Evolving Enterprise Architectures for Digital Transformations

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Abstract: The digital transformation of our society changes the way we live, work, learn, communicate, and collaborate. This disruptive change interacts with all information processes and systems that are important business enablers for the digital transformation since years. The Internet of Things, Social Collaboration Systems for Adaptive Case Management, Mobility Systems and Services for Big Data in Cloud Services environments are emerging to support intelligent user-centered and social community systems. They will shape future trends of business innovation and the next wave of information and communication technology. Biological metaphors of living and adaptable ecosystems provide the logical foundation for self-optimizing and resilient run-time environments for intelligent business services and related distributed information systems with service-oriented enterprise architectures. The present research investigates mechanisms for flexible adaptation and evolution of Digital Enterprise Architectures in the context of integrated synergistic disciplines like distributed service-oriented Architectures and Information Systems, EAM - Enterprise Architecture and Management, Metamodeling, Semantic Technologies, Web Services, Cloud Computing and Big Data technology. Our aim is to support flexibility and agile transformations for both business domains and related enterprise systems through adaptation and evolution of digital enterprise architectures. The present research paper investigates digital transformations of business and IT and integrates fundamental mappings between adaptable digital enterprise architectures and service-oriented information systems.

Keywords: Digital Transformation, Digital Enterprise Architecture, Service-oriented Information Systems, Metamodel Integration Method, Adaptable Services and Systems

1 Introduction

Information, data and knowledge are fundamental concepts of our everyday activities. Social networks, smart portable devices, and intelligent cars, represent only a few instances of a pervasive, information-driven vision [PF91] for the next wave of the digital economy and better-aligned information systems. Currently some major trends for digital enterprise transformation are investigated by [Le14]:

1. Digitization of products and services: products and services are enriched with value-added services or are completely digitized,

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2. Context-sensitive value creation: though popularity of mobile devices location contexts are used more frequently and enable on demand customized solutions,
3. Consumerization of IT: One of the challenges is the safe integration of mobile devices into a managed enterprise architecture for both business and IT,
4. Digitization of work: Today it is much easier to work together over large distances, which allows often an uncomplicated outsourcing of business tasks,
5. Digitization of business models: Businesses need to adapt and have to rethink their business models to develop innovative business models according to employees' current skills and competencies.

Enterprise Architecture Management [Zi11] and Services Computing is the approach of choice to organize, build and utilize distributed capabilities for Digital Transformation [Ai11]. They provide flexibility and agility in business and IT systems. The development of such applications integrates Web and REST Services, Cloud Computing and Big Data management, among other frameworks and methods for architectural semantic support. Today's information systems span a broad range of domains including: intelligent mobility systems and services, intelligent energy support systems, smart personal health-care systems and services, intelligent transportation and logistics services, smart environmental systems and services, intelligent systems and software engineering, intelligent engineering and manufacturing.

Platform Ecosystems [Ti13] like Amazon, Google, Apple, and Facebook are integrated with enterprise systems and have to support flexible transformation patterns for adaptable Digital Enterprise Architecture. In our understanding of the vision - adaptable and evolutionary information systems and Enterprise Architectures are self-optimizing systems, which have self-healing properties of distributed service-oriented environments with evolutionary service-oriented Enterprise Architectures. The technological and business architectural impact of Digital Transformation has multiple aspects, which directly affect adaptable Digital Enterprise Architectures and their supported systems. Smart companies are extending their capabilities continuously to manage their changing Business Operating Model [Ro06] by developing and managing Enterprise Architectures as the architectural part of a changing IT Governance [WR04].

In our current research we are extending our first version of the Enterprise Services Architecture Reference Cube (ESARC) [Zi11], [Zi13b], and [SM13] by mechanisms for architectural integration and evolution to support adaptable information systems and architectural transformations for transformable business models. ESARC is an integral Service-oriented Enterprise Architecture classification framework, which sets a conceptual baseline for analyzed Enterprise Architecture models. ESARC makes it possible to verify, define and track the improvement path of different business and IT changes considering alternative business operating models, business functions and business processes, enterprise services and systems, their architectures and related cloud-enabled technologies, like infrastructures and platforms as a service. We are interested in a discussion about our approach of evolving Enterprise Architecture to support Digital Transformations. The novelty in our current research about digital enterprise Architectures comprises new aspects for architectural evolution and integration methods as an instrument to guide digital transformation endeavors.

The following Section 2 describes our research platform for Digital Enterprise Architecture, which is a starting point of our mapping approach and scope for agile and adaptable information systems. Section 3 extends our previous Architecture Metamodel Integration Method and covers the seeding research for agile adaptable and transformable enterprise architectures and systems. Finally, we summarize in Section 4 our research findings, our ongoing validations in academic and practical environments and our future research plans.

2 Digital Enterprise Architecture

The discipline of Enterprise Architecture Management (EAM) [Jo14], [La13], [Be12] defines today with frameworks, standards [To11] and [Ar12], tools and practical expertise a quite large set of different views and perspectives. These abundance of ingredients for EAM leads in practice often to a "heavy EA" approach, which is not always feasible enough to support practical initiatives of software development and maintenance within a living and changing business and system environment. We argue in this paper that a new refocused service-oriented EA approach should be both holistic [Zi11] and [Zi13b] and easily adaptable [Zi14] for practical support of software evolution and transformation of information systems in growing business and IT environments, which are based on new technologies like social software, big data, services & cloud computing, mobility platforms and systems, security systems, and semantics support.

We have developed our integration approach in [Zi13a] to unify and integrate most valuable parts of existing EA frameworks and metamodels from theory and practice. Our approach, which is based on correlation matrixes, is economically focused and sparingly driven by preventing us to integrate every existing or unusable feature. According to [Bu11] we are building the conceptualization of EA in 4 steps – from stakeholders' needs, to the concerns of stakeholders, then the extraction of concepts, and last but not least the definition of relationships for new tailored EA models. In our current research we are using the BEAMS Modeling Method [Sc11] and [Sc11] to model systematically the conceptual base for new tailored functions of our reference enterprise architecture for platform and application ecosystems.

The BEAMS methodology contains an activity method framework [Sc11] with building blocks for supporting continuous and self maintaining management functions for EA by processes like: develop & describe, communicate & enact, analyze and evaluate, as well as configure and adapt. Additionally to the mentioned Method Building Blocks BEAMS provides through [Sc11] important Language Building Blocks to describe the metamodel of EA information. The Information Building Blocks from [Sc11] give support for the syntax of the EA modeling language defining necessary information concepts and their relationships, while the Viewpoint Building Blocks provide the graphical notation for the EA modeling language. We are additionally applying the modeling of the supply and demand chains for architectural information as in [Bu11].

ESARC – Enterprise Services Architecture Reference Cube [Zi11], [Zi13b] (see Fig. 1) is our architectural reference model for an extended view on evolved digital enterprise architectures. ESARC is more specific than existing architectural standards of EAM – Enterprise Architecture Management [To11] and [Ar12] and extends these architecture standards for services and cloud computing. ESARC provides a holistic classification model with eight integral architectural domains. These architectural domains cover specific architectural viewpoint descriptions [Iso11] and [EH09] in accordance to the orthogonal dimensions of both architectural layers and architectural aspects [Ar12], [La13], and [Ia15]. ESARC abstracts from a concrete business scenario or technologies, but it is applicable for concrete architectural instantiations to support digital transformations. The Open Group Architecture Framework [To11] provides the basic blueprint and structure for our extended service-oriented enterprise architecture domains (Fig. 1) of ESARC [Zi11], [Zi14] like: Architecture Governance, Architecture Management, Business and Information Architecture, Information Systems Architecture, Technology Architecture, Operation Architecture, and Cloud Services Architecture. ESARC provides a coherent aid for examination, comparison, classification, quality evaluation and optimization of architectures.

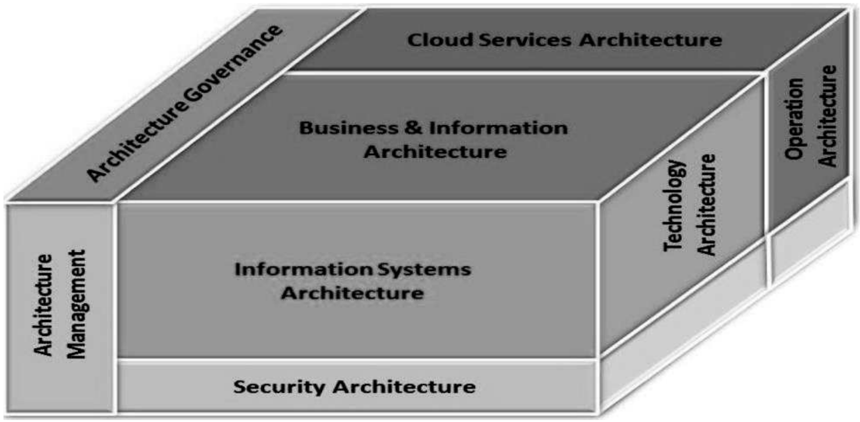

Fig. 1. Enterprise Services Architecture Reference Cube [Zi11], [Zi14]

The OASIS Reference Model for Service Oriented Architecture defines an abstract framework, which guides our concept of reference architectures, as in [BCK13], [Ke06], [Es08], and [Og11]. Reference models are conceptual models of a functional decomposition of model elements together with the data flows between them. The Reference Model for Service Oriented Architecture of OASIS [Og11a] defines fundamental generic elements and their relationships of a service-oriented architecture.

Architecture Governance, as in [WR04] and [Ro06] defines and maintains the Architecture Governance Cycle. It sets the abstract governance frame for concrete architecture activities within the enterprise or a product line or ecosystem development and specifies the following management activities: plan, define, enable, measure, and control. The second aim of Architecture Governance is to foster the business-IT alignment and define rules for architecture compliance related to internal and external standards. The integration of business-IT alignment is very important to support the business goals. Therefore, the standing of the IT department can be improved. In the past, IT departments were defined as a collection of risks as well as a cost driver. Enterprise and software architects are acting on a sophisticated connection path emanating from business and IT strategy to the architecture landscape realization for interrelated business domains, applications and technologies.

The Business and Information Reference Architecture - BIRA [Zi11] [Zi14] provides, for instance, a single source and comprehensive repository of knowledge from which concrete corporate initiatives will evolve and link. This knowledge is model-based and defines an integrated enterprise business model, which includes organization models and business processes. The BIRA opens a connection to IT infrastructures, IT systems, and software as well as security architectures. The BIRA confers the basis for business-IT alignment and therefore models the business and information strategy, the organization, and main business demands as well as requirements for information systems, such as key business processes, business rules, business products, services, and related business control information.

The Information Systems Reference Architecture – ISRA [Zi11] [Zi14] is the application reference architecture and contains main application-specific service types, defining their relationship by a layer model of building services. The core functionality of domain services is linked with application interaction services and with the business processes of the customer organization. In our research we are considering the standard reference models [Ke06] and reference architectures [Es08] and [Og11a] for services computing. We have differentiated a consistent set of layered service types (Fig. 2).

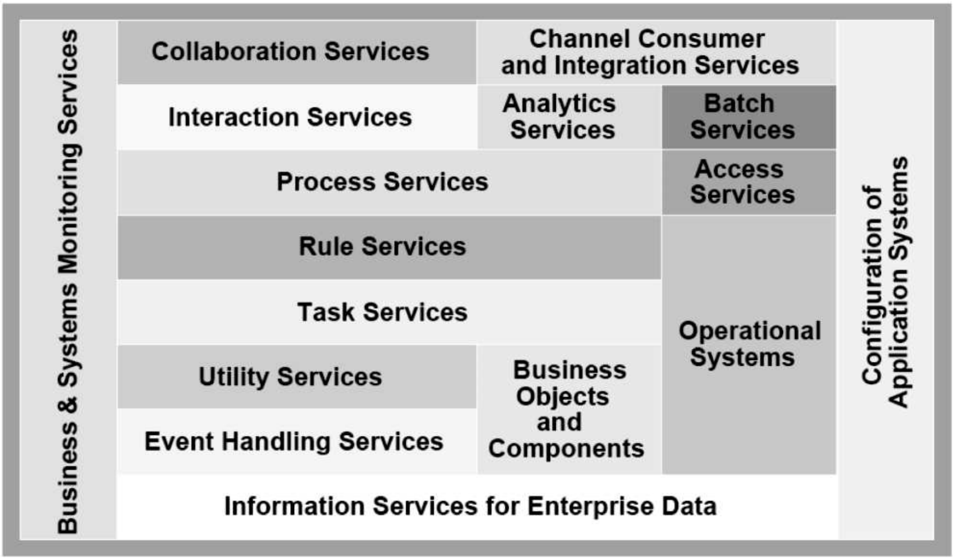

Fig. 2. Information Systems Reference Architecture

The information services for enterprise data can be thought of as data centric components [Zi13b] and [Zi14], providing access to the persistent entities of the business process. Close to the access of enterprise data are context management services, which are provided by the technology architecture: error compensation or exception handling, seeking for alternative information, transaction processing of both atomic and long running and prevalent distributed transactions. Process services [Zi11] [Zi14] are long running services, which compose task services and information services into workflows, to implement the procedural logic of business processes. Process services can activate rule services, to swap out a part of the potentially unstable gateway-related causal decision logic. Process services are activated by interaction services or by specific diagnostic service or process monitoring services.

Cloud architectures are still under development and have not reached so far their full potential in integrating EAM with Services Computing and Cloud Computing [Li11]. Integrating and exploring these three architectural dimensions into consistent reference architectures is a central part of our current research. The Cloud Services Reference Architecture provides a reference-model-based synthesis of current standards and reference architectures from [Li11], [Be11a], [CSA09]. Furthermore, Cloud Computing based architectures can enable Big Data analytics for small and medium-sized enterprises and organizations [BG14]. The NIST Cloud Computing Reference Architecture [Li11] defines the Conceptual Reference Model for Cloud Computing. Some standard extensions for Cloud Reference Architectures, like [Be11], [CSA09] provide practical additions for supporting more directly modern business architectures by BPaaS – Business Process as a Service and giving a direct link to Service-oriented Enterprise Architectures. The IBM Cloud Computing Reference Architecture provides in [Be11a] additionally to the standardization of NIST best-of-industry knowledge and cloud product specifications by integrating the NIST standard with own technology stacks, middleware, as well as service-oriented programming and runtime platforms. The Service-Oriented Cloud Computing (SOCCI) Framework [Og11b] is an enabling framework for an integrated set of cloud infrastructure components. Basically it is the synergy of service-oriented and cloud architectures by means of a consistent As-a-Service-Mechanism for all types of cloud services.

3 Architectural Adaptability and Evolution

We have developed the architectural evolution approach to integrate and adapt valuable parts of existing EA frameworks and metamodels from theory and practice [Zi13a]. Additionally to a new building mechanism for dynamically extending core metamodels we see a chance to integrate small decentralized mini-metamodels, models and data of architectural descriptions coming from small devices and new decentralized architectural element, which traditionally are not covert by enterprise architecture environments. Our focused model integration approach is based on special correlation matrixes (Fig. 3) to identify similarities between analyzed model elements from different provenience and integrate them according their most valuable contribution for an integrated model. According to [Bu11] we are building the conceptualization of EA in 4 steps – from stakeholders' needs, to the concerns of stakeholders, then the extraction of stakeholder relevant concepts, and last but not least the definition of relationships for new tailored architectural metamodels.

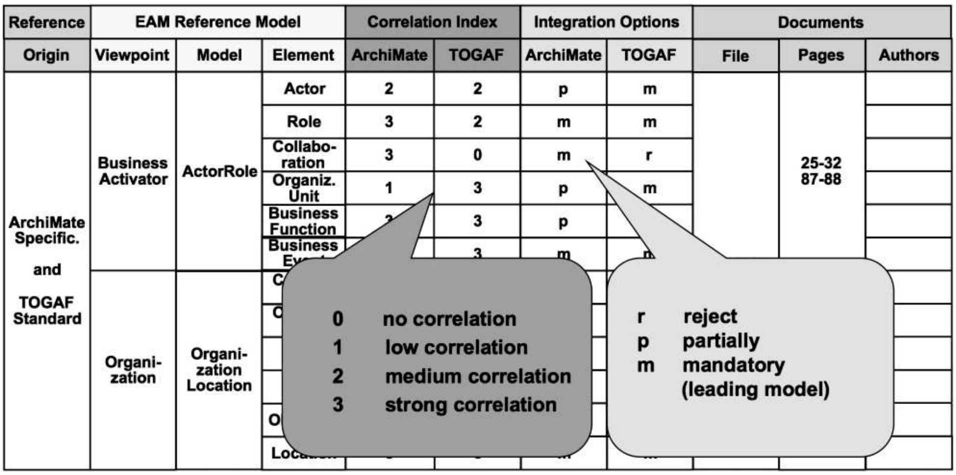

Fig. 3. Correlation Analysis and Integration Matrix

First we analyze and transform given architecture resources with concept maps and extract their coarse-grained aspects in a standard way [Zi13a] by delimiting architecture viewpoints [La13], [Iso11], architecture models [Ia15], their elements, and illustrating these models by a typical example. Architecture viewpoints are representing and grouping conceptual business and technology functions regardless of their implementation resources like people, processes, information, systems, or technologies. They extend these information by additional aspects like quality criteria, service levels, KPI, costs, risks, compliance criteria a. o. We have adopted modeling concepts from ISO/IEC 42010 [Iso11], [EH09] like Architecture Description, Viewpoint, View, and Model. Architectural metamodels are composed of their elements and relationships, and are represented by architecture diagrams.

We are extending architecture metamodels as an abstraction for architectural elements and relate them to architectural ontologies [Zi13a], [An13]. Ontologies are a base for semantic modeling of digital enterprise architectures in a most flexible way. As mentioned in this section, integration of enterprise architectural elements is a complex task, which is today mainly supported by human effort and integration methodologies, and only additionally by some challenging federated approaches [Fa12], [Tr15] for automated Enterprise Architecture model maintenance. We believe that a part of this manual integration could be automated or supported by architectural cockpits, if we better understand the analysis approaches [BMS09] and collaborative architectural decision mechanisms [Be12], [JE07], [JS14], and [JSZ15] for easy adaptable digital enterprise architectures as a base for the digital business transformation.

We have adopted an agile manageable spectrum of multi-attribute analysis metamodels and related architectural viewpoints from [Jo14] to support adaptable enterprise architectures: application modifiability, data accuracy, application usage, service availability, interoperability, cost, and utility. We have extracted the idea of digital ecosystems from [Ti13] and linked this with main strategic drivers for system development and their evolution. Core concepts of ecosystem's enterprise architectures are based in our approach on specific microarchitectures, which are placed in the context of Internet systems. The preferred mechanisms for modularization rely on decoupling and on interface standardization. Architecture governance models show the way to achieve adaptable ecosystems and to orchestrate the platform evolution.

The potential value of EA for SMEs [BG14] involves benefits like: agility to adjust ecosystems to changing environments, strategy planning and decision making, continuous business/IT alignment, management of complexity, integration of business processes, unify and integrate data and link with external partners, and achieve more value for IT. The focus of the ADaPPT [Sh11] EA approach is on primarily aligning four strategic EA domain elements: people, processes, data, and technologies.

We are currently integrating the perspectives of agile software models [He06], [Sa10] for an adaptable enterprise architecture management, and extend the agility perspective for EA in SMEs with aspects of Data Consistency and Big Data [Be13] for EAM. Additionally to the state of science we are currently analyzing and integrating EAM capability models from both industrial partners and from EA tools.

From the point of view of modeling adaptive EA metamodels we got inspirations from the Adaptive Object-Model Architectural Style, promoted by [Yo02] to enable flexibility and run-time system configuration. Business rules are explicitly represented and stored outside of the program code. The power of this approach is that business architects can flexibly and easily configure the adaptive object model at runtime. Patterns of Object-Oriented Meta-Architectures from [Fe10] enables reflective architectures, which are able to inspect and dynamically adapt their structure and behavior at run time. Three core patterns can be located in most object-oriented meta-architectures: Everything is a Thing, Closing the Roof, and Bootstrapping.

Adaptation drives the survival [Ti13], [He04], [Be11b] of enterprise architectures [Ha10], platforms and application ecosystems. Adapting rapidly to new technology and market contexts improves the fitness of adaptive ecosystems. Volatile technologies and markets typically drive the evolution of ecosystems. Also we have to consider internal factors. Most important for supporting the evolution of ecosystems is the systematic architecture-governance alignment. Both are critical factors, which affect the ecosystem-wide motivation and the ability to innovate ecosystem structures and change processes. The alignment of Architecture-Governance shapes resiliency, scalability and composability of components and services for distributed information systems.

4 Conclusion and Future Work

In this paper, we have introduced a new perspective for adaptable enterprise architectures, which is model-based and relies on main EA standards, technologies and agile business models. Decision support for EA should be based on fundamental EA analytics and profound EA models and accurate EA data, showing main dependencies and impacts for practical interventions on business and IT. EA knowledge at the level of different stakeholders is still quite poor and should be part of our attention and support by knowledge-based systems and special knowledge dissemination and certification programs.

We have developed a metamodel-based EA model extraction and integration approach for enterprise architecture viewpoints, models, standards, frameworks and tools for EAM towards consistent semantic-supported service-oriented reference enterprise architectures in cloud environments. The presented architectural classification and integration approach supports new architectural integration aspects for the Internet of Things and other small or mobile environments as well. Our goal is to be able to better support architecture development, assessments, architecture diagnostics, monitoring with decision support, and optimization of the business, information systems, and technologies. We intend to provide a unified and consistent ontology-based EAM-methodology for the architecture management models of relevant information resources, especially for service-oriented and cloud computing systems. Today we additionally observe companies adopting a three level architecture: On the basic level the classic systems of records, on a further level the systems of differentiation, and at the third level new IT opportunities for the systems of innovation. Expanding the classical EAM agenda thru ontology support with business rules and metamodel updating we see the chance for future work and research.

We contribute to the current IS literature by introducing this new perspective for adaptable digital enterprise architectures. EA managers can benefit from new knowledge about adaptable enterprise architectures and can use it for decision support and can reduce operational risks. Some limitations (e.g. use and adoption in different sectors) must be considered. Future research can adopt and evaluate our results for EAM and can take a look at the use in different industry sectors.

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