Benefit of the concept is the world wide access to data stored in different data management systems using a web browser. This enables the navigation through products with assemblies and parts, the presentation of simulation data, the retrieval of manufacturing data and the use of mobile devices. If an appropriate MIME (Multipurpose Internet Mail Extensions) exists, the standard viewer to view the data is automatically chosen by the web browser. CAD and simulation data can be visualized by viewers, if they are installed on the device. In theory, the modification of data is also possible using the HTTP method POST.

4.2 Information Model

After a request of the user has been sent to the web service, e. g. retrieving all simulation data of a particular part, the web service retrieves the information from the xDM systems. For a manufacturing company, an exemplary information model is shown in Figure 5 in form of an UML class diagram. For simplicity, the order scheme is considered only for product data management, simulation data management and factory data management. But the method can be applied also for other system environments.

In this information model an item is a part or an assembly. The assembly itself consists of subitems, which deduces a product structure. An item offers various operations like getting an ID (getID), getting the name (getName) or getting the version (getVersion). Simulation items have an input deck, a result file, an image of a simulated property (e. g. strength) and optionally an animation of the simulated property. Simulation items are related to parts and vice versa. Factory items offer the operations to get work schedules (getWorkSchedule), machine capacity (getMachineCapacity), resources (getResources) and test specifications (getTestSpecifications).

The web service uses the existing connections in the software infrastructure of the company. Therefore, the web service has to be connected to the xDM systems and must be able to retrieve information from the xDM systems. As stated in section 3.4, many interfaces to existing software do already exist (e. g. OMG PLM Services 2.0 and Teamcenter 8 using SOA).

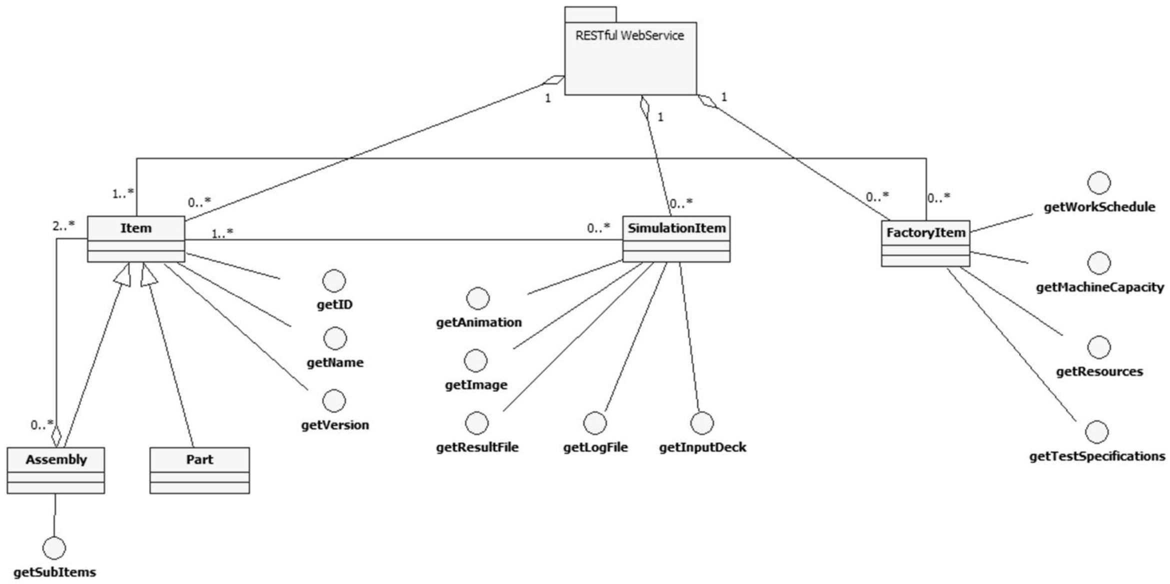

Figure 14: Exemplary information model for a RESTful web service

The exemplary information model contains a class for items, which can be assemblies or parts (PDM system), a class for simulation items (SDM system), and a class factory items (FDM system). An adequate solution for the organisation of the order scheme is to set the root element of the URI in relation to the according xDM system. The root for addressing an item in the PDM system is */PDM*, for an item in the SDM system is */SDM*, etc. A list of all items in the PDM system is retrievable with */PDM/Item*. The properties of a particular part PART_001 can be retrieved with */PDM/Item/PART_001*. If all simulations of any parts are requested, the address is */SDM/SimulationItem*. In order to retrieve information of PART_001 gathered from several xDM systems, */Item/PART_001* can be used.

The addressing of particular parts, assemblies, simulation or other items requires an addressing convention under the conditions of an order scheme and the uniqueness of addresses. Because the order scheme must be flexible enough for different areas of business, each implementation requires an individual order scheme to map the real infrastructure.

Examples for PDM and SDM item addresses with their explanation are:

GET /PDM/Items	Returns a list of all items
GET /PDM/Item/PART_001	Returns the properties of part PART_001
GET /PDM/Item/ASSY_051	Returns the properties of assembly ASSY_051
GET /PDM/Item/PART_001/Simulations	Returns the simulations of part PART_001
GET /PDM/Item/PART_001/Simulation/S_02	Returns a particular simulation S_02 of part PART_001
GET /SDM/SimulationItems	Returns all simulations
GET /SDM/SimulationItem/S_02/items	Returns all items according to simulation S_02
GET /Item/PART_001	Returns all information related to part PART_001

Using this addressing convention, users or machines can retrieve particular information based on the URI in the web browser address bar. It is also possible to navigate through the pages using hyperlinks starting at the root page of the web service. Another possibility is to use the Quick Response Code (QR-Code) [ISO06] technology, which enables a comfortable way to call a URI simply by taking a photo of the matrix barcode with the camera of mobile devices. The matrix barcode enables the encoding of an URI. The application of another web service enables the transformation of a number to an URI. With this, a scanned radio-frequency identification (RFID) [ISO08] number of a part can serve as input for a data request.

5 USE CASES

For the validation of the concept two use cases are applied. The first use case describes how product data and related simulation data can be accessed and visualized on mobile devices in order to perform a design review. In the second use case RESTful web services are used within the building process of a prototype in manufacturing and the comparison of physical and virtual prototype.

5.1 Review of product and related simulation data using mobile devices

The department of product development has the task to develop a new pneumatic cylinder. The responsible product manager has to review the FEM simulation results to release the cylinder cover as soon as possible. Because he is on a business trip, he can only access the product and simulation data via his tablet computer.

The RESTful web service enables the product manager to retrieve information from the federative xDM systems by using the browser of his tablet computer. He starts a web browser on the tablet and enters the website of the service. The product manager sees some hyperlinks to the different services of the web service, e. g. retrieval of a part list. If he clicks on this hyperlink, the browser shows the content of */PDM/Items,* which is a part list of all parts, see Figure 6a. The task is to review part PART_002 whose hyperlink points to */PDM/Item/PART_002*. After clicking on this hyperlink, the product manager sees the properties of part PART_002 and a hyperlink to the simulation data for this part, which points to */PDM/Item/PART_002/Simulations*. The addressed page with the simulation results is shown in Figure 6b. In this scenario, the product manager sees four simulation results for part PART_002, which differ in the underlying mesh, used for Finite Element Method (FEM) simulation. From this point, the product manager is able to navigate to the input deck or to a specific result of the stress simulation and is enabled to perform his review.

Figure 15: Example view of the retrieval of a part list (a) and simulation results (b) using a web browser on a tablet computer

5.2 Using RESTful web services in manufacturing for building of prototypes

In manufacturing, the concept enables the access to relevant product and manufacturing data. In this use case the building process of a prototype and the matching of the physical prototype with a virtual prototype from product development is described. A pneumatic cylinder serves as prototype.

The manufacturing worker at shop floor level has the work task to build the prototype of a new pneumatic cylinder. He uses his tablet computer to access the PDM system in order to download the released parts list, assembly instructions and assembly animation. Then he accesses the FDM system with his tablet computer to check the available resources. In the FDM system the worker gets the information which parts and subassemblies are in stock and where they are stored as well as which parts have to be manufactured. The information about machine capacity is also stored in the FDM system and can be accessed via the tablet computer. When all parts of the pneumatic cylinder are available and manufactured, the worker can start the assembly process. For this he uses the downloaded assembly instructions and animation. When the worker has finished the assembling process, he can compare the physical prototype with the 3D model of the virtual prototype.

By using RESTful web services the worker is completely independent of any stationary work station and has always the required information portable on his tablet computer. The reduction of time for information retrieval and the avoidance of unnecessary ways at shop floor level leads to cost and time savings in manufacturing.

6 CONCLUSION AND OUTLOOK

The world wide access to information stored in xDM systems is a key challenge in product lifecycle management, in order to reduce cost and time to market. The use of modern internet technologies and mobile devices like tablet computers plays a major role in providing information in a suitable form. This paper introduces a concept for the retrieval of data stored in xDM systems based on RESTful web services to improve interoperability. The information model represents the access structures and the applied methods. The concept is validated by the application of two use cases. The first use case demonstrates a review process for product and simulation data on mobile devices. In the second use case the usage of mobile devices in manufacturing is shown in the building process of prototypes.

The concept enables users to easily access product, simulation and manufacturing data via a web browser. A broad range of data formats can be displayed directly with the web browser or with an installed viewer. Thus, costs for license fees and employee qualification can be reduced.

Future research will focus on the integration of an IT security concept for the world wide data access (authentication, knowledge protection) and the implementation of a rights management. The potentials for a combination of SOAP concepts with RESTful web services will be analyzed. When using file systems for data management with a non-reading access, some synchronization mechanisms must be applied by the web service. This is an issue for future research.

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