Collaborative Enterprise Architecture Design and Development with a Semantic Collaboration Tool

Frank Fuchs-Kittowski, **Daniel Faust**
Fraunhofer Institute for Software and Systems Engineering ISST
Mollstr. 1, 10178 Berlin, Germany
Tel.: +49-30-24306-100
Fax: +49-30-24306-599
E-mail: [frank.fuchs-kittowski|daniel.faust]@isst.fraunhofer.de

Abstract
The design and evolution of an enterprise architecture (EA) is a challenging and complex task. A participative approach to collaborative EA management is needed to support the collaboration of all individuals involved in the process of EA design and evolution. This paper presents our concept of a semantic collaboration tool for collaborative EA management. This includes the concept of a semantic, wiki-like collaboration tool for collaborative EA management and an EA ontology as a formal representation of the EA. Additionally, the prototypical implementation of the semantic collaboration environment and its architecture are described and the benefits of the approach discussed.

Keywords: Enterprise Modeling, IS Architecture, Collaborative Work, Community, Groupware, Knowledge Base, Ontologies, Semantic Data Model

INTRODUCTION

Enterprise architecture (EA) management is widely accepted as an essential instrument for ensuring an enterprise's agility, consistency, compliance, and efficiency, and is especially used as a basis for a continually aligned steering of IT and business (IT business alignment) (Bucher et al, 2006; Ross, Weill & Robertson, 2006; Wagter, van den Berg & Luijpers, 2005). EA management is the field of managing whole EA's as well as the artifacts that constitute EA's. While an EA model represents an enterprise's as-is or to-be architecture (Rood, 1994; Lankhorst, 2005), an EA framework provides meta-model(s) for EA description and method(s) for EA design, development, use, and evolution (Open Group, 2003; Schekkerman, 2004).

Nevertheless, the design and evolution of an EA is still a challenging and complex task (CIO, 2001; Lankhorst, 2005). It is a cost intensive and time-consuming process, especially in large scale enterprises with numerous, spatially distributed locations. It consists of many participants responsible for different kinds of information for different parts of the EA using different methods and tools for information gathering. Different business functions (data owners) provide information required for the divergent needs of various stakeholders with different interests. Structuring such a process is difficult due to the involvement of many stakeholders from

different business functions and cultures, thus resulting in increased communication and coordination efforts for all involved.

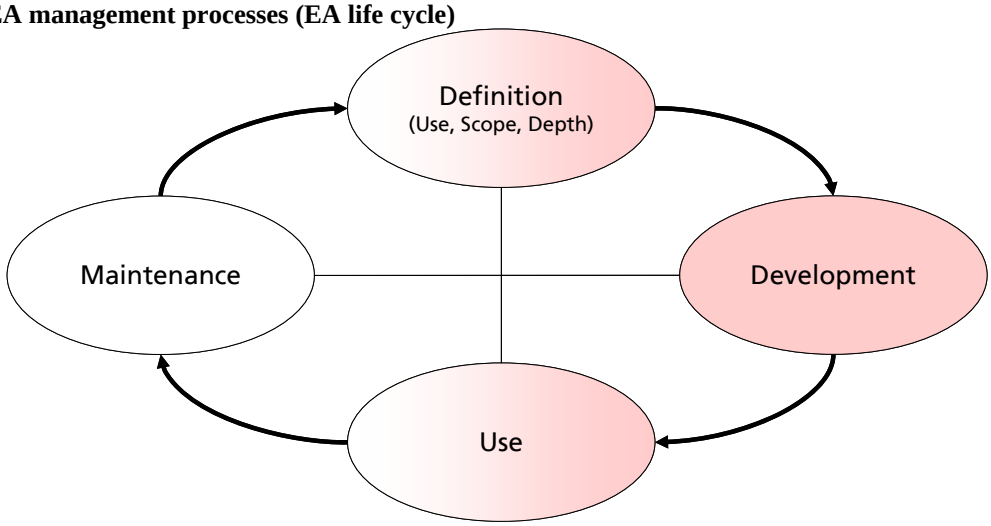
Our goal is the design of a collaboration environment to support the collaboration of all individuals involved in the process of EA design and evolution. In particular, it must be possible for a large and spatially located group of individuals to gather information about EA collaboratively and with minimal effort. Furthermore, information gathering for EA management must be possible without having to plan and structure this process in advance. Our approach to achieve this goal of a participative EA management is a semantic, wiki-like collaboration environment. This is a solution based on the concept of semantic web and the paradigm of Web-2.0, e.g. user-generated content, participation, collective intelligence. This semantic collaboration tool allows the combination of formal, semantic structuring of EA information (in an EA ontology) with informal, participative processes of gathering this EA information (supported by a wiki-like collaboration environment).

This paper presents the concept of a semantic collaboration tool for collaborative EA management. An EA management application scenario is presented to further characterize the problem and to derive requirements on a collaboration environment supporting collaborative gathering and maintenance of EA information. Based on this scenario, the approach is presented to include the concept of a semantic, wiki-like collaboration tool for collaborative EA management and an EA ontology as a formal representation of EA. Additionally, the prototypical implementation of the semantic collaboration environment is described and the benefits of the approach are discussed.

EA APPLICATION SCENARIO

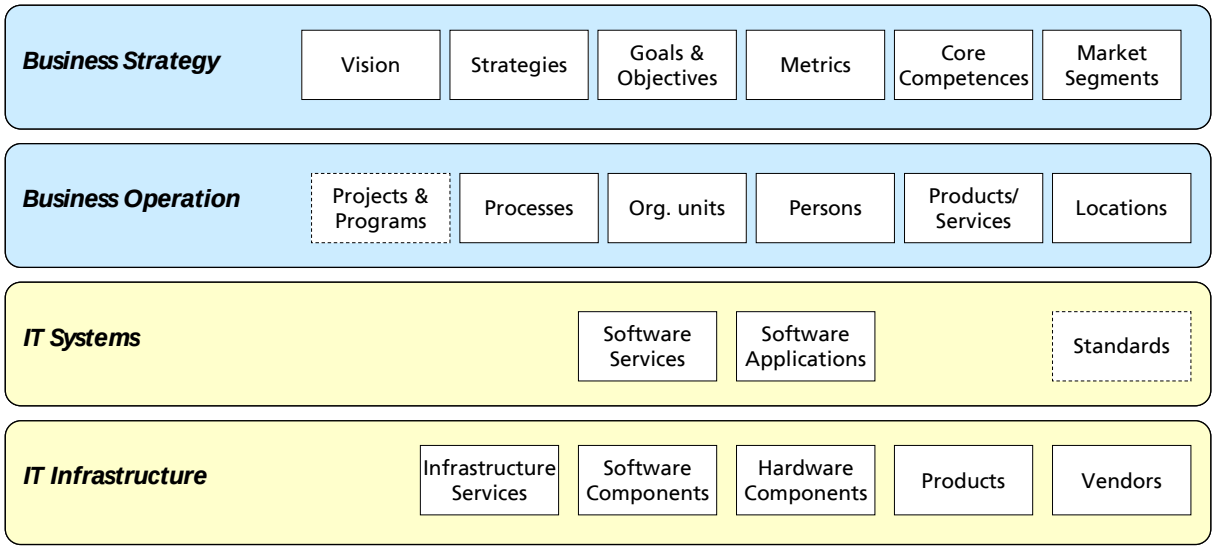
A large number of methods for EA management has been developed by academia and practitioners (e.g. Aziz et al., 2005; Aziz et al., 2006; Bittler & Kreizmann, 2005; CIO 2001; DoDAF, 2007; IFIP-IFAC, 1999; Open Group, 2003). These methods usually distinguish between the following EA management processes as a life cycle model of the EA: (a) strategic architecture visioning and definition, (b) EA development, (c) EA use, (d) EA maintenance (figure 1). Almost all of these methods pay little attention to specifying information gathering procedures for EA model data in detail – especially during EA development and use (Jonkers et al., 2006).

Figure 1: EA management processes (EA life cycle)



An EA is comprised of a large number of artifacts. Since creating EA models is expensive and without intrinsic value, it is desirable to only create EA models that support good decision making (Narman, Johnson & Nordstrom, 2007). Therefore, an EA needs to include only those artifacts (and relationships) that promote well-defined analyses for a certain EA application scenario (e.g. IT consolidation). As an example, following current divisions of EA in layers and artifacts in EA frameworks (e.g. FEAF (CIO, 2001), TOGAF (OpenGroup, 2003)), scientific literature (e.g. Sebis, 2005; Winter & Fischer, 2006; Bucher et. al., 2006; Kaisler, Amour & Valivullah, 2005; Janssen & Hjort-Madsen, 2007), or meta-models of commercial EA tools (e.g. E2AF (Schekkerman, 2006), MEAF (TrouxMetis, 2006)), we decompose EA into four EA layers and propose a simple 4-layered EA with core artifacts (figure 2): business strategy (goals, markets, products/services, etc.), business operation (processes, organizational structure, etc.), IT systems (software service, software application, software components and data structures, etc.), and IT infrastructure (infrastructure services, platform/hardware component, products, etc.).

Figure 2: Simple 4-layered EA



In practice, the different (sets of) EA artifacts are developed and maintained by different individuals. Very often, EA coexists with other, more specialized or detailed artifacts that cover a subset of these artifacts (Bernard, 2005; Winter & Fischer, 2006). Therefore, EA should integrate these existing artifacts as well as the used modeling techniques and tools (Lankhorst, 2004) and useful interfaces have to be specified and established (Winter & Fischer, 2006). Interfaces could be established, for example, to an ERP system (products and services), process modeling tool (business process models), or hardware inventory (hardware data).

Moreover, an EA has to represent not only isolated artifacts but also the entire complexity of an enterprise with all its relationships and dependencies. Supporting EA-relevant decisions requires knowledge of multiple artifacts of the EA. For example, "IT planning's" main task is to combine the business process requirements with appropriate IT systems within a limited budget. This need-driven planning has to follow an integrative approach where the perspectives of (a) business structures and processes, (b) IT systems and infrastructures, and (c) finances have to be combined. To achieve this, an EA has to gather and document not only the isolated artifacts but also the relationships between them.

As most of the required EA information in heterogeneous and spatially distributed environments is owned and maintained by different individuals, the integration process becomes very important. This process has to ensure that various information from different business departments, functions, domains and individuals have to be interlocked. Only if the information is integrated, inconsistencies and cost-intensive incorrect planning can be avoided. The need for integration ties the separate information gathering processes of different individuals much closer together. The situation of multiple participants and stakeholders results in diverse requirements. Besides the modeling of isolated and shared artifacts, this includes communication and documentation among the various participants and stakeholders involved in the EA development process. In addition, different tools and description formats may be used.

The foremost method of information gathering for EA models in practice is to task external consultants with collecting and modeling the EA information in enterprises. This approach is expensive since it requires experienced consultants, time consuming since the required data is not on hand, frequently incomplete since efforts and expenses to document the entire EA are too high. Compared to this method - which focuses on EA information gathering by only a small group of "outsiders" - our approach focuses on involvement of the data owners and other individuals such as stakeholders. Therefore, the technical support of the collaborative process of a large group of individuals is necessary.

Existing EA methods and most of the commercial EA tools (e.g. planningIT by alfabet, Metis by Troux Technologies) focus on a process-oriented EA management approach[1]. Characteristics of the process-oriented approach are: (a) the detailed, formal description of a process necessary to gather EA information, (b) the specification of roles to execute, manage and control all process activities, (c) the mapping of roles to process activities by means of responsibility charting (i.e. by specification of responsibility, accountability, etc. for each process activity). But for a large number of participants the process-oriented approach is inadequate. It is hardly possible to

[1] See (Sebis, 2005) for a detailed description of existing commercial EA tools.

structure the entire process in advance if a lot of individuals from different functions, domains and cultures are involved. In addition, fixed roles do not allow for participative flexibility.

In order to address the challenge of EA information gathering by a large group of individuals, we propose a participative approach. It does not focus on the definition of processes, roles and responsibilities, and gathering EA information by a small group of external staff but rather on internal stakeholders (data owners), their interaction and the resulting processes of change. In the participative approach the responsibility for gathering EA information is delegated to the data owners and other individuals such as stakeholders. The participative modeling process involves a large group of individuals (stakeholders) that identify, document, and consolidate their different knowledge and interests concerning the problem modeled - as the required knowledge mainly exists in their minds, opinions, intentions, work routines, experiences, etc..

Participative EA modeling methods (for example, (Bubenko, Persson & Stirna, 2001; Bubenko, Stirna & Brash, 1997; F3, 1994; Loucopoulos et al., 1997) lead to improved quality as well as an increased consensus and acceptance of the business decisions. An empirical study (Persson & Stirna, 2001) shows that participative EA modeling can successfully support both, business development objectives and quality assurance objectives. It also facilitates maintaining and sharing knowledge about the business as well as organizational learning (for example, (Stirna et al., 2002; Persson et al., 2003)). The full and positive effects of participative EA modeling heavily depend on the ability of its users to manage situational factors which characterize, influence and constrain development situations where EA modeling is used (Persson, 2000).

The goal of a participative EA development is the involvement of data owners and stakeholders. Hence, the integration of a large group of individuals as well as a tool support of the collaborative process of this large group – providing an integration space for the participants - is necessary.

The proposed semantic collaboration tool for participative, collaborative EA management (especially EA information gathering and development) enables - compared to existing (semantic) wikis (e.g. SemanticMediaWiki (Völkel et al., 2006), IkeWiki (Schaffert, 2006), Kaukolu (Kiesel, 2006), Sweet wiki (Buffa et.al., 2006)) where textual content is addressed - the semantic representation and structuring of EA information (ontology) and - compared to existing commercial EA tools which promote a process-oriented approach to EA management - a participative process of EA design and evolution and - compared to existing ontology editing tools (e.g. Protégé) which do not focus on a collaborative process and require expertise in formalisms and ontology engineering (Noy, Grosso & Musen, 2000) - a collaborative, fine-granular participative and community-oriented EA ontology information gathering and development process by a large number of non-experts.

CONCEPT AND ONTOLOGY OF A SEMANTIC, WIKI-LIKE COLLABORATION ENVIRONMENT

To resolve the before-mentioned problems, the presented concept will support collaborative EA design and development more effectively. To reach this goal a participative approach is proposed

which will be achieved by a semantic web 2.0-like collaboration tool. Web 2.0 tools, like wikis and weblogs, support the generation, gathering and exchange of knowledge in large, spatially distributed groups. However, they do not offer possibilities for the (semantic) representation of EA information and are, therefore, inadequate for EA design and evolution. Semantic web tools support the classification, structuring, and representation of large, unstructured stocks of information but do not support collaborative EA design and evolution effectively.

Hence, our solution is a semantic web 2.0-like collaboration tool that combines the advantages of the two innovative technologies. This solution provides an integration space to bridge the gap between the participants in EA information gathering since it (a) provides means for collaborative information gathering and communication regarding a certain subject and (b) it provides a formal foundation for handling and integrating EA information. This solution supports the collaboration of a large number of individuals based on a semantic representation (ontology) of the EA. The following sections describe the main components of the concept: (a) a semantic (web 2.0-oriented) collaboration tool to support EA information gathering and modeling; (b) an EA ontology to enable an integrated, formal, semantic representation and structuring of EA information.

Concept of a Semantic, Wiki-like Collaboration Environment for EA Management

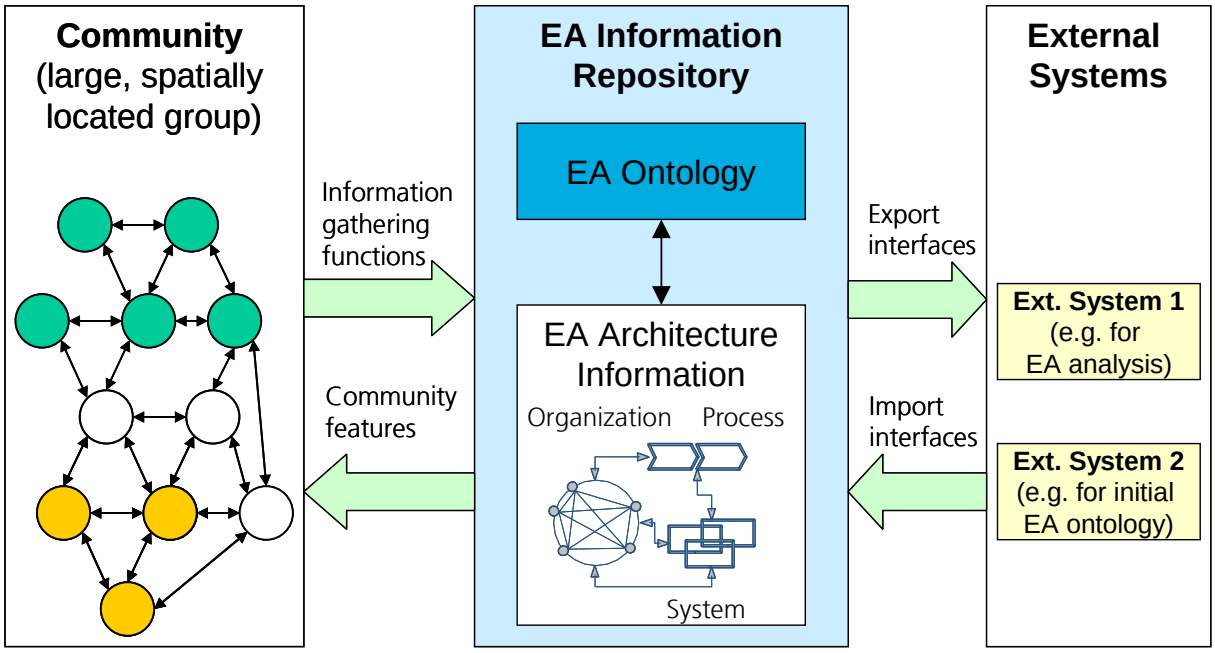
The semantic, wiki-like collaboration environment organizes the collaboration of a large number of spatially located individuals based on the semantic representation (ontology) of the EA. The concept is composed of three main components: (a) community features, (b) EA information repository, and (c) interfaces to external systems (figure 3).

The core component is the EA information repository. It enables the manipulation and management of semantic EA information (ontology). Furthermore, it serves as an integration space for all participants. All individuals involved in the EA design and development work on only one common, shared model of the EA (instead of each individual modeling his/her own model). This way EA development is not restricted to one partition of the EA (i.e. a subset of artifacts) which is relevant to only one domain. With the aid of the semantic collaboration tool they are able to model and document the EA with a standardized notation (ontology). It is essential that all individuals involved use the same tool to access the same repository and the same EA (ontology) data. This integration of the information gathering and modeling for the different artifacts of an EA (e.g. organizational goals, processes, software applications, etc.) enables a continuous, integrated design and development of the EA (bird’s eye view).

Another important component are the community features. There are mechanisms for community support which enable an informal, participative process of EA information gathering and modeling and ensure a high degree of quality and up-to-dateness of the EA information. We propose the concept of annotating these community features to each ontology element. Community features include mechanisms for feedback, review, discussion, rating, and negotiation. These are annotated to each item of the model data (ontology). This way communication about the process and the results of information gathering is focused on smaller items which enables efficient collaboration in a very large group.

As a third component, the semantic collaboration tool provides interfaces (adapters) for import and export of EA information from or to external systems. Thereby, the formal representation or notation of the EA (ontology) supports the seamless import/export. On one hand, EA ontology data is imported from a holistic EA model or uses data from existing specialized models to keep modeling efforts to a minimum. On the other hand, EA ontology data can be exported (e.g. for analysis or visualization) to enable reuse.

Figure 3: Components of a semantic, wiki-like collaboration environment for EA management



The functionality of the semantic collaboration tool allows users to modify the EA, create relations between EA items, and annotate communication to certain parts of the EA ontology. The aim is to minimize efforts for information gathering and maintenance and, therefore, to minimize communication and process costs. Most importantly, this functionality provides possibilities for fine-granular and intuitive gathering and editing of the EA ontology, e.g. EA classes and EA instances as well as their properties and relationships.

Concept of an Ontology Representing the EA (EA Ontology)

Ontology has been introduced as a key concept in informatics to facilitate and encompass access to domain knowledge in different application domains. Gruber has defined ontology as an "explicit specification of a conceptualization" (Gruber, 1993). Very often existing standards for ontology representation such as the Resource Description Framework (RDF) and the Web Ontology Language (OWL) are adopted. RDF is a simple graph-like format for describing metadata about resources (RDF, 2004) that are described using a Uniform Resource Identifier (URI). OWL is defined on top of RDF/RDFS and provides a standard ontology vocabulary for describing ontologies based on description logics (OWL, 2004).

A first attempt to represent an EA as ontology is the Enterprise Ontology (EO) (Uschold, 1998). The purpose of EO includes: (1) to guarantee smooth communication between participants to facilitate sharing the unified understanding about the enterprise model by providing necessary

and sufficient vocabulary, (2) to provide an infrastructure that is stable but at the same time adaptable to the change of understanding about and requirements to the enterprise model, (3) to augment interoperability of various application programs of an enterprise model by using EO as a mutual language (Interlingua) for information exchange. Typical terms (concepts) contained in this EO are: activity (e.g. activity specification, sub-activity, event, plan, process specification, capability, skill, resource), organization (e.g. person, machine, corporation, partner, organizational unit), strategy (e.g. purpose, objective, vision, mission, goal), marketing (e.g. sale, vendor, customer, product, market, competitor) and time (for example, time line, time interval). However, these concepts only cover the business (upper) layer of an EA.

For the EA application scenario, a conceptual structure specifying concepts and their relations might be useful to predetermine the initial structure of the information space (repository). Contrary to (semantic) wikis supporting the emergence of wiki content or knowledge structures (ontologies) out of existing wiki content (Völkel et al., 2006, Schaffert, 2006, Kiesel, 2006; Buffa et.al., 2006), this alternative proposal results in a semantic, wiki-like collaboration tool based on a predefined knowledge structure that supports the emergence of the knowledge structure (EA ontology) or the emergence of ontology data (EA information) out of the knowledge structure (EA ontology). Thus, the EA ontology provides a frame for its own development and for adding further ontology data (EA information) within a limited application scenario, e.g. business continuity planning (BCP), portfolio management (applications, partners, projects), evaluation of strategic options, IT service management.

The main purpose of the EA ontology is to supply the initial structure to the EA information space (repository) of the semantic, wiki-like collaboration environment enabling the gathering and documentation of EA information by the different groups involved (e.g. detailed process structures by business, detailed application architectures by architects, detailed software architectures and data flows by developers). Thereby, the EA ontology serves as a shared mental model to facilitate communication among the participants by providing a shared understanding of the EA under development and enforcing conceptual integrity. Instead of determining the collaborative process, only the goal ("the big picture") is roughly described by the EA ontology. This way, the EA ontology serves as a shared mental model of the EA to be developed, supports communication and provides orientation in a self-organized, participative collaboration process, and ensures convergence of the collaboration process towards a result to be achieved. In addition, the EA ontology also provides means for formalization. A more formalized EA allows validation and verification of the EA or other tool-supported analyses based on a formally defined semantic as well as a seamless import and export of external resources.

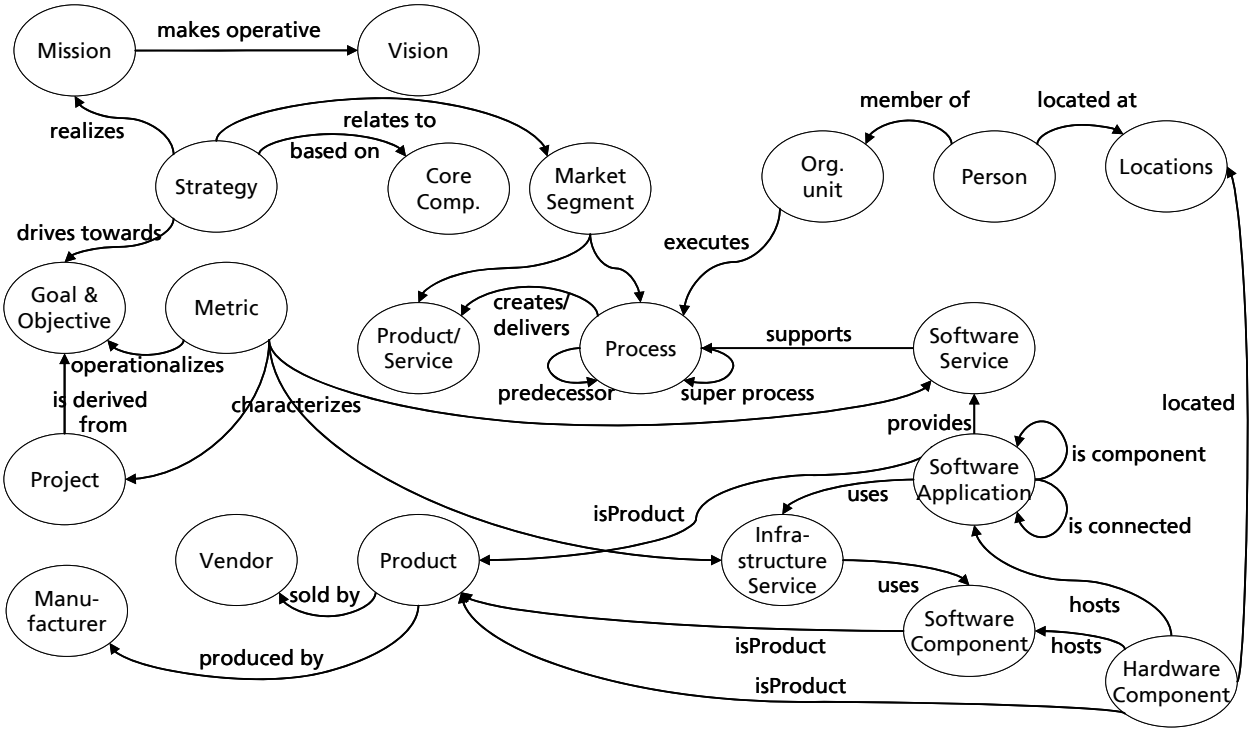
For this purpose the ontology has to include central layers and artifacts (concepts) of an EA (see figure 2). It consists of the relevant classes (persons, locations, products, etc.), their attributes (name, org. unit, position, location, room, etc. for a person), the associations between classes (persons and hardware components are located at one location, persons are members of organizational units, products are sold by vendors, etc.), and an additional glossary collecting specialized terms and their meanings.

In an EA every single artifact (e.g. process model, software architecture) can be decomposed into detailed models. Accordingly, the EA ontology decomposes artifacts into a hierarchy of artifacts

(class hierarchy). The example EA ontology in figure 5 shows a class hierarchy. Here, for example, the class “IT Infrastructure” contains the subclasses “Hardware Component” and “Software Component”, and “Computer” and “Network Devices” are subclasses of “Hardware Component”.

But, additionally, the EA ontology focuses on relationships between artifacts across all layers. For example, “Hardware Component” hosts “Software Application” which provides “Software Service” to support “Process” which is executed by an “Organizational Unit” (figure 4). This provides an integrated information model connecting the different layers of an EA and knowledge across multiple artifacts or layers of the EA that is required to support EA relevant decisions. Because of these relationships across layers and artifacts, EA ontology can better address business driven questions, e.g.: Which company products and services are affected if an application is outsourced? Which processes are affected if a system platform fails? Therefore, EA addresses strategic business issues and diminishes the gap between business and IT perspectives.

Figure 4: Enterprise Architecture Ontology



Each concept shown in figure 4 includes a class hierarchy of concepts with arbitrary relations to other concepts in the same or other class hierarchies. The prototype implementation in the next section shows an example for the concept “IT Infrastructure” with its direct subconcepts (figure 5). Other information displayed for a concept/class are its instances, object properties and data type properties.

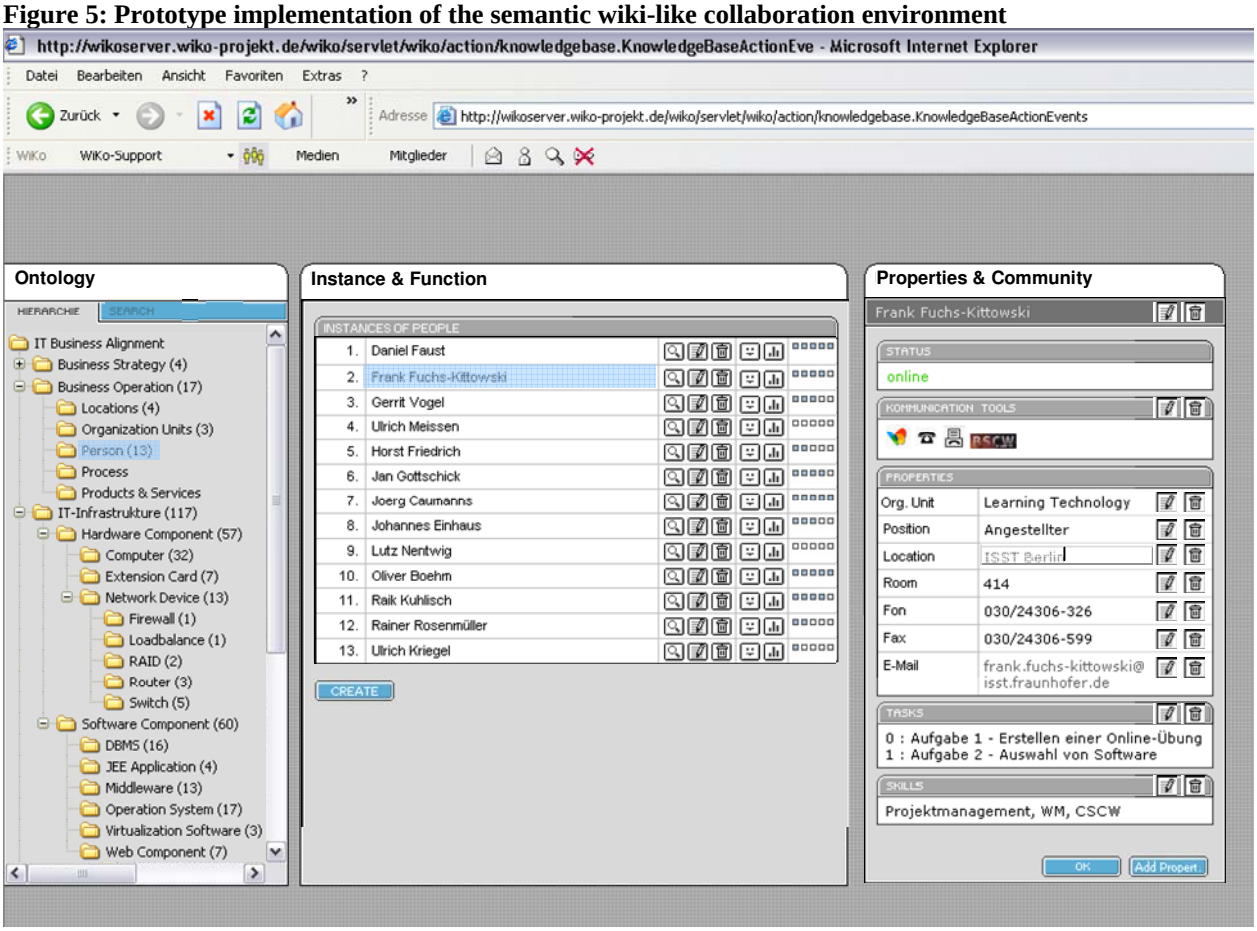
PROTOTYPE IMPLEMENTATION

This section presents the functionality and the architecture of a prototype implementation of the approach to a semantic, wiki-like collaboration tool for collaborative EA design. This implementation is based on the open source, semantic web application development framework pOWL (Auer, 2005) and is incorporated in the integrated knowledge and collaboration environment "WiKo" (German: Wissens- und Kooperationsplattform) (Fuchs-Kittowski et al., 2005) which also provides the relevant community functionality. WiKo incorporates collaborative knowledge work in an integrated collaboration environment with organizational knowledge work in an integrated organizational knowledge environment.

Functionality of the User Interface

The web-based user interface is consistently subdivided into three areas: (1) "Ontology" (orientation: navigation & search), "Instance & Function" (ontology content and functions), "Properties and Community" (instance properties and community features). Furthermore, a toolbar represents the menu for central WiKo functionality (figure 5).

Figure 5: Prototype implementation of the semantic wiki-like collaboration environment



Under the heading "Ontology" (on the left) orientation and finding EA information is supported by means of "navigation" and "search". The user gets an overview of ontologies available in the system. The class hierarchy of a selected ontology is presented. Via a context menu to each class

of the class hierarchy a new subclass or instance can be created, all existing instances can be listed, and the class description can be viewed, edited or deleted.

Under “Instance and Function” (center) the ontology data and functionality is presented according to the current navigation and search context. Upon selection of a class (or ontology) (on the left), the center area shows an overview of the instances. For each instance functionalities are available that are shown as a button on the right-hand side of the instance name. These functionalities enable the user to present the instance properties (), edit (), and delete instances (). In addition, each instance is provided with community functionality to support convergence in the collaborative EA development process. There are community functionalities for rating (), discussion (), and negotiation ().

Under “Properties and Community” (on the right) for each instance selected under “Instance & Function” (center) its available instance property functions (present, edit, delete) and its available community functionalities (rate, discuss, negotiate) are shown. Once the edit function of an instance was selected, the screen switches from the presentation mode (as shown in figure 5) to the edit mode to display an editable form (on the right) according to the class definition of the instance which supports editing all existing properties as well as adding new properties. Even in the presentation mode single properties can be edited by clicking on the “edit” button (). In this case, the value of the property can be changed or resources can be linked. If a community function is selected, the corresponding data and actions are provided. For example, in case of a negotiation, a new negotiation can be started or an existing negotiation can be participated in, e.g., vote for one of the available negotiation alternatives.

Experiences

The EA ontology and the semantic collaboration environment have been partly applied with two IT planning projects called “ISBJ” and “WIND Next Generation”. In these projects information about the IT infrastructure had to be gathered. Therefore, the EA ontology was incorporated into the semantic collaboration environment and was used as a set of vocabulary and a structure for information gathering.

It could be confirmed that EA ontology worked as a common vocabulary to lead participants to a common understanding about the EA model. However, the ontology had to be continuously extended according to the changing needs of the projects. Participants were faced with difficulties modifying the ontology and, therefore, the ontology had to be edited by EA ontology experts.

An important organizational issue was to find all the responsible data owners in the organization and to explain to them what information they should contribute to which part of the ontology. Some time and effort were necessary for this task.

Additionally, while searching and browsing the EA ontology supported understanding and analysis of the EA, participants had difficulties finding those parts of the ontology quickly which they wanted to contribute information to. Participants need more support to find or be aware of the relevant parts that they could be responsible for or should contribute to (e.g., role-based access, personalization).

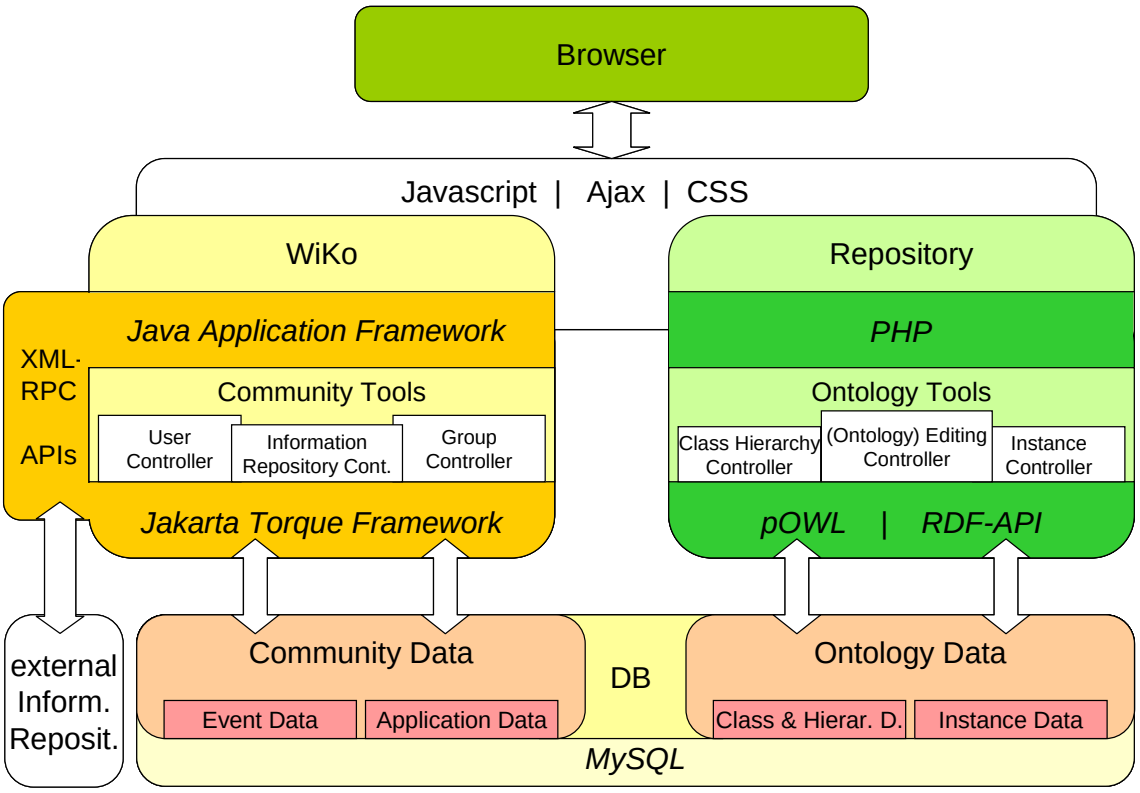
The possibilities for inline-editing small parts of an EA ontology resulted in smoother work overall.

The collaboration features contributed to the consensus building between the different stakeholders. But initially, participants had to be motivated to use the community features annotated to each ontology element (e.g., discussion about an instance).

Architecture

The architecture of the semantic, wiki-like collaboration environment is designed as a web-based three-tier architecture (figure 6). For the purpose of integrating the repository and community functions, the architecture incorporates pOWL and WiKo components. This integration occurs on the view tier.

Figure 6: Architecture of the semantic, wiki-like collaboration environment



The repository includes two main components: “Class Hierarchy Controller” and “Instance Controller” and is mainly implemented with PHP and based on pOWL. A third component is the “(Ontology) Editing Controller” which controls the manipulation of classes (concepts of the ontology) using “Class Hierarchy Controller” as well as the creation or augmentation of instances using “Instance Controller”.

The community functions are implemented with Java and JSP and are based on WiKo which consists of three main components: The “User Controller” tracks all activities of the user

(including its online status), the “Group Controller” manages the group activities, and the “Information Repository Controller” ensures the connections to external information repositories.

Both parts of the architecture’s application layer use (on the data layer) the same database with separate data spaces for each part.

Summary and Conclusion

We presented the concept and implementation of a novel semantic collaboration tool that supports a participative approach of collaborative gathering of EA information. Popular web 2.0 concepts for participation and community support are integrated with semantic web methods for semantic knowledge representation resulting in the effective support of gathering and documenting EA information by a large group.

This approach to collaborative EA information gathering and development has – among others – the following benefits: (a) It builds on the general advantages of web 2.0 technologies that support collaborative settings of a large number of individuals, thus providing a scalable means for the development of an EA. (b) It integrates different groups of individuals involved in the information gathering and EA development process. The (ontology) repository provides an integration space. EA information and their relationships previously gathered and maintained separately are now collected, integrated, and managed in a central location. (c) The formal representation (ontology) of the EA supports focusing on the relationships between EA artifacts, a better searching and browsing of the EA elements, ensures semantic consistency, enhanced analysis of the EA and the import/export of EA information from/to external resources.

The underlying technologies and concepts of web 2.0 are still in an early stage of maturity. Therefore, statements still cannot be made about the acceptance of the approach. Currently, an implementation and evaluation of our approach is realized in cooperation with a German logistics service provider.

References

Auer, S. (2005). Powl - A Web Based Platform for Collaborative Semantic Web Development. In *Proceedings of 1st Workshop Scripting for the Semantic Web (SFSW'05)*, Hersonissos, Greece. www.CEUR-WS.org/Vol-135/paper9.pdf.

Aziz, S., Obitz, T., Modi, R., & Sarkar, S. (2005). *Enterprise Architecture: A Governance Framework - Part I: Embedding Architecture into the Organization*. Technical report. Infosys Technologies Ltd.

Aziz, S., Obitz, T., Modi, R., & Sarkar, S. (2006). *Enterprise Architecture: A Governance Framework - Part II: Making Enterprise Architecture Work within the Organization*. Technical report. Infosys Technologies Ltd.

Bernard, S.A. (2005). *An Introduction to Enterprise Architecture.* 2nd Edition. Bloomington, IN: Authorhouse.

Bittler, R.S., & Kreizmann, G. (2005). *Gartner Enterprise Architecture Process - Evolution 2005*. Stamford, CT: Gartner Inc.

Bubenko, J.A.j., Persson, A., & Stirna, J. (2001). *User Guide of the Knowledge Management Approach Using Enterprise Knowledge Patterns.* Project report, Hypermedia and Pattern Based Knowledge Management for Smart Organisations, project no. IST-2000-28401. Stockholm, Sweden: Department of Computer and Systems Sciences, Royal Institute of Technology.

Bubenko, J.A.j., Stirna, J., & Brash, D. (1997). *EKD User Guide*. Technical report. Stockholm, Sweden: Department of Computer and Systems Sciences, Royal Institute of Technology.

Bucher, T., Fischer, R., Kurpjuweit, S., & Winter, R. (2006). Analysis and Application Scenarios of Enterprise Architecture - An Exploratory Study. In *Proceedings of the EDOC Workshop on Trends in Enterprise Architecture Research TEAR 2006*, Tenth IEEE International EDOC Conference EDOC 2006 (p. 28). Los Alamitos, CA, USA: IEEE Computer Society.

Buffa, M., Crova, G., Gandon, F., Lecompte, C., & Passeron, J. (2006). SweetWiki - Semantic Web Enabled Technologies in Wiki. In M. Völkl & S. Schaffert (eds.), *Proceedings of First Workshop on Semantic Wikis - From Wiki to Semantic at the 3rd Annual European Semantic Web Conference* ESWC (pp. 74-88), CEUR Workshop Proceedings, Vol-206, http://CEUR-WS.org/Vol-206/.

CIO (Chief Information Officer) Council (2001). *A Practical Guide to Federal Enterprise Architecture*. Technical report. Springfield, VA: Federal CIO Council.

DoDAF Working Goup (2007). DoD Architecture Framework - Volume I: Definitions and Guidlines. Version 1.5, 23 April 2007. http://www.defenselink.mil/cio-nii/docs/DoDAF_Volume_I.pdf.

F3 (1994). *F3 Reference Manual*. Technical report, ESPRIT III Project 6612 Deliverable. Stockholm, Sweden: F3-Consortium.

Fuchs-Kittowski, F., Faust, D., Loroff, C., & Reuter, P. (2005). WiKo- Eine integrierte Wissens- und Kooperations-Plattform. *I-Com*, 4(1), 12-19.

Gruber, T.R. (1993). A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5(2), 199-220.

IFIP–IFAC (1999). *GERAM - Generalised Enterprise Reference Architecture and Methodology*. Version 1.6.3, IFIP–IFAC Task Force on Architectures for Enterprise Integration. http://www.cit.gu.edu.au/~bernus/taskforce/geram/versions/geram1-6-3.

Janssen, M., & Hjort-Madsen, K. (2007). Analyzing Enterprise Architecture in National Governments - The cases of Denmark and the Netherlands. In *Proceedings of the 40th Hawaii International International Conference on Systems Science* (HICSS-40 2007). Waikoloa, Big Island, HI, USA: IEEE Computer Society.

Jonkers, H., Lankhorst, M., ter Doest, H., Arbab, F., Bosma, H., & Wieringa, R.J. (2006). Enterprise Architecture: Management tool and blueprint for the organisation. *Information Systems Frontier*, 8(2), 63-66.

Kaisler, S.H., Amour, F., & Valivullah, M. (2005). Enterprise Architecting - Critical Problems. In *Proceedings of the 38th Hawaii International Conference on System Sciences* (HICSS-38 2005), Big Island, HI, USA: IEEE Computer Society.

Kiesel, M. (2006). Kaukolu - Hub of the Semantic Corporate Intranet. In M. Völkl & S. Schaffert (eds.), *Proceedings of First Workshop on Semantic Wikis - From Wiki to Semantic at the 3rd Annual European Semantic Web Conference* ESWC (pp. 31-42), CEUR Workshop Proceedings, Vol-206, http://CEUR-WS.org/Vol-206/.

Lankhorst, M. (2004). Enterprise architecture modelling - the issue of integration. *Advanced Engineering Informatics*, 18(4), 205-216.

Lankhorst, M. (2005). *Enterprise Architecture at Work - Modelling, Communication and Analysis.* Berlin et al.: Springer.

Loucopoulos, P., Kavakli, V., Prekas, N., Rolland, C., Grosz, G., & Nurcan, S. (1997). *Using the EKD Approach - The Modelling Component*. Technical report. Manchester, UK: UMIST.

Narman, P., Johnson, P., & Nordstrom, L. (2007). Enterprise Architecture - A Framework Supporting System Quality Analysis. In *Proceedings of the 11th IEEE International Enterprise Distributed Object Computing Conference EDOC 2007* (pp. 130-141). Washington, DC, USA: IEEE Computer Society.

Noy, N., Grosso,W., & Musen, M. (2000). Knowledge-Acquisition Interfaces for Domain Experts - An Empirical Evaluation of Protégé-2000. In *Proceedings of the Twelfth International Conference on Software Engineering and Knowledge Engineering* (SEKE2000). Chicago, IL: Knowledge Systems Institute.

Open Group (2003): *TOGAF - The Open Group Architecture Framework* (Version 8.1 “Enterprise Edition”). San Francisco, CA, USA: The Open Group.

OWL (2004). Web Ontology Language (OWL). W3C.

Persson, A. (2000). Investigating the influence of situational factors on Participative Enterprise Modelling - making a case for a qualitative research approach. In *Proceedings of the Conference on Advanced Information Systems Engineering* (CAiSE'00), Stockholm, Sweden, June 5th-6th 2000, http://page.mi.fu-berlin.de/hinze/caise00_DC/papers.html.

Persson, A., & Stirna, J. (2001). An explorative study into the influence of business goals on the practical use of Enterprise Modelling methods and tools. In *Proceedings of the 10th International Conference on Information Systems Development* ISD 2001 (pp. 465-468). London, GB: Kluwer.

Persson, A., Stirna, J., Dulle, H., Hatzenbichler, G., & Strutz, G. (2003). Introducing a Pattern Based Knowledge Management Approach - the Verbundplan Case. In *Proceedings of the 4th International Workshop on Theory and Applications of Knowledge Management* (TAKMA 2003), 14th International Workshop on Database and Expert Systems Applications (DEXA 2003). Prague, Czech Republic: IEEE Computer Society.

RDF (2004). *Resource Description Framework* (RDF). W3C.

Rood, M.A. (1994). Enterprise Architecture - Definition, Content, and Utility. In *Proceedings of the IEEE Third Workshop on Enabling Technologies, Infrastructure for Collaborative Enterprises* (pp. 106-111). Morgantown, WV, USA: IEEE Computer Society.

Ross, J.W., Weill, P., & Robertson, D.C. (2006). *Enterprise Architecture as Strategy - Creating a Foundation for Business Execution.* Boston, MA: Harvard Business School Press.

Schaffert, S. (2006). *IkeWiki - A Semantic Wiki for Collaborative Knowledge Management*. Technical report, Salzburg, Austria: Salzburg Research, http://ikewiki.salzburgresearch.at/.

Schekkerman, J. (2004). *How to Survive in the Jungle of Enterprise Architecture Frameworks - Creating or Choosing an Enterprise Architecture Framework.* 2nd edition, Victoria, British Columbia: Trafford Publishing.

Schekkerman, J. (2006). *Extended Enterprise Architecture Framework (E2AF) - Essentials Guide v1.5*. Amersfoort, Netherlands: Institute for Enterprise Architecture Developments.

Sebis (2005). *Enterprise Architecture Management Tool Survey 2005*. Report. München: Technical University München, Chair for Informatics 19 (sebis).

Stirna, J., Mikelsons, J., Kalnins, J.R., Kapenieks, A., Kazakovs, M., Vanaga, I., Sinka, A., Persson, A., & Kaindl, H. (2002). *Trial Application in the Riga City Council*. Technical report, deliverable D6, IST Programme project Hypermedia and Pattern Based Knowledge Management for Smart Organisations, project no. IST-2000-28401. Riga, Latvia: Riga City Council.

TrouxMetis (2006). *Metis Enterprise - Metamodeling and Modeling with Metis Enterprise Architecture Framework (MEAF)* v5.2. Troux Technologies Inc.

Uschold, M., King, M., Moralee, S., & Zorgios, Y. (1998). The Enterprise Ontology. *Knowledge Engineering Review* (Special Issue on Putting Ontologies to Use), 13(2), http://www.aiai.ed.ac.uk/project/enterprise/enterprise/ontology.html.

Völkel, M., Krötzsch, M., Vrandecic, D., Haller, H., & Studer, R. (2006). Semantic Wikipedia. In *Proceedings of the 15th international conference on World Wide Web* WWW 2006 (pp. 585-594). New York, NY: ACM Press.

Wagter, R., von den Berg, M., & Luijpers, J. (2005). *Dynamic Enterprise Architecture - How to Make It Work*. Hoboken, NJ: John Wiley & Sons.

Winter, R., & Fischer, R. (2006). Essential Layers, Artifacts, and Dependencies of Enterprise Architecture. In *Proceedings of the EDOC Workshop on Trends in Enterprise Architecture Research TEAR 2006*, Tenth IEEE International EDOC Conference EDOC 2006 (p. 30). Washington, DC, USA: IEEE Computer Society.