Federated Application Lifecycle Management Based on an Open Web Architecture

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Abstract: In software maintenance one of the most important assets is a coherent, consistent and up-to-date documentation of the application. In practice, this information is often not accessible, outdated, or scattered over a multitude of special-purpose systems. We propose to abandon the idea of a perfect documentation in a central repository, and to apply the successful principles and technologies of the open web architecture to arrive at a federated architecture to capture, connect and query distributed information over the full lifecycle of an application.

The contributions of the paper are a concise problem analysis, an identification of relevant related work in software engineering and lessons learned from open web architectures. Based on these, we highlight how our approach can contribute to substantial quality and productivity improvements in the maintenance phase. The paper concludes with a discussion of research and development issues that need to be addressed to realize and validate such a federated application lifecycle management.

1 Motivation

For long-lived business applications, maintenance efforts and expenses exceed by far the costs of the initial development [Leh91]. As indicated in Figure 1, during the full lifecycle of a large business application numerous stakeholders with different roles carry out highly-specialized activities that generate and use digital artifacts of various types which are managed using problem-specific tools and repositories. If one looks at the system maintenance and evolution phase, change requests and bug reports are generated which are managed using tools like *ClearQuest* or *Bugzilla*. To assess the change requests and to resolve bugs, a deep understanding of the software application and its past evolution is required. Artifacts generated by other activities and managed in other tools and repositories (e.g. the Rational Software Architect or a wiki) have to be consulted and connected to gain this understanding. As an example, an explanation of the rationale for a design decision helps to choose evolution options consistent with the initial design.

However, even if the system was initially well documented, the quality of the documentation degrades over time since new or changing requirements lead to an evolution of the

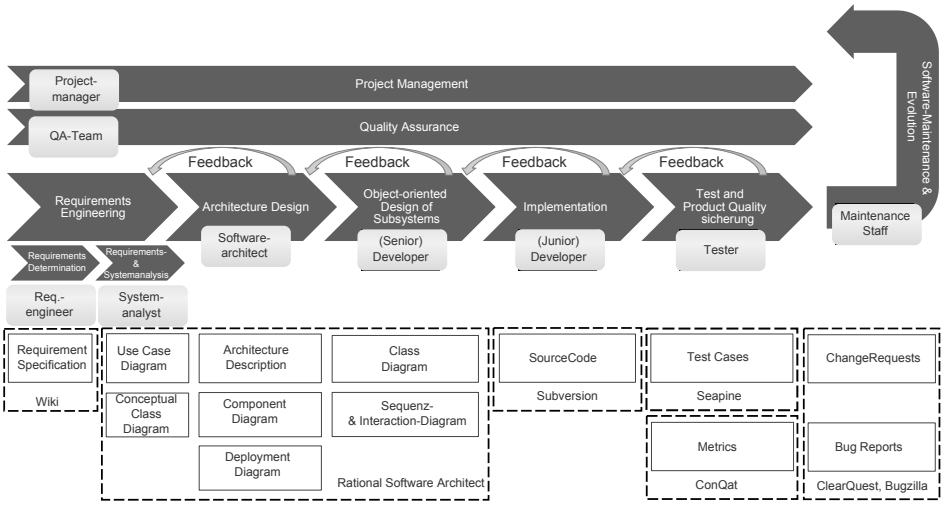

Figure 1: Activities, stakeholders, artifacts and tools in the application lifecycle

implementation and the associated documentation is often not updated accordingly, making it a useless and dead artifact in the long run [FRJ09]. To prevent this, it is necessary to detect anomalies and inconsistencies (e.g., invalid references) as early as possible and thereby keep the efforts for further documentation updates low.

Our paper is structured as follows: Section 2 analyzes the problems related to software maintenance and documentation in more detail. In Section 3 we briefly cover related work in software engineering addressing these problems. In Section 4 we outline web technologies inspiring our approach of a network of federated systems with web-based interfaces which is then presented in Section 5. In Section 6 we identify further research issues deduced from the suggested open distributed architecture and conclude with Section 7.

2 Problem Statement

Availability, completeness, quality and a holistic view of all artifacts containing documentation of the software, especially of its architecture, are critical for the success and efficiency of software maintenance activities. In the following, we identify potential factors which constrain these activities and may compromise their success.

In the literature various models can be found describing the activities and tasks during the software development process, e.g. the Waterfall Model [Boe76] and the V-Modell XT [RB08]. All of these approaches have in common that different stakeholders contribute to the project during different phases of the development. Stakeholders involved in earlier phases of the process (e.g., requirements engineering, design, implementation) often either are not available, when the software is maintained, or do not remember details of the documentation artifacts. Their knowledge is only present in those artifacts. Furthermore,

different views and different understandings of the participating stakeholders may lead to inconsistencies [FRJ09].

For the above mentioned reasons, software documentation artifacts are especially important for the software maintenance activities [Leh91]. A common problem is that these artifacts are either incomplete or do not exist at all. This is often caused by tight and short-term project plans and a limited budget [Par94]. Since these are very common and fundamental problems, the maintenance staff usually have to be content with the available artifacts created during the execution of the particular development phases and have to make best use of those resources. Most of them are strongly interrelated and have an architectural documentation character. For instance, the software architecture itself is documented in an object-oriented model, the description of software components and their dependencies are captured in textual documents (e.g., wiki pages), the architecture is realized by source code elements, which are coupled with the object-oriented models, the component descriptions and the source code documentation. To create and manage these various kinds of artifacts, a large set of highly specialized tools is utilized. Purposes of these tools include but are not limited to requirements management, bug tracking, change request management, version control for source code, workflow management, creation of graphical architecture and design models, build and release management or testing. Additionally, important information resides directly in the source code as inline comments.

A system evolves over time responding to changes in its environment, requirements and the implementation technologies [RLL98]. Thereby different version of the artifacts emerge. So it is challenging to keep all artifacts up-to-date and synchronized with regard to these versions. For instance, assume that the architecture of a software component is documented on a wiki-page. For all public interfaces of this component hyperlinks to the Java-Interface-Files are provided. The versions of those files are stored in a source code repository. If the signature of an interface needs to be modified, e.g., caused by a change request, and thus the version of the file within the repository changes, the reference in the documentation-wiki might need to be updated with regard to this version.

When considering artifacts during maintenance activities, it is helpful to have references available to other resources relevant for the current context. Unfortunately, artifacts are often separated and disconnected. Links between artifacts of different tools cannot be created because of incompatible APIs, heterogeneous protocols and different storage formats. Moreover the documentation artifacts cannot be found, because no unified search over all content is provided. To bridge these gaps between distributed tool-specific repositories, various vendors try to consolidate functionality from other tools in a single uniform platform and provide APIs to enable data exchange. This endeavor is challenging, because of the resulting system complexity, the enormous integration effort, and the lack of generally accepted interchange formats and protocols [Wie09].

In the following sections we present a web-based approach to provide solutions for some of these problems.

3 Related Work

In [WTA+08] Weber et. al. describe their approach of using Web 2.0 technologies to manage the information involved in the software development process. They introduce the concept of a central Wiki-based tool called a Software Organization Platform (SOP). Focusing on small and medium sized organizations (SME) their goal is to better leverage the collective knowledge associated with a single project as well as knowledge about processes that can be reused in later projects.

The Jazz initiative by IBM Rational Software aims at supporting team collaboration by the information integration and at providing guidance for the development process [Fro07]. The initiative offers an IDE-centered approach backed by a server-side central data repository. Further, it allows the integration of third-party tools but requires them to conform to certain web-based interfaces to access the Jazz services. Complementing the individual tool functionalities, there is a set of generic cross-tool capabilities like querying, content discovery or process administration provided by the Jazz platform.

Rooting in the experiences with the Jazz platform, the Open Services for Lifecycle Collaboration (OSLC) community aims at establishing common, less restrictive, web-based standards among software engineering tools [Wie09]. Inspired by the internet, the community is working on shared protocols and formats allowing independent tools to connect and easily access contents. This is very close to our approach, presented in Section 5, but differs in so far that we focus on opportunities not requiring universal standards beyond those currently established in the web, although we share the same long-term vision.

The SYSIPHUS project focuses on collaboration in geographically distributed teams. Its goal is to capture knowledge as a side effect of development and structuring it for long-term use [BDW06]. It provides a uniform framework for models and collaboration artifacts supporting the awareness of relevant stakeholders and the traceability of requirements. All artifacts reside in a single shared repository, which can be accessed through a variety of tools including a web-based client providing a hypertext view of the contents.

4 Web Technology – State of the Art and Trends

In this section, starting from the characteristics of hypertext systems, we outline which fundamental kinds of tools and applications have emerged in the past as well as current trends that we consider relevant in a network of federated software engineering tools.

4.1 General characteristics and trends of open hypertext systems

The most significant characteristic of an open hypertext system like the world wide web is the fact that from within one document it can be easily linked to any other document in the system. This is true for human readable documents as well as for more structured

ones interpretable by machines [BL06]. Furthermore, the uniformity of the presentation format allows the navigation in the complete system using a single tool – namely a web browser. However, the term *document* is misleading in so far that it suggests only static content is considered. Instead we are meanwhile used to seeing dynamically generated content everywhere on the web. Today there is even a clear trend towards complete desktop applications – meaning they were traditionally perceived as desktop applications – like email clients and word processors moving into the browser, facilitated by frameworks as for example *Eclipse RAP*[1]. We expect that even integrated development environments (IDEs) will be realized as web applications soon which would be particularly interesting for our approach (see Section 5).

4.2 Indexing and search

The most common approach to retrieve relevant documents on the web is full text search over all accessible documents via search engines like Google. One important aspect here is that not only the text contents of the documents can be considered but also the structure of the links between them. Additionally there exist so-called meta-search engines [MYLL02] which combine the results of other search engines and thereby intend to improve the relevance of the retrieved documents.

Manual building of structured catalogues of the available web content is on the one hand made difficult by the sheer amount of documents, on the other hand, it is infeasible to keep track of the changes and new additions. However, companies like yahoo offer a hierarchical catalogue of the most popular websites and of course for particular topics there exist special directories of relevant resources.

A recent phenomenon are services allowing users to upload their personal bookmarks of interesting sites and share them with others – known as *social bookmarking* [Neu07]. The idea is that users assigns labels – also called *tags* – to the bookmarks for personal organization. Additional value is generated by aggregating the tags of all users and thus creating a repository of URLs categorized by these tags and ranked by popularity. Furthermore, it is possible to subscribe to certain tags and that way effectively monitor new additions to the repository – filtered according to personal interests.

4.3 Content syndication and mashups

Making the contents of websites available for use in the context of external applications is known as *content syndication*. The data providers make part or all of their data available mainly to increase their reach. Subscribers have the opportunity to enrich their sites by providing the user with more relevant information and thus enhance their attractiveness. Common means for data exchange in this context are XML-based formats and protocols like RSS and ATOM, especially used by news portals and blogs mainly to inform about

[1] `http://www.eclipse.org/rap`. Visited on August 30th 2009

new additions to their contents. However, also non textual information like geographical maps (*Google Maps*[2]), videos (*youtube*[3]) and even mind maps (*mindmeister*[4]) or diagrams (*gliffy*[5]) are made available for use in other applications by the hosting site which usually provide libraries for the scripting language *JavaScript* or Flash plug-ins to embed the content in another site. While these mechanisms effectively determine the presentation of the data, lightweight and mostly XML-based RESTful interfaces, i.e., conforming to the REST architectural style [Fie00], allow to retrieve and modify the available data in an abstract format.

Content syndication enables a new class of applications, so-called *mashups*. These applications combine or enrich the contents provided by other applications and thereby add additional value for the user. A typical example is integrating small advertisements or photos with geographical maps (e.g., *panoramio*[6]).

4.4 Advances in browser technology

In addition to embedding functionality directly into the document by the hosting site, in recent years the trend can be identified that the browser itself can be enhanced with additional functionality. Most browsers offer a plug-in interface allowing developers to create arbitrary kinds of feature-rich add-ons realized for example as additional toolbars or menu items. Minor extensions can also come in the form of small portions of JavaScript code stored in and triggered as a browser bookmark, so-called *bookmarklets*.

Applications reach from generic tools for example for quick look-up of words in a dictionary or filtering advertisements out of the displayed page to functionality that is related to specific services as social bookmarking sites or social networks. A good example showing how far the integration of the contents of these specific services with arbitrary documents on other sites can go is *diigo*[7], a social bookmarking website. Diigo offers a browser extension in form of a toolbar which allows the user to place sticky notes and comments on any page, highlight text for future reference and even start discussions with other users directly in the context of any piece of text or resource on the page.

Modifying the contents of a page by filtering out parts of it or adding further information is also known as *augmented browsing* or *client-side web personalization* [AV08]. Moreover, there are browser extensions specializing on changing web pages via scripts every time before they are loaded and thus forming the basis for other plug-ins making use of this functionality. A popular such extension for the Firefox browser is *Greasemonkey*[8].

[2] `http://maps.google.com`. Visited on August 30th 2009
[3] `http://www.youtube.com`. Visited on August 30th 2009
[4] `http://www.mindmeister.com`. Visited on August 30th 2009
[5] `http://www.gliffy.com`. Visited on August 30th 2009
[6] `http://www.panoramio.com`. Visited on August 30th 2009
[7] `http://www.diigo.com`. Visited on August 30th 2009
[8] `https://addons.mozilla.org/en-US/firefox/addon/748`. Visited on August 30th 2009

5 Improving software maintenance using a web-based architecture

We consider the following kinds of interfaces elementary for software engineering tools for effectively being part of a federated network that facilitates the software maintenance process. Our requirements are very similar to those described by the OSLC community (see Section 3):

1. Every resource that is managed by or resides in one of the tools is accessible via a distinct and persistent URL. On the one hand, this URL serves as an identifier for the respective resource and on the other hand the document behind the URL provides some human readable information about it.
2. A tool provides information about recent updates of its content base via RSS feeds. It is possible to filter these feeds according to the internal structure of the content base. For example, if a tool organizes artifacts in a hierarchical folder structure, it is possible to subscribe to changes in a particular subtree of this hierarchy.
3. Extended access to the contained artifacts is enabled by lightweight RESTful APIs. This extended access includes listing all artifacts, search for them by particular properties and optionally modification.

Fulfilling the first requirement can be considered the absolute minimum for a tool for effectively being part of a federated network, while the last is not likely to be found in all tools in the network. In contrast to OSLC, we do not require shared resource formats among the tools. However, this issue will be covered later in Section 6.

Figure 2 illustrates how additional services make use of the interfaces provided by basic tools while providing the same interfaces themselves. Although it is not explicitly displayed in the figure for the sake of clarity, tools on the same level are allowed to use the interfaces of each other – for example to provide direct links to related resources.

Inspired by applications which have proven successful on the web (see Section 4), in the following, we describe some opportunities for additional services that build on the interfaces we suggested above.

5.1 Discovering relevant content

Perhaps the most important benefit of the outlined approach is that it allows indexing the resources contained by all tools effectively enabling a full-text search of all contents. However, an additional requirement for the searched systems is that they not only provide URLs for each resource, but these resources are at least indirectly reachable via HTML-links starting from one dedicated page of each system.

In contrast to automatic indexing, it is possible to build systems allowing users to bookmark certain resources and label them with tags, effectively categorizing the contents. This

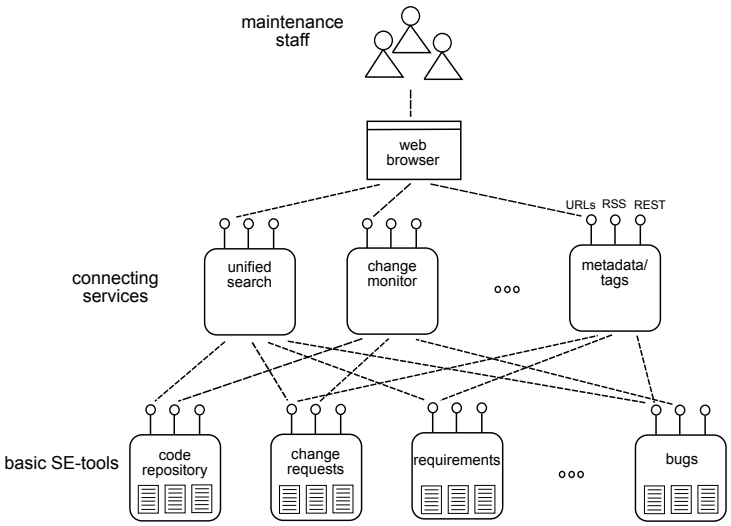

Figure 2: Additional connecting services built on simple web interfaces

can be seen as the equivalent of social bookmarking (see Section 4.2) in the context of software documentation artifacts. Since the user base is rather limited, not all advantages of this approach may unfold. However, we consider this simple and lightweight categorization of resources residing in separate systems a substantial advantage, since in addition to its usefulness for content discovery it can serve as the basis for additional services described later in this section.

5.2 Connecting contents of separate systems

The most fundamental link between two resources of web-based tools is apparently an HTML-link from within the representation of one resource to the URL of another one. For example in the context of a bug report it is possible to reference the documentation of the affected components or a processed change request that possibly caused the bug.

Another option is to directly embed the views on artifacts of one system in the context of documents residing in another system. This can be established through content elements like images – being static or generated upon each HTTP-request – or special Flash plug-ins provided by the system containing the artifacts to embed. For instance the online diagram software gliffy (see Section 4.3) allows to embed views on its diagrams as images into any HTML-document. This way – making manual exports of graphical representations or updating of links obsolete – it is easier to keep different separate documentation artifacts consistent with each other.

When linking or embedding contents directly within a document is not possible or appropriate, another possibility is to connect contents on the client side by enhancing the

presentation in the browser. The technologies presented in Section 4.4 allow for example parsing of a documents content each time before it is displayed and adding a link to Javadoc class documentation to any word matching the respective class name.

Another opportunity for bringing contents together on the client side is to make use of a central bookmarking and tagging application – as mentioned above – and display links to related resources in a browser sidebar. The relation of the documents would in this case be established via the tags of the current document and matching tags of other resources. Tags in this context can be considered not only classifiers but rather implicit links. By applying the same tag, as for instance the name of a component in the application architecture, to several resources, a relation between these resources is established without directly manipulating them.

5.3 Awareness

If changes are made to related pieces of information in separate places by different people, it is very hard to keep this information consistent if there is no mechanism for monitoring these changes in order to react if necessary. These inconsistencies always bear the risks of errors that are introduced because wrong assumptions are made by the developers resulting from outdated documentation. Therefore, persons with particular responsibilities concerning the maintained application are in need of tools keeping them informed of changes with regard to these responsibilities, whether those relate to certain parts of the application or global aspects as usability and security.

Content syndication mechanisms like RSS can help to meet these information needs by allowing systems to provide web feeds about changes to the resources they contain. Since we demand that the feeds provided can be filtered, it is possible to subscribe to task-specific subsets of the resources of each system. However, we only required that the native filtering provided by a tool resembles the respective internal organization of its resources which generally cannot accommodate any appropriate view on the contents. Here it can be useful to rely on tags attached to the URLs of the resources for filtering instead. For aggregating the various feeds, one option is to use special desktop applications like feed readers, email clients or a web browser capable of viewing RSS feeds. Additionally, the feeds can be viewed using special tools automatically aggregating a configurable selection of feeds on a website, effectively generating a dashboard that contains the current information about changes to content, relevant for a particular user.

5.4 Connecting to external knowledge

During software maintenance, especially when trying to understand existing code, familiarity with the application domain plays an important role [SV98]. However, software developers often have insufficient knowledge of the application domain, so being able to access information concerning the meaning of particular concepts is important for them

when editing a program. Additionally, it might be necessary to identify persons having the respective expertise. Provided that at least part of this information is stored in e.g. an enterprise wiki, a web-based architecture makes it easy to connect to this content in a way that is similar to those suggested above. The connection and exchange of knowledge can even cross the boundaries of different organizations, for example by leveraging the knowledge provided by projects like *The Open Model Initiative* [KSF06], a current effort to collaboratively create and refine conceptual models in a public process.

6 Research issues in federated application lifecycle management

Keeping track of different versions of artifacts becomes a serious issue when links exist between them, especially when they reside in separate systems having different versioning mechanisms. For example for each link it should be possible to make the distinction whether it points to a specific version of a resource or if it has to be adjusted when a new version of the resource is created. Considerable efforts have to be made to motivate and establish common standards among tools regarding the traceability of changes and the notion and representation of versions.

Having no central system but a variety of federated tools, the identification and authorization of users becomes another important challenge. On the one hand, it is desirable that the identity of a user does not have to be managed for each individual system, on the other hand, a user's roles and access rights have to be present when a resource is accessed locally. Decentralized authentication standards like OpenID[9] provide a solution for part of this problem. However, since a systems can contain links and metadata referring to resources of another system, more complicated problems arise that require further research: One example is that a user having no rights for a particular resource must not be granted access to meta information of this resource residing in another system.

While providing a distinct identification mechanism for resources and facilitating the discovery of related content items is a major benefit of the presented approach, for many tasks this is not sufficient. When for example searching for contents that were created or modified at a particular date or by a particular author, the access to structured metadata of the resources is required. To accomplish this, the systems in the network have to expose at least part of their internal schema. Further, the corresponding concepts of the various models have to be identified and mapped onto each other to make use of the provided schema information [Ste04]. Thereby we distinguish two types of schemas. On the one hand, data schemas provided by tools for specific purposes, e.g., the definition of requirements. An advantage of those schemas is that the concepts and their relationships are predefined and static. Therefore, mappings and data exchange protocols between multiple tools can be created in advance. On the other hand, some tools, e.g., wikis, are not intended to address a specific purpose. However, some of them allow the definition of metadata by adding semantic annotations to the contents. In this case the data schema and the formal definition of the concepts and their relationships is emerging bottom-up over time. Because of the

[9] `http://www.openid.net`. Visited on August 30th 2009

volatility of those schemas, a predefined resource mapping is infeasible. Yet, technologies like the RDF (Resource Description Framework[10]) provide means for dynamically making semantic information available to other applications. However, since we do not expect a single data interchange format and semantic representation for resources among all tools in the future, it remains challenging to combine data from various schemas to provide services like global search and querying, particularly if some schemas evolve dynamically.

As mentioned above, tags can serve as a generic tool for connecting resources of different systems. While research has been done on large tagging systems and their potential (e.g., [GH06] or [HKGM08]), tagging in a comparatively small environment like a software project is not well studied yet. An interesting research question in this context is for example in how far tagging can contribute to establishing a shared vocabulary of technical terms as well as concepts of the application domain among the developers. Additionally, solutions have to be found to combine tagging functionality of different systems which is not trivial because they can differ in various ways like for instance the possibility to assign weights or visibility restrictions to tags. Furthermore, the identification of synonymical tags among separate systems has to be accomplished. For this problem the mapping of tags to URLs – particularly wiki pages [HSB07] – might provide a solution.

7 Conclusion

Software maintenance is a complex and costly task relying heavily on the access to up-to-date documentation of the maintained system. To better accommodate this information need, we suggested that all tools being used during the application lifecycle offer certain web-based interfaces that allow them to form a federated network making all created documentation artifacts accessible in a hypertext format. Inspired by current trends and successful applications on the web, we demonstrated the opportunities the approach offers for the field of application lifecycle management. Finally, we identified the particular challenges of our approach and topics for future research, respectively.

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