TOWARDS A HOLISTIC INTEGRATION OF SOFTWARE LIFECYCLE PROCESSES USING THE SEMANTIC WEB

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Keywords: Software Lifecycle Processes, Software Engineering, Semantic Web.

Abstract: For comprehensive software lifecycle processes, a trichotomy continues to subsist between the software development processes, enterprise IT processes, and the software runtime environment. Currently, integrating software lifecycle processes requires substantial effort, and the information needed for the execution of (semi-)automated software lifecycle workflows is not readily accessible and is typically scattered across semantically heterogeneous sources. Consequently, an interrupted flow of information ensues between the development/maintenance phases and operational phases in the software lifecycle, resulting in ignorance, inefficiencies, and suboptimal product quality and support levels. Furthermore, today's abstract IT (e.g., ITIL) and software processes are often derived into concrete processes and workflows manually, causing errors, extensive effort, and limiting widespread adoption of best practices. This paper describes an approach for improving information flow throughout the software lifecycle via the (semi-)automated realization of abstract software lifecycle processes and workflows in combination with Semantic Web technologies.

1 INTRODUCTION

For a long time, software development and operation were regarded as separate disciplines. However, there is an increasing interest in a holistic view on the entire software lifecycle. For enterprises, software lifecycle processes such as the ITIL (ITSMF, 2004) application management process provide an abstract view that includes phases of the software lifecycle as shown in Figure 1. Software lifecycle processes tend to have a broader view than most software development processes, which typically include only the phases from requirements analysis to roll-out, but often ignore the operation and the retirement phases of software. Application development entails the requirements, design, and build phases. Service management consists of the deploy, operate, optimize, and retirement phases. For instance, it is theoretically possible to use information gathered during one phase to help optimize another. Operational information could be used for optimizing the software design.

To realize advantages of software lifecycle processes economically and efficiently, it is necessary to have information flows of semantically-annotated information with appropriate information retrievable in a diverse operational infrastructure across organization boundaries.

Today, however, various barriers impede the necessary efficient information flow capability. Therefore, this paper will analyze barriers for realizing the advantages of comprehensive software lifecycle processes and provide an initial approach to towards overcoming some of these impediments.

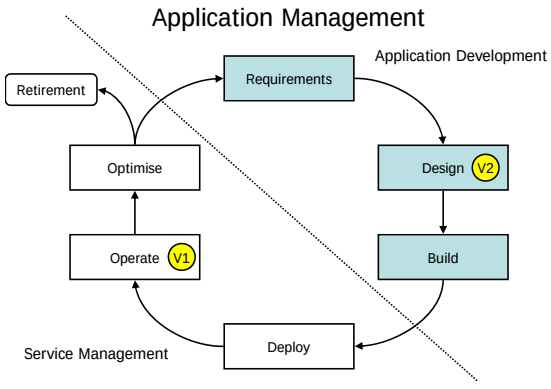

Figure 1: ITIL application management.

Oberhauser R. and Schmidt R. (2007).
TOWARDS A HOLISTIC INTEGRATION OF SOFTWARE LIFECYCLE PROCESSES USING THE SEMANTIC WEB.
In *Proceedings of the Second International Conference on Software and Data Technologies - Volume ISDM/WsEHST/DC*, pages 137-144
DOI: 10.5220/0001343101370144

2 PROBLEM

While comprehensive software lifecycle processes offer a number of advantages, in practice these are rarely fully exploited. Two reasons are plausible: realizing integrated software lifecycle processes requires significant effort, and the information needed for the execution of (semi-)automated software lifecycle workflows is not readily accessible and is typically distributed across semantically heterogeneous sources.

2.1 High Implementation Effort for Software Lifecycle Processes

The prodigious implementation effort for software lifecycle processes is due to a large extent because of the semantic gap between the abstract process descriptions and the executable process, as shown in Figure 2. Furthermore, there is no appropriate representation of best practices. Workflows which already have been proven as beneficial cannot be easily reused, because they are not easily accessible and a common representation is missing. Thus, the derivation of executable processes from the abstract process description has to be done manually. However, the manual derivation causes a number of subsequent problems: it is an error-prone task. Second, the degree of reuse is low; the executable software lifecycle processes reuse only few elements, leading to a higher error rate because tested workflows are rarely reused. Third, there is only a low degree of standardization. This is of particular consequence when the software lifecycle process spans multiple interacting organizations.

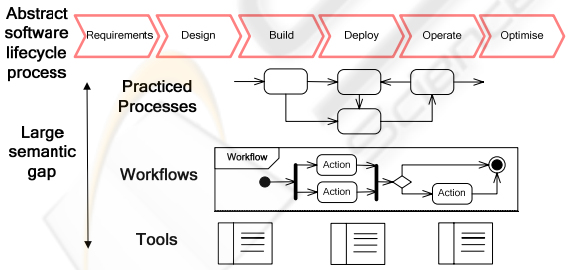

Figure 2: Semantic gap.

2.2 Breaks in Information Flows

An encumbering problem for the efficient implementation of software lifecycle processes are breaks in the information flows between software operation and software development as shown in Figure 3.

After transferring the software to the run-time environment, only few or no information is passed back to the software developer. This information can be divided into two sets.

First, there is run-time information which is machine-observable. That means, this information can be gathered automatically. Such machine observable run-time information is, for example, the application log, the server log, and the system log. Furthermore, data in the application database may be important for debugging, etc.

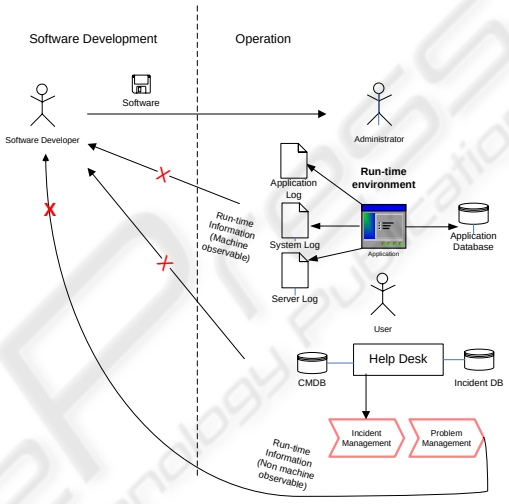

Figure 3: Breaks in information flows.

Second, there is run-time information which cannot be directly gathered by a machine, e.g., functional defects in the software: the software continues its operations but delivers invalid results or exhibits incorrect behavior. This information is gathered indirectly by a user or administrator and usually communicated to a single point of contact, called a help or service desk. All information gathered by the help desk is processed by incident and problem management processes (as defined in ITIL) and stored in an incident database. The incident and problem analysis is supported by the configuration management database which contains information about the configuration of the run-time environment, e.g., details such as software versions used on which systems, hardware, networking, etc.

In practice, an important problem is deciding which information can be used to diagnose which type of problem. Figure 4 shows three hypothetical examples. For performance problems, the server log and the application database could be analyzed. Reliability problems can be analyzed using the server, system and application log in conjunction with the configuration management database

(CMDB). Finally problems in the application logic (e.g., incorrect behavior) can be analyzed using the application database and incident database where observations of incorrect behavior of the application are stored.

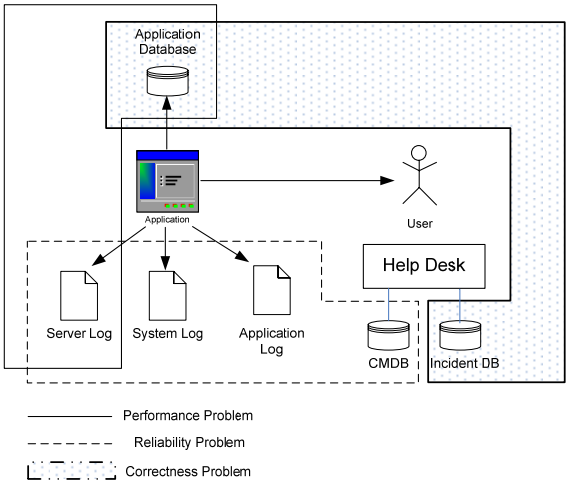

Figure 4: Best practices for problem diagnosis.

It is evident that the selection of the appropriate information sources non-trivial. But in practice, there is no means to appropriately store the information about which kind of problem requires which information sources. This knowledge is not theory-based, but comes from observation and experience and can be seen as a collection of best practices.

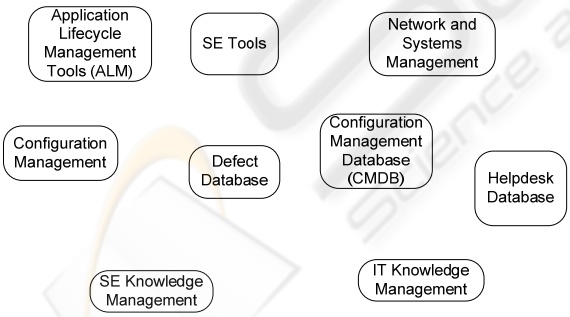

Figure 5: Scattered Information Island Landscape.

While both machine-readable and human-readable run-time information could provide a significant benefit to the software developer - however, differences in syntax and semantics impede the usage of such information. Furthermore, important information is not discoverable because of the dispersion across different sources using incompatible syntaxes and semantics. Consequently a landscape of isolated tools, systems, and databases emerges as shown in Figure 5.

3 SOLUTION APPROACH

Any feasible and concomitantly practical approach towards a holistic solution needs to address the previously mentioned problems of section 2 within realistic constraints. E.g., to further adoption, it should be platform-independent, vendor-neutral, utilize standards, and support a high degree of flexibility and loose-coupling. A possible approach that this paper presents is SWLIFE: Semantic Web-based Lifecycle Integration Framework for Enterprises. Before describing the framework elements, the underlying principles of the framework's architecture will be elucidated.

3.1 Solution Principles

This section describes the key principles of the solution approach.

I) *Holistic need-based integration of human and machine processes, services, and ontologically structured data for the operational lifecycle.* The lack of integration between software engineering processes and customer (e.g., enterprise or IT) software operational processes (e.g., ITIL) causes extensive inefficiencies, especially in the maintenance phase of a software product - both in the processes and access to necessary data. Yet this is typically the longest, most expensive, and least predictable phase.

II) *Round-trip Process Engineering: prescriptive while concurrently descriptive abstract processes*. Too often abstract processes are not transformed or mapped to concrete processes correctly, thereby losing its prescriptive nature. Abstract processes hereby are mapped (semi-)automatically to concrete processes, and customized current concrete processes are abstracted to determine if they still conform to the abstract processes. If not, either they or the abstract processes are adjusted so that the abstract processes are also descriptive.

III) *Semantic Web accessibility and utilization of meaningful data*. Instead of hidden, obscure (operational) data in applications and tools such as log files, this data is discoverable, accessible, and its meaning described via Semantic Web Services.

IV) *(Semi-)Automated exchangeability and reuse of machine-readable best practices in the form of workflows*. Rather than just textual exchange via documents, which are difficult and arduous to automate, both abstract and concrete processes and workflows are described in standardized Markup Languages, e.g., including XMI (e.g., from UML Activity Diagrams), BPEL4WS, various Grid Workflow languages, etc. These are stored and exchanged in enterprise-wide and trusted internet repositories. Apposite choices or standards for such Markup Languages are outside the scope of this paper.

V) *Service-Oriented Architecture (SOA)*. In order to achieve the level of integration necessary, SOA principles including loose-coupling, encapsulation, reusability, composability, discoverability, etc. are applied, generally in conjunction with Web Services standards.

VI) *Feasible and reasonable automation*. Common operational or maintenance routines are automated to the degree reasonable and economical for workflows and the (semi)-automated composition of services.

VII) *Web-based human process documentation and integrated infrastructure binding*. Web-based process documentation of software engineering processes (e.g., VM-XT, RUP) and IT processes (e.g., ITIL) are tailored to the context and bound to the actual human and machine workflows used, with the services hyperlinked within the documentation. Thus a human can determine the status of a workflow, start an (automated) workflow, etc., all in the context of the organization's processes.

3.2 Solution Description

This section describes the solution approach of SWLIFE as depicted in the illustration of Figure 6. The layers used are for grouping purposes and are not intended to show strict abstraction or dependency relations. The white rectangles show examples of possible current processes and tools. The black rectangles show new areas that SWLIFE provides or enables. It is not intended to be exhaustive but rather illustrative of the approach, additional layers and items are conceivable.

The vertical column Vendor Development Operations (see Fig. 6) includes the processes and infrastructure of a product developer, while the vertical column Enterprise IT Operations includes those of the product customer who operates the software product. Black hashed ellipses between these columns show a new permeation between these two usually distinct organizational entities at a given layer.

The Process Layer (see Fig. 6) can include processes defined at an organizational level, and depicts abstract process models (e.g., RUP or ITIL) that are tailored via a Process Mapping Framework to concrete processes. These processes typically include workflows performed at various points by various human roles defined by theses processes, and can include machine-based workflows to automate certain recurring tasks. The Process Mapping Framework includes techniques and tooling to support the tailoring of abstract processes and workflows to concrete processes, and for analyzing concrete processes and workflows, abstracting them, and comparing them to intended or previous abstract processes. The Process and Workflow Repository provides a retrieval, update, and exchange mechanism for processes and workflows, such as software engineering-related, domain-specific (e.g., ecommerce, banks), enterprise-specific, platform-specific, and vendor- and application- specific areas. Such a mechanism could improve quality and reduce investment costs by enhancing the distribution and interchange of best practices in these areas. The Integrated Process and Workflow Transformation and Execution Subsystem ensures that integrated human and machine processes and workflows are transformed, including (semi-)automatic composition, as necessary at run-time, and ensures and monitors their execution.

The transformations and mappings in the Process Layer can utilize, where available, a Knowledge Layer, where Knowledge Management repositories of the applicable organizations may contain knowledge in the form of rules for defining process and workflow transformation.

The Semantic Integration Layer (see Fig. 6) includes the Semantic Web interfaces for tools and services, including adapters when not provided, and any necessary infrastructure. This includes existing subsystems on the vendor and enterprise side for ontology loading and reasoning, as well as an integrated capability for SWLIFE scenarios.

The Infrastructure and Technology Layer in Fig. 6 includes the tools, applications, and technology utilized in the various organizations.

Governance Management includes the aspects necessary to govern the integration between organizations, including the integration of policy management.

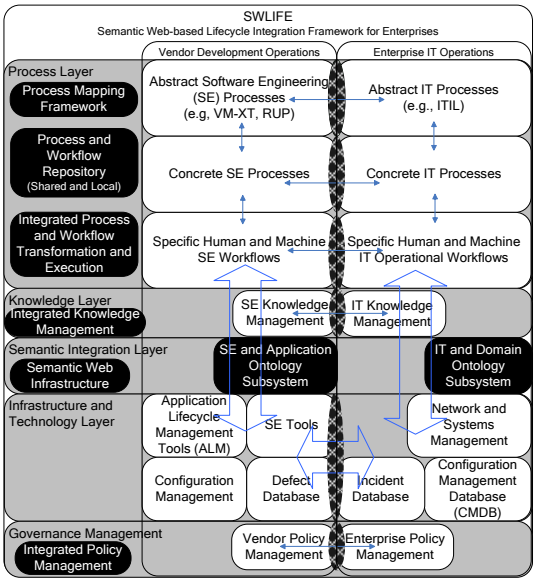

Figure 6: SWLIFE.

An example of the interaction of the layers is shown in Figure 7. The Semantic Integration Layer encapsulates Semantic Web Services (SWS) interfaces of information sources such as CMDB, Incident DB, and Application Logs. In the Semantic Integration Layer, ontologies both from the vendor and enterprise are used to classify the SWS and to clarify their relationships. Aggregation and filtering is done via a Reasoner to support the workflow transformation process. Rules provided in the Knowledge Management Layer assist the Workflow Transformation Service in order to transform integrated workflows from the vendor and enterprise into concrete executable workflows which are provided and executed as SWS.

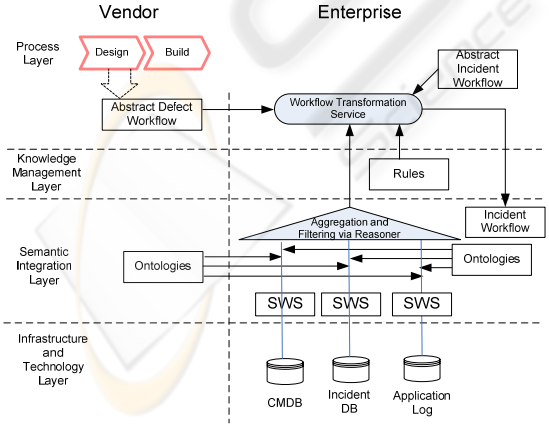

Figure 7: Layer interaction.

4 SOLUTION REALIZATION

The implementation of the SWLIFE approach has focused on the problem of the transformation of abstract processes to and from concrete processes. To support an efficient, correct, and reliable transformation, the support non-trivial workflows and their (semi-)automatic composition should be supported on tooling suitable in engineering and IT settings. Although there is much research in the automatic composition of OWL-S based services, various HTN planners mentioned in research were considered unsuitable, e.g., due to the lack of access, instability, or lack of usable results in practice. E.g., OWLS-XPlan was considered, but lacked branching capabilities, sufficient documentation, and an execution engine for its PDDXML workflow format. E.g., Mindswap Composer also lacked branching and loop capabilities.

With the current lack of usable planners for workflow composition, a separate and practical solution for the Workflow Transformation Service was developed that combines an Ontology Subsystem with a Rule Engine, as shown in Figure 8. For the Ontology Subsystem, the Protégé OWL API 3.2 Beta, was used to read in the ontologies, and the integrated Protégé Reasoner was used (external reasoners are an option) to select a set of possible service matches. For the Rule Engine, JBoss Rules 3.0.5 was chosen. As the abstract workflow is read in and parsed, any abstract concepts are detected and the Reasoner returns a set of service instances that are a possible match. Because the choices may be highly dependent on a number of factors, this set is passed to the rule engine as a fact model and inserted into its working memory. The rule engine then selects the appropriate service based on the set of rules in the Rule Base. The use of a rule engine allows a greater degree of flexibility and change for enterprises without the encumbrances inherent in lower-level programming languages, although script languages are an alternative. If no matching service was found, an error is issued. If more than one service matched, then the first one was used, replacing the abstract concept in the workflow with a concrete service.

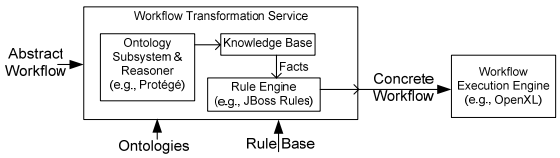

Figure 8: Abstract to Concrete Workflow Transformation.

Various workflow languages would be suitable for SWLIFE, however, the domain-specific language Service Language Layer (SLL) (Kossmann et al, 2005)(Dinger et al, 2006 SLL), was chosen for the implementation due to its simplicity as a workflow language at the programming language level and because of its service-centric nature. SLL can also be viewed in its XML form and be transformed into BPEL4WS or another workflow language.

For feasibility test purposes for such a workflow scenario, Web Service adapters and OWL-S descriptions for typically non-SOA software lifecycle applications (e.g., Subversion version control system, compiler, etc.) were created, along with an abstract workflow specified in SLL that specified various abstract tools to automatically generate a report for an engineer. This abstract SLL workflow was passed to the Workflow Transformation Service which then converted it into a concrete SLL workflow referencing concrete tool service instances, and the workflow was then deployed and executed as a service on the OpenXL platform.

For performance measurements, a Windows XP SP2 PC with an AMD 2600+ CPU, 1GB RAM, a 1Mb/s Internet connection, Java 5, Apache Tomcat Version 5.5.20, Apache Axis 1.4, and OpenXL 1.0 was used.

In applying a SWLIFE scenario, it was determined that a major contributing factor to the performance of the workflow transformation was the ontology loading time. Because of the difficulty of creating local copies, adapting import URLs, and maintaining these against new version, Internet retrieval of OWL-S related ontologies is a highly likely use case. The average across 100 attempts for inserting an OWL-S based service ontology to the knowledge base was 5.66 seconds. This would indicate that it is best to load and initialize the Workflow Transformation Service once as a long-running service even in an enterprise setting.

Table 1: Average workflow transformation time.

Number of possible Services	4 Abstract concepts (ms)	100 Abstract concepts (ms)
5	86	111
10	92	120
25	106	123

The actual abstract to concrete workflow transformation time given a simple rule file was measured, averaged across 500 attempts as shown in Table 1, based on the number of available services, and utilizing 4 or 100 abstract concepts. This shows that the performance of workflow transformation from abstract to concrete workflows utilizing a rule engine is practicable.

5 RELATED WORK

Approaches for a holistic access and integration of information include collaboration software, ALM (Application Lifecycle Management) and ECM (Enterprise Content Management) which allows the management of an organization's unstructured information, wherever it exists as the AIIM (Association for Information and Image Management) intends. Yet most of the current applications in these areas have only partial solutions, non-standard interfaces, and little to no integration in the operational IT processes of customers. Grid technologies, platforms (e.g., the Globus Toolkit), and related research (e.g., the Adaptive Services Grid) could well provide an infrastructural basis for some aspects of SWLIFE, so while this approach does not preclude it, it does not require the Grid since the primary focus of SWLIFE is not the sharing computational resources or services. The concept of virtual organizations as used in the Grid could be leveraged for the ad-hoc integration and access by a vendor to the provided customer software and/or data.

The SWLIFE approach can leverage and integrate work on software engineering ontologies, e.g., (Calero, 2006) includes work on SWEBOK, software maintenance, software measurement, and other related ontologies. Work on generic IT and domain-specific ontologies could be used in SWLIFE, an example is the Health Information Technology Ontology Project (HITOP).

The approach presented here also has relationships to the semantic-based composition of web services as described in (Sivashanmugam et al., 2004), (Medjahed et. al., 2003) and (McIllraith et al., 2000). These approaches show how Web Services can be integrated using semantic web technologies. This also applies to the ontology-based description of business processes as defined in (Koschmider et al., 2005) and in (Rosemann et al., 2002) and (Rosemann et al., 2004). Work utilizing the Semantic Web for automated software engineering purposes includes (Dinger, 2006 SWS-ASE). A tighter relationship exists with approaches for the ontology-based representation of service processes such as the incident and problem management processes as defined in (Schmidt et al., 2007). The semantic alignment of business processes using

ontologies is described in (Brockmanns et al., 2006). Ontologies can also be used for supporting the composition of web services as described in (Agarwal et al., 2005). A mixed-initiative framework for Semantic Web service discovery and composition is presented in (Rao et al., 2006). It interleaves human decision making and automated functionality. Thus it can also be applied even if annotations are incomplete and inconsistent. This scenario is rather similar to the scenario of SWLIFE, and therefore this approach will be further investigated.

6 CONCLUSION

The lack of integration of between the stages in comprehensive lifecycle processes between product vendors and enterprise customers continues to plague the software industry. This manifests itself perplexed administrators, in extensive, expensive and difficult defect remediation, long defect duration times, long service response and patch turn-around times, etc. As software continues to increase in its complexity and degree of integration, this situation will deteriorate without attention.

To address this situation, the SWLIFE approach bridges these process and information flow breaks by supporting integrated lifecycle processes, shared human and machine (semi-)automated workflows, and enabling better quality and more efficient semantic integration of infrastructure elements and artifacts. SWLIFE is influenced by background trends such as a high degree of networked systems, increasing integration via Service-Oriented Architecture (SOA) and Web Services, Semantic Web, outsourcing, and cross-organizational value creation, and service providing in the IT area.

Economically, an advantage of the SWLIFE approach is that each vendor of a product invests in the Semantic Web interface to its product once, and all customers can benefit from faster and higher quality maintenance response, providing an incentive to customers. Customers can utilize the Semantic Web interfaces to automate workflows, integrate workflows into higher-level processes, and more efficiently gather and analyze quality metrics. Via a standardized exchange format and repositories for processes and workflows, the investments can be incremental and shared. The implementation work showed that a feasible and practical solution for the (semi-)automatic composition of workflows using Semantic Web Service interfaces for the tools and services involved in SWLIFE scenarios exists.

A future market for packaged processes and workflows (analogous to the IBM Rational Unified Process) which are trusted, supported, and maintained, is thinkable. In addition, Semantic Web Service adapters can be provided to integrate legacy or non-conforming products.

Even a partial application of the SWLIFE approach can yield advantages via increased and systematic application of best practices in the form of human and machine-readable processes and workflows, the holistic needs-based integration of vendor and customer infrastructure, and the utilization of machine-processable semantic infrastructure. This a viable approach to addressing the skyrocketing complexity and maintenance costs associated with the use of software products.

Some challenges for the SWLIFE approach include: the need for highly-trained personnel for semantic, ontology, process, and workflow creation and usage; for cross-organizational access trust, security, authorization, and policy issues need to be addressed; the lack of (standardized) ontologies in the various SE and IT areas; and the adoption and usage of abstract processes and their description in machine-processable form.

Further work will include exploring additional application scenarios, for instance, enhanced response workflows for security intrusions, where rapid response and high quality incident data play important roles.

ACKNOWLEDGEMENTS

The authors would like to thank and acknowledge Thomas Ilzhöfer for his thesis work.

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