A Systematic Review on Service-Oriented Reference Models and Service-Oriented Reference Architectures

Lucas Bueno Ruas de Oliveira
Elisa Yumi Nakagawa

Abstract

Service-Oriented Architecture (SOA) has received increasing attention by providing low coupling, reuse, productivity, and a better understanding of the business domain. However, there are still challenges in creating quality solutions using services. In this context, based on SOA, reference models and reference architectures have been proposed to support the understanding, development, and standardization in the development of service-oriented systems. Considering the relevance of SOA, as well as the lack of a complete panorama about these models and architectures, this paper aims at presenting a detailed and analytical view about the establishment and use of these models and architectures. For this, we conducted a systematic review, which is a technique coming from Evidence-Based Software Engineering. As main results, we observed a recent increase in the number of work regarding reference models and reference architectures based on SOA, including models and architectures for different domains. Furthermore, based on the presented view, we identified interesting and important perspectives for future research.

Contents

List of Figures

List of Tables

Chapter

1

Introduction

SOA has arisen as a new architectural style to develop software systems. It has been recently focus of considerable attention of the academy and industry. In SOA, software functionalities are packaged in independent, self-contained and well-defined modules, called services, that are the basis to compose more complex service-oriented systems. SOA intends to contribute with low coupling systems and, as a consequence, it can promote reuse and productivity in software development (Papazoglou et al., 2008). In this perspective, there are recent examples of use of SOA in different domains (Costagliola et al., 2008; Hemalatha et al., 2008; Zirpins e Emmerich, 2008). However, in spite of the relevance of SOA, there is still challenges to create efficient solutions using this architectural style (Arsanjani et al., 2007).

In another perspective, Software Architecture has received increasing attention as an important research area of Software Engineering. According to Shaw and Clements (Shaw e Clements, 2006), software architectures will attain the status of all truly successful discipline. Besides that, software architectures play a major role in determining system quality, since they form the backbone to any successful software-intensive system. In this context, reference models and reference architectures have emerged as elements that aim at facilitating and systematizing the development of software systems. In this work, we have adopted reference model as an abstract framework that presents a minimal set of unifying concepts, axioms and relationships within a particular problem domain, independently of specific standards, technologies, implementations, or other concrete details

(OASIS, 2006). Otherwise, the reference architecture aggregates knowledge of a domain, identifying abstract solutions of a problem and promoting reuse of design expertise by achieving solid, well-recognized understanding of a specific domain. In other words, while reference model is usually in a higher abstraction level, reference architecture intends to provides more details. In this scenario, reference models and reference architectures have been proposed for different domains, such as for embedded systems (Eklund et al., 2005) and even for software engineering (Nakagawa et al., 2007). In order to contribute to development of service-oriented software systems, service-oriented reference model and service-oriented reference architecture (i.e., models and architectures that are based on SOA) can also be found; for instance, the OASIS reference model (OASIS, 2006) and Service-Oriented Solution Stack (S3) reference architecture (Arsanjani et al., 2007). In this context, a complete and detailed view about these models and architectures seems to be very relevant, considering the impact that they can have to the service-oriented system development.

The main objective of this paper is to present a detailed panorama about how reference models and reference architectures based on SOA have been recently proposed and used. For this, we have adopted and applied the systematic review technique (Kitchenham, 2004) that makes possible to have a complete and fair evaluation about a topic of interest. As main results of our systematic review, we have observed that in the last years there is an increase in the number of work involving reference models and reference architectures based on SOA, showing a real interest by both academy and industry. Furthermore, this panorama makes possible to identify interesting and important research topics that could be investigated yet.

The remainder of this paper is organized as follows. In Chapter 2, we present an overview about topics related to this work. In Chapter 3, we present the conducted systematic review. In Chapter 4, we discuss results, lessons learned and limitations of this work. Finally, in Chapter 5, we present our conclusions.

Chapter

2

A Brief Overview

Since SOA, reference architectures, reference models and systematic review technique are basis of this work, in this chapter, we present a brief overview about them.

2.1 Service-Oriented Architecture - SOA

SOA has been recently disseminated as a new architectural style to organize software systems. SOA introduces the concept of business service (or simply service) as a fundamental unit to design, build and composite service-oriented software systems (Papazoglou et al., 2008). A service provides usually business functionalities; furthermore, it is independent of the context and of the state of other services (Papazoglou e Heuvel, 2007). For the services to work property, SOA requires the establishment of mechanisms for communication among services, or through a direct communication or using broker (i.e., a mediator among the services). Besides that, to build service-oriented systems, a highly distributable communication and integration backbone is important. This functionality can be provided by the Enterprise Service Bus (ESB) that refers to an integration platform to support a wide variety of communications patterns over multiple transport protocols and deliver value-added capabilities for SOA applications (Papazoglou e Heuvel, 2007). Through composition of simple services, more complex service-oriented systems can be built and, according to Papazoglou and Heuvel (Papazoglou e Heuvel, 2007), in the more productive and agile way. In other words, SOA intends the cooperation of low coupling

services in order to create dynamic and flexible business processes. Service composition is therefore considered one of the most promising characteristic of SOA. In this context, concepts, such as service orchestration and service choreography (Peltz, 2003), are important. To ensure the quality and interoperability among services, contracts can be used as a formal agreement to specify the relation between a service and its clients, expressing each part's rights and obligations (Dai et al., 2007).

According to Kreger (Kreger, 2003), Web services seem to be the preferred implementation technology for realizing SOA. Based on open and pervasive standards and using infrastructure, such as HTTP, SOAP, and XML, Web services aim at maximizing service sharing, reuse, and interoperability.

2.2 Reference Models and Reference Architectures

The idea of creating software systems from existing software rather than building systems from scratch is not new and was first introduced at the end of 60's (McIlroy, 1968). Firstly, reusing source code was the main focus. Following, higher level artifacts — analysis/design specifications and database scheme, for instance — become to be reused. Later, concern with reuse was inserted in requirements engineering. In the same perspective, it is noted that the use of software architectures as an approach to software reuse has been broadly investigated (Avgeriou et al., 2007; Krueger, 1992). In the middle of 90's, descriptions of software system architectures were studied and a number of architectural styles, i.e., patterns that occur regularly, were identified (Shaw e Garlan, 1995). Some popular architectural styles are pipeline, layered and repository. Besides architectural styles, reference models have been also proposed. They aim at facilitating understanding of the domain, providing common vocabulary and presenting the parts and their relationships; however, implementation details are not considered (OASIS, 2006). With a similar objective of the reference models, reference architectures have been also proposed. A reference architecture plays a dual role with regard to specific target software architectures (Angelov et al., 2009; Gallagher, 2000; Muller, 2008): it generalizes and extracts common functions and configurations; and it provides a base for instantiating target systems. In other words, they can be seen as a knowledge repository of a given domain. In this perspective, it seems to be relevant the use of reference models and reference architectures as artifacts to be reused. Software architectures, including reference models and reference architectures, can play a major role in determining system quality – performance and maintainability, for instance – since they form the backbone for any software-intensive system. With the emergence of SOA, reference models and reference architectures have been focus of research. In spite of diversity of work, there is a lack of work that present a

detailed panorama about how them have been used in the development of service-oriented systems.

2.3 Systematic Review

Systematic review has been widely investigated and adopted in the Evidence-Based Software Engineering (EBSE). EBSE has attracted much attention of the software engineering community in recent years (Dybå et al., 2005; Kitchenham et al., 2004), aiming at providing knowledge about when, how, and in what context technologies, processes, methods or tools are more appropriate for software engineering practices (Kitchenham et al., 2004).

It is noticed that as a research area matures, there is almost always an increase in the number of reports and results made available. During the study of a new knowledge area, researchers usually conduct a bibliographical review (almost always an informal review) to identify publications related to a specific subject. However, this kind of review does not use a systematic approach and does not offer any kind of support to avoid bias during the selection of the publications that will be analyzed. Thus, it is important to have mechanisms to summarize and provide overview about an area or topic of interest (Petersen et al., 2008). In particular, systematic review provides a comprehensive and systematic evaluation of research using a predefined strategy of search aiming at minimizing bias (Kitchenham e Charters, 2007). It makes possible systematically to obtain literature review and it is used to summarizing, assessing and interpreting the relevance of all evidence related to a specific question, topic area, or phenomenon of interest. An individual evidence (for instance, a case study or an experimental study divulged in a publication/paper) which contributes to a systematic review is called *primary study*, while the result of a systematic review is a *secondary study*.

Considering its relevance, systematic review has been applied for different topics of interest. In the context of software architecture, systematic reviews can be also found (Dilorenzo et al., 2008; Farenhorst e Boer, 2009; Pei-Breivold e Crnkovic, 2010). In particular, Farenhorst and Boer (Farenhorst e Boer, 2009) apply systematic review to specifically understand how the term “architectural knowledge” has been used by community and what is it related to.

Chapter

3

Systematic Review Application

Our systematic review was conducted in the software architecture domain, aiming at identifying relevant primary studies related to service-oriented reference models and service-oriented reference architectures. It was conducted from September/2009 to December/2009 and was carried out by four people (one software architecture researcher, one systematic review specialist and two graduate students). In order to conduct our systematic review, we followed the process proposed by Kitchenham (Kitchenham, 2004) and presented in Figure 3.1. In short, this process presents three main phases: (i) **Phase 1 - Planning:** In this phase, the research objectives and the review protocol are defined. The protocol constitutes a pre-determined plan that describes the research questions and how the systematic review will be conducted; (ii) **Phase 2 - Conduction:** During this phase, the primary studies are identified, selected and evaluated according to the inclusion and exclusion criteria established previously. For each selected study, data are extracted and synthesized; and (iii) **Phase 3 - Reporting:** In this phase, a final report is formatted and presented. In next sections, we present how these phases were conducted in our systematic review.

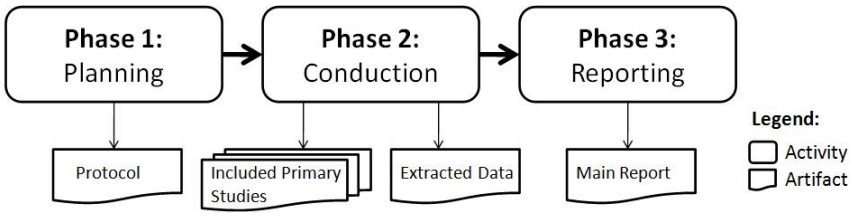

Figure 3.1: Systematic review process (Adapted from (Kitchenham, 2004)).

3.1 Phase 1: Planning

In this phase, we established the review protocol. For this, we specified: (i) research questions; (ii) search strategy; (iii) inclusion and exclusion criteria; (iv) data extraction and synthesis methods.

(i) **Research Questions**: Aiming at finding all primary studies to understand and summarize evidences about reference models and reference architecture based on SOA, the following research questions (RQ) were established:

- **RQ1:** Which SOA characteristics have been considered during the design and development of reference models and reference architectures?
- **RQ2:** How reference architectures and reference models can enhance the development of service-oriented systems and which are the main benefits of their use?
- **RQ3:** In which contexts (academy or industry) service-oriented reference architectures and service-oriented reference models have been applied?
- **RQ4:** Which is the validation level of the service-oriented reference architectures and service-oriented reference models, considering their use to implement service-oriented systems?
- **RQ5:** What are the "inputs" that support the development of service-oriented reference architectures and service-oriented reference models?

Each research question was built and analyzed from different viewpoints:

- **Population:** The population consists of projects that are guided or use service-oriented reference architectures or service-oriented reference models;
- **Intervention:** It refers to what is observed in the context of the systematic review. In our case, the intervention is represented by service-oriented reference architectures and service-oriented reference models;

- **Comparison:** It refers to what is compared in the context of the systematic review. In our case, it is not applicable; and
- **Outcomes:** The expected results are the set of characteristics that are basis to the development of service-oriented reference architectures and service-oriented reference models. Furthermore, we expect to identify the domains that have used them, as well as the benefits of their application.

(ii) **Search Strategy**: In order to establish the search strategy, considering the research questions, we identified initially the main keywords. Thus, the keywords "Reference Architecture" and "Service Oriented Architecture" were identified. Following, we found synonyms for these keywords: "Reference Model", "Service based", "Service Oriented" and "SOA". It is worth highlighting that the keywords chosen must be simple enough to bring many results and, at the same time, rigorous enough to cover only the desired research topic. We used the boolean OR operator to link the main terms and their synonyms. Finally, all these terms were combined using the boolean AND operator. Thus, the final search string was:

```
(("Reference Architecture" OR "Reference Model")
   AND ("Service Oriented Architecture" OR
"Service based" OR "Service Oriented" OR SOA ))
```

In addition to the research questions and search strategy, we established which search sources (i.e., publication databases) would be used to find the primary studies. The criteria used to select the sources were: **content update** (publications are regularly updated); **availability** (full text of the papers are available); **quality of results** (accuracy of the results returned by the search); and **versatility export** (since much information are returned through the search, a mechanism to export the results is required). These criteria are also discussed in (Dieste et al., 2009). Thus, the selected databases to our systematic review are shown in Table 3.1. According to Dybå et. al (Dybå et al., 2007), these databases are efficient to conduct systematic review in the context of software engineering. Furthermore, *Scopus* was added, since it is considered the largest database of abstracts and citations (Kitchenham e Charters, 2007).

(iii) **Inclusion and Exclusion Criteria**: Another important element of the systematic review planning is to define the Inclusion Criteria (IC) and Exclusion Criteria (EC). These criteria make possible to include primary studies that are relevant to answer

Table 3.1: Selected Databases

Source	Location
ACM Digital Library	www.portal.acm.org
IEEE Xplore	www.ieeexplore.ieee.org
ScienceDirect	www.sciencedirect.com
Scopus	www.scopus.com
Springer	www.springer.com/lncs
Web of Science	www.isiknowledge.com

the research questions and exclude studies that do not answer them. Thus, the inclusion criteria of our systematic review are:

- **IC1:** The primary study presents a service-oriented reference architecture or a service-oriented reference model; and
- **IC2:** The primary study presents some experience involving a service-oriented reference architecture or service-oriented reference model.

The exclusion criteria established are:

- **EC1:** The primary study presents a reference architecture or reference model; however, it involves a specific characteristic or a part of SOA (for instance, reference architecture for systems that support *Enterprise Service Bus* (ESB) or systems that manage *Service Level Agreement* (SLA));
- **EC2:** The primary study presents a reference architecture or a reference model to other types of systems that do not contain features related to service; and
- **EC3:** The primary study does not propose or discuss about service-oriented reference architectures or service-oriented reference models.

(iv) **Data Extraction and Synthesis Method**: In order to extract data, we plan to build data extraction tables related to each research question. These tables must synthesized results aiming at facilitating to obtain conclusions. During the extraction process, the data of each primary study will be independently extracted by two reviewers. If disagreement occurs, discussion will be conducted. To summarize and describe the set of data, statistical synthesis method will be used.

3.2 Phase 2: Conduction

In this phase, the search by primary studies was conducted according to previously established plan. This identification was done by looking for all primary studies that match

with the search string in the search sources. This was automatically conducted, since these sources provide an efficient search engine.

To support the organization of the primary studies, we used JabRef[1], an open source reference manager system. It makes possible to store information on the primary studies (for instance, title, authors and abstract), as well as the exclusion/exclusion criteria applied to select each primary study.

In Figure 3.2, the three steps of the conduction phase of our systematic review are illustrated. In Step 1, we identified primary studies in the databases, following the systematic review plan established previously. As result, 181 studies were identified. In the next step (Step 2), we selected the primary studies, through reading of titles and abstracts and application of the inclusion and exclusion criteria. Thus, a total of 46 studies were selected. However, five studies were not available online (Castellano et al., 2006; Correia et al., 2008; Liu et al., 2009; Schroth, 2008; Shan, 2007) and three studies were written in Chinese language (Li et al., 2006; Ma e Chen, 2006; Yang et al., 2005); therefore, 38 studies were considered. It is worth highlighting that only papers written in English were considered in our systematic review, since English is more widely adopted to write scientific papers. In Step 3, the 38 papers were read in full and inclusion and exclusion criteria were again applied. Finally, 21 studies were considered as the most relevant to our systematic review.

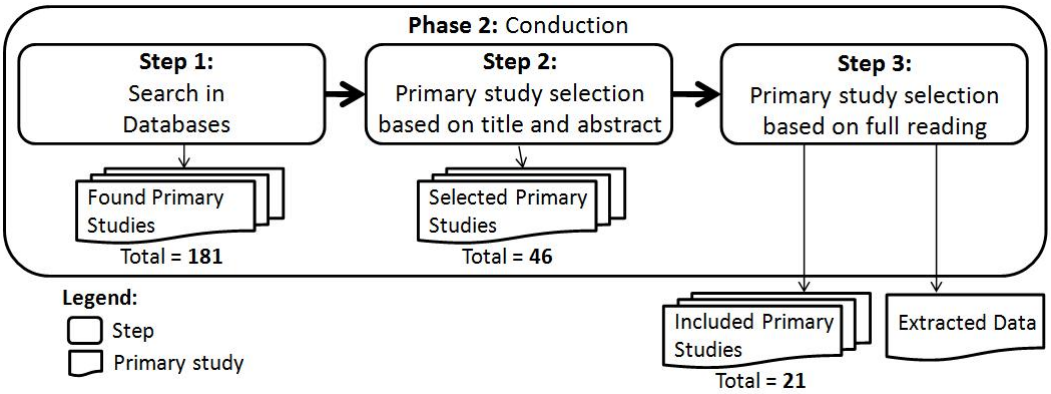

Figure 3.2: Selecting primary studies

Table 3.2 summarizes the total of primary studies obtained in each database, the number of studies included, the rate index[2] and the search date. It is important to observe that Scopus indexes studies of other databases, such as IEEE xplore and Springer. Thus, it can cause an increase in the number of repeated studies; among 36 studies, 15 were therefore repeated. However, Scopus was the most efficient source, since 66.7% of all

[1]http://jabref.sourceforge.net/

[2]Ratio between the total of included studies of a database and the total of primary studies obtained.

included papers were obtained in this source. Otherwise, ACM contributed with only 4.8% of papers.

Table 3.2: Search sources, obtained and included primary studies

Database	Obtained	Included	Rate Index	Date
ACM Digital Library	7	1	0.048	10/27/2009
IEEE Xplore	41	7	0.333	09/29/2009
Science Direct	4	1	0.048	10/29/2009
Scopus	67	14	0.667	10/30/2009
Springer	19	5	0.238	10/28/2009
Web of Science	43	8	0.381	10/27/2009

Table 3.3 presents the 21 primary studies included. Column "Type" indicates if the study is related to a service-oriented reference model (RM) or a service-oriented reference architecture (RA). Column "Doc. type" indicates if the primary study was published in a Journal Article (JA), Conference Paper (CP), Technical Report (TR) or a Book Chapter (BC). Moreover, almost all studies were included by criteria 1 (i.e, the primary study presents a service-oriented reference architecture or a service-oriented reference model). Following, a more detailed analysis was conducted on the 21 primary studies included in our systematic review and data were extracted.

3.3 Phase 3: Reporting

In this last phase, we present analytical results of our systematic review. Figure 3.3 shows the number of primary studies separated by year. It is important to note that only primary studies published until September/2009 or October/2009 were considered. It is observed an increase in the number of primary studies related to service-oriented reference models and service-oriented reference architectures. This indicates an increasing interest on this topic of research. Moreover, Table 3.4 summarizes the objective of each primary study.

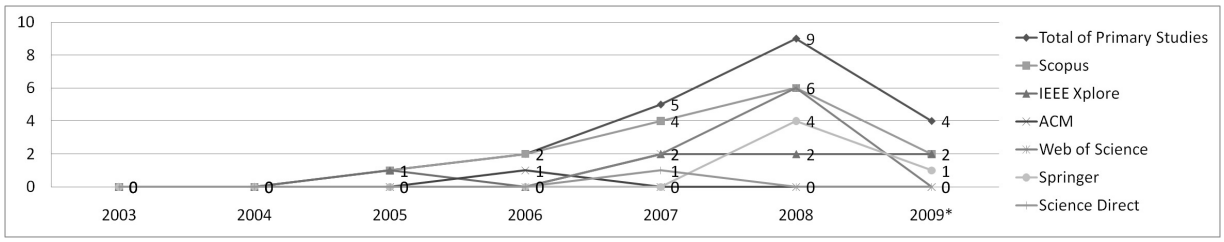

Figure 3.3: Primary studies published throughout the years

The data extraction and synthesis of knowledge arisen considering each research question are discussed below:

Table 3.3: Included primary studies

Study	Authors	Publication year	Type	Inclusion criteria	Doc. type
S1	Arsanjani, A. et al. (Arsanjani et al., 2007)	2007	RA	IC1, IC2	JA
S2	Brehm, N. and Gomez, J. (Brehm e Gómez, 2007)	2007	RA	IC1	CP
S3	Choi, H. et al. (Choi et al., 2009)	2009	RA	IC1	CP
S4	Costagliola, G. et al. (Costagliola et al., 2008)	2008	RM	IC1	JA
S5	Costagliola, G. et al. (Costagliola et al., 2006)	2006	RM	IC1	CP
S6	Dillon, T. et al. (Dillon et al., 2008)	2008	RA	IC2	CP
S7	Duro, N. et al. (Duro et al., 2005)	2005	RA	IC2	CP
S8	Fioravanti, F. et al. (Fioravanti et al., 2007)	2007	RA	IC2	CP
S9	Futo, I. (Futo, 2007)	2007	RM	IC1	CP
S10	Hemalatha, T. et al. (Hemalatha et al., 2008)	2008	RA	IC1	CP
S11	Lan, J. et al. (Lan et al., 2008)	2008	RA	IC1, IC2	CP
S12	Leppaniemi, J. et al. (Leppaniemi et al., 2009)	2009	RA	IC1	CP
S13	Liu, L. et al. (Liu et al., 2008)	2008	RA	IC1, IC2	CP
S14	Murakami, E. et al. (Murakami et al., 2007)	2007	RA	IC1	JA
S15	OASIS (OASIS, 2006)	2006	RM	IC1, IC2	TR
S16	Peristeras, V. et al. (Peristeras et al., 2009)	2009	RA	IC1, IC2	JA
S17	Ramanathan, S. (Ramanathan et al., 2008)	2008	RA	IC2	JA
S18	Reiff-Marganiec, S. et al. (Reiff-Marganiec et al., 2008)	2008	RA	IC1	CP
S19	Zheng, Q. et al. (Zheng et al., 2008)	2008	RA	IC1	CP
S20	Zimmermann, O. et al. (Zimmermann et al., 2009)	2009	RA	IC2	BC
S21	Zirpins, C. et al. (Zirpins e Emmerich, 2008)	2008	RM	IC1	JA

RQ1: Regarding RQ1 (i.e., SOA characteristics in reference models and reference architectures), we have identified five main characteristics that have been more widely treated in the primary studies. Table 3.5 summarizes these characteristics and presents the total of primary studies that address each characteristic. Definition for these characteristics can be found in (Arsanjani et al., 2007). It is worth highlighting that in some primary studies, we had to infer about the SOA characteristics that the studies were dealing with, since they was not explicitly indicated. Among these characteristics, "service publication" and "service composition" have had more attention.

Table 3.4: Short description of the objective of each primary study

Study	Objective of the Primary Study
S1	A detailed definition of reference architecture based on SOA.
S2	Distribution of functionalities of a federated ERP system as services.
S3	Information integration of research and development projects in the NTIS service portal.
S4, S5, S19	Full inter-operability among learning management systems and learning objects as services.
S6	Studying architectural styles as a first step to establish a SOA-based reference architecture.
S7	Inter-operability among ground software systems based on SOA.
S8	Discussion about evolution of a reference architecture of the multimedia domain to the context of SOA.
S9	Supporting the development of SOA-based application for public institutions.
S10	Supporting the delivery of image processing system on network using SOA.
S11	Practices and guidance for the development process of SOA systems.
S12	Proposal of a service-oriented reference architecture to support inter-operability and low coupling in situational awareness systems.
S13	Establishment of controlled self-organization in a SOA environment.
S14	Integration of different systems and resources in the precision agriculture domain.
S15	Definition of the essence of SOA, the vocabulary and the common understanding of SOA.
S16, S18	Supporting inter-operability in collaborative work environment.
S17	Reduction of operational expenses and service life cycle of telecom service projects.
S20	Discussion about architectural knowledge in the industry to create reference architecture based on SOA.
S21	Proposal of a reference model for collaborative network coordination.

Table 3.5: SOA characteristics in the reference architectures and reference models

Characteristic of SOA	Total	Percentage	Primary Studies
Service publication	16	76.19%	S1, S2, S3, S4, S5, S6, S8, S10, S14, S15, S16, S17, S18, S19, S20, S21
Quality of service	11	52.38%	S1, S2, S7, S9, S11, S13, S15, S16, S17, S18, S20
Politics and governance	8	38.10%	S1, S2, S9, S11, S13, S18, S19, S20
Service composition	12	57.14%	S1, S3, S6, S9, S10, S11, S16, S17, S18, S19, S20, S21
Enterprise service bus	7	33.33%	S1, S3, S11, S14, S17, S19, S20

RQ2: This research question addresses the support that reference architectures and reference models have provided to the service-oriented system development. We have concluded that these architectures and models have been mainly used to provide facilities to the development of systems related to a specific domain. Moreover, the primary studies

have pointed out that a common "basis" to develop a set of systems is interesting. We identified also the main benefits by using these architectures and models: inter-operability, better comprehension of the domain, establishment of a common vocabulary, architectural reuse, consistence in the system representation and a better time-to-market.

RQ3: This research question refers to the context in which service-oriented reference architectures and service-oriented reference models have been applied. We have observed that these architectures and models have been applied in different domains. Table 3.6 presents the list of the application domains addressed by primary studies. In particular, domains that involve governmental systems (Choi et al., 2009; Futo, 2007; Leppaniemi et al., 2009), collaborative work environments (Peristeras et al., 2009; Reiff-Marganiec et al., 2008) and e-learning (Costagliola et al., 2006, 2008; Zheng et al., 2008) have been investigated. We have also identified efforts to establish architectures and models that are independent of a specific domain (Arsanjani et al., 2007; Dillon et al., 2008; Liu et al., 2008; OASIS, 2006; Zimmermann et al., 2009). For instance, S3 reference architecture (Arsanjani et al., 2007) and OASIS reference model (OASIS, 2006) are two initiatives widely known, cited and used as basis of other reference architectures and reference models (Choi et al., 2009; Futo, 2007; Hemalatha et al., 2008; Leppaniemi et al., 2009). However, in spite of these efforts, it is worth highlighting that there are still several other domains that could be considered.

Table 3.6: Application domains of the reference architectures and reference models

			Context	
Application domain	Total	Percentage	Academy	Industry
Generic (domain independent)	6	28.57%	S6, S11, S13	S1, S15, S20
Governamental system	3	14.29%	S3, S9, S12	
E-learning	3	14.29%	S4, S5, S19	
Collaborative work	2	9.52%	S16, S18	
Enterprise resource planning (ERP)	1	4.76%	S2	
Multimedia	1	4.76%		S8
Image processing	1	4.76%	S10	
Precision agriculture	1	4.76%	S14	
Telecommunication	1	4.76%		S17
Collaborative network organization	1	4.76%	S21	
Ground software system	1	4.76%	S7	

RQ4: This research question addresses the *validation level* of the service-oriented reference architectures and service-oriented reference models. We have considered the use of some method, such as SAAM (Software Architecture Analysis Method) and ATAM (Architecture Tradeoff Analysis Method). We have observed that there is a lack of studies that evaluate or validate these architectures and models. Table 3.7 presents how these ar-

chitectures and models have been applied; we have named it validation level. It is observed that, on the one hand, 61.90% (4.76% + 14.28% + 42.86%) of the primary studies have presented an instantiation and/or implementation based on the proposed architecture or model; on the other hand, eight studies (38.10%) have presented only the architecture or the model, but they do not have any validation level. It is important to observe that none study has explicitly treated evaluation of reference architectures and reference models. According to Clements et. al (Clements et al., 2002), the application of evaluation methods in software architectures can improve the success of systems built from these architectures. Thus, it seems to be interesting to concentrate efforts to investigate the possibility of evaluation of architectures and models based on SOA, since they are basis of a set of concrete architectures.

Table 3.7: Validation level of the reference architectures and reference models

Validation level	Total	Percentage	Primary Studies
Evaluate	0	0%	–
Architectural instantiation (a)	3	14.28%	S2, S11, S21
Implementation (b)	1	4.76%	S10
Both (a) and (b)	9	42.86%	S3, S4, S5, S14, S16, S17, S18, S19, S20
None	8	38.10%	S1, S6, S7, S8, S9, S12, S13, S15

RQ5: The RQ5 refers to the "inputs" that support the development of service-oriented reference architectures and service-oriented reference models. The inputs to the reference architectures and reference models involved in our systematic review are: existing systems, concrete architectures, similar reference architectures, and knowledge coming from domain experts. These inputs were also pointed by Angelov et. al (Angelov et al., 2009) to establish reference architectures and reference models. Table 3.8 summarizes the inputs that we have found through the 21 primary studies considered. For instance, the most of primary studies (53.38%) have used knowledge and experience coming from domain experts. We have also observed that five primary studies (23.81%) used other reference architectures and reference models as input; however, these architectures and models are not based on SOA.

Table 3.8: Inputs used to design the reference architectures and reference models

Input	Total	Percentage	Primary Studies
Existing systems and concrete architectures	5	23.81%	S1, S6, S19, S20, S21
Other reference architectures or reference models	5	23.81%	S4, S5, S7, S8, S14
Knowledge and experience of the domain expert	11	52.38%	S2, S3, S9, S10, S11, S12, S13, S15, S16, S17, S18

Chapter

4

Discussion

Results of our systematic review point out that reference architectures and reference models based on SOA have received recently increasing attention from both academia and industry. In this chapter we discuss our observations and limitations.

We have observed that there is not a consensus about how to represent service-oriented reference models and service-oriented reference architectures. Some of them have used UML techniques; however, the most of them have used particular and informal way to represent them. Thus, different understanding can be obtained, disturbing the real purposes of these models and architectures. We have also observed that the included primary studies have been published in different conferences and periodicals. In other words, they are not concentrated, for instance, in only software architecture or SOA events. In this perspective, the conduction of a systematic review seems to be an adequate choice, aiming at finding possibly all primary studies in this context.

In spite of positive results, our systematic review could be conducted again, aiming at inserting primary studies published from September/2009 until now. Besides that, relevant primary studies written in other languages can have been ignored, since we considered only paper in English. Although the databases used in our systematic review are usually considered efficient sources to Software Engineering area, other databases, such as Compendex[1] and Google Scholar[2], could be included.

[1] http://www.engineeringvillage.com
[2] http://www.scholar.google.com

Chapter

5

Conclusion

The main contribution of this work is to present a detailed panorama about proposal, use and evaluation of reference models and reference architectures based on SOA. For this, we have applied a systematic review. As main result, we can conclude that these models and architectures have been focus of increasing attention in the last years. Another important contribution of this work is to make possible identification of new research lines; for instance, evaluation of service-oriented reference architecture and establishment of architectures and models for other domains that have not been considered yet. Thus, there are still different perspectives that could be investigated, aiming at improving reuse, productivity and quality of service-oriented systems.

Acknowledgments:

The authors are thankful to Katia Romero Felizardo and Daniel Feitosa for providing useful comments and suggestions on this work. This work is supported by Brazilian funding agencies: FAPESP, CAPES, and CNPq.

Referências

Angelov, S.; Grefen, P. W. P. J.; Greefhorst, D. A classification of software reference architectures: Analyzing their success and effectiveness. In: *WICSA'09*, Cambridge, UK, 2009, p. 141–150.

Arsanjani, A.; Zhang, L.-J.; Ellis, M.; Allam, A.; Channabasavaiah, K. S3: A service-oriented reference architecture. *IT Professional*, v. 9, n. 3, p. 10–17, 2007.

Avgeriou, P.; Kruchten, P.; Lago, P.; Grisham, P.; Perry, D. Sharing and reusing architectural knowledge – architecture, rationale, and design intent. *ICSE'07 Companion*, v. 00, p. 109–110, 2007.

Brehm, N.; Gómez, J. M. Web service-based specification and implementation of functional components in federated erp-systems. In: *BIS'07*, Poznan, Poland: Springer-Verlag, 2007, p. 134–146 (LNCS v.4439).

Castellano, M.; Fiorino, F.; Arcieri, F.; Summo, V.; de Grecis, G. B. A web mining process for e-knowledge services. *Data Mining VII: Data, Text and Web Mining and Their Business Applications*, v. 37, p. 253–264, 2006.

Choi, H.; Lim, C.; Kim, J. Defining reference architecture for NTIS development. In: *ICACT'09*, Phoenix Park, Korea, 2009, p. 284–287.

Clements, P.; Kazman, R.; Klein, M. *Evaluating software architectures: Methods and case studies*. The SEI Series in Software Engineering. Boston, MA: Addison-Wesley, 2002.

Correia, A.; Grama, C.; Stokic, D.; Campos, A.; Silva, R. N.; Aguirre, J. An architecture for collaborative working environments in manufacturing industry. In: *ECEC'08*, Porto, Portugal, 2008, p. 79–85.

Costagliola, G.; Ferrucci, F.; Fuccella, V. SCORM run-time environment as a service. In: *ICWE'06*, New York, USA, 2006, p. 103–110.

Costagliola, G.; Ferrucci, F.; Fuccella, V. Boosting the adoption of computer managed instruction functionalities in e-learning systems. *Journal of Web Engineering*, v. 7, n. 1, p. 42–69, 2008.

Dai, G.; Bai, X.; Wang, Y.; Dai, F. Contract-based testing for web services. In: *COMPSAC'07*, Washington, USA, 2007, p. 517–526.

Dieste, O.; Grimán, A.; Juristo, N. Developing search strategies for detecting relevant experiments. *Empirical Software Engineering*, v. 14, n. 5, p. 513–539, 2009.

Dillon, T. S.; Wu, C.; Chang, E. Reference architectural styles for service-oriented computing. In: *IFIP/NPC'07)*, Dalian, China: Springer-Heidelberg, 2008, p. 543–555 (LNCS v.4672).

Dilorenzo, E.; Cavalcanti, R.; Neiva, D.; Oliveira, T.; Barachisio, L.; de Almeida, E. S.; Meira, S. L. Evaluating domain design approaches using systematic review. In: *ECSA'08*, Berlin, Heidelberg: Springer-Verlag, 2008, p. 50–65.

Duro, N.; Moreira, F.; Rogado, J.; Reis, J.; Peccia, N. Technology harmonization - developing a reference architecture for the ground segment software. In: *IEEE Aerospace Conference*, Big Sky, Montana, USA, 2005, p. 3968–3979.

Dybå, T.; Dingsoyr, T.; Hanssen, G. K. Applying systematic reviews to diverse study types: An experience report. In: *ESEM'07*, Los Alamitos, USA: IEEE Computer Society, 2007, p. 225–234.

Dybå, T.; Kitchenham, B.; Jørgensen, M. Evidence-based software engineering for practitioners. *IEEE Software*, v. 22, n. 1, p. 58–65, 2005.

Eklund, U.; Örjan Askerdal; Granholm, J.; Alminger, A.; Axelsson, J. Experience of introducing reference architectures in the development of automotive electronic systems. *SIGSOFT Softw. Eng. Notes*, v. 30, n. 4, p. 1–6, 2005.

Farenhorst, R.; Boer, R. C. *Software architecture knowledge management*, cáp. Knowledge Management in Software Architecture: State of the Art p. 21–38, 2009.

Fioravanti, F.; Spinu, M.; Campanai, M. AXMEDIS as the service oriented architecture for the media: Is it feasible? In: *AXMEDIS'07*, 2007, p. 264–269.

Futo, I. A functional IT reference model for public institutions. In: *ITI'07*, Cavtat, Croatia, 2007, p. 419–424.

Gallagher, B. P. *Using the architecture tradeoff analysis method to evaluate a reference architecture: A case study.* Relatório Técnico CMU/SEI-2000-TN-007, Software Engineering Institute, 2000.

Hemalatha, T.; Athisha, G.; Jeyanthi, S. Dynamic web service based image processing system. In: *ADCOM'08*, 2008, p. 323–328.

Kitchenham, B. *Procedures for performing systematic reviews.* Relatório Técnico TR/SE-0401 and NICTA Technical Report 0400011T.1, Keele University and National ICT Australia Ltd, 2004.

Kitchenham, B.; Charters, S. *Guidelines for performing systematic literature reviews in software engineering.* Relatório Técnico EBSE 2007-001, Keele University and Durham University Joint Report, 2007.
Disponível em `http://www.dur.ac.uk/ebse/resources/Systematic-reviews-5-8.pdf`

Kitchenham, B.; Dybå, T.; Jørgensen, M. Evidence-based software engineering. In: *ICSE'04*, Edinburgh, Scotland, UK, 2004, p. 273–281.

Kreger, H. Fulfilling the web services promise. *Communications of the ACM*, v. 46, n. 6, p. 29–34, 2003.

Krueger, C. W. Software reuse. *ACM Comput. Surv.*, v. 24, n. 2, p. 131–183, 1992.

Lan, J.; Liu, Y.; Chai, Y. A solution model for service-oriented architecture. In: *WCICA'08*, Chongqing, China, 2008, p. 4184–4189.

Leppaniemi, J.; Linna, P.; Soini, J.; Jaakkola, H. Toward a flexible service-oriented reference architecture for situational awareness systems in distributed disaster knowledge management. In: *PICMET'09*, Portland, USA, 2009, p. 959–965.

Li, J.; Chen, S.; Ma, H. Research of service-oriented architecture reference model and its application. *Jisuanji Gongcheng/Computer Engineering*, v. 32, n. 20, p. 100–102, 2006.

Liu, J.; Yan, Z.; Qiao, J.; Lin, S. A role-based reference model for the service properties of service oriented architecture. In: *IFITA'09*, Chengdu, China, 2009, p. 341–344.

Liu, L.; Thanheiser, S.; Schmeck, H. A reference architecture for self-organizing service-oriented computing. In: *ARCS'08*, Dresden, Germany: Springer-Heidelberg, 2008, p. 205–219 (LNCS v.4934).

Ma, Z.-Y.; Chen, H.-J. Service-oriented architecture reference model. *Jisuanji Xuebao/Chinese Journal of Computers*, v. 29, n. 7, p. 1011–1019, 2006.

McIlroy, M. D. Mass produced software components. *Software Engineering: Report on a conference by the NATO Science Committee*, p. 138–150, 1968.

Muller, G. *A reference architecture primer.* Relatório Técnico, Eindhoven Univ. of Techn, Eindhoven, whitepaper, 2008.

Murakami, E.; Saraiva, A. M.; Ribeiro, Junior, L. C. M.; Cugnasca, C. E.; Hirakawa, A. R.; Correa, P. L. P. An infrastructure for the development of distributed service-oriented information systems for precision agriculture. *Computers and Electronics in Agriculture*, v. 58, n. 1, p. 37–48, 2007.

Nakagawa, E. Y.; ao, A. S. S.; Ferrari, F.; Maldonado, J. C. Towards a reference architecture for software testing tools. In: *SEKE'07*, Boston, USA, 2007, p. 1–6.

OASIS *Reference model for service oriented architecture 1.0.* Relatório Técnico, OASIS Standard, 2006.

Papazoglou, M. P.; Heuvel, W.-J. Service oriented architectures: approaches, technologies and research issues. *The VLDB Journal*, v. 16, n. 3, p. 389–415, 2007.

Papazoglou, M. P.; Traverso, P.; Dustdar, S.; Leymann, F. Service-oriented computing: a research roadmap. *Int. Journal of Cooperative Information Systems*, v. 17, n. 2, p. 223–255, 2008.

Pei-Breivold, H.; Crnkovic, I. A systematic review on architecting for software evolvability. In: *ASWEC'10*, Auckland, New Zealand, 2010.

Peltz, C. Web Services Orchestration and Choreography. *IEEE Computer*, v. 36, n. 10, p. 46–52, 2003.

Peristeras, V.; Fradinho, M.; Lee, D.; Prinz, W.; Ruland, R.; Iqbal, K.; Decker, S. CERA: A collaborative environment reference architecture for interoperable CWE systems. *Service Oriented Computing and Applications*, v. 3, n. 1, p. 3–23, 2009.

Petersen, K.; Feldt, R.; Shahid, M.; Mattsson, M. Systematic mapping studies in software engineering. In: *EASE'08*, Bari, Italy, 2008, p. 1–10.

Ramanathan, S.; Alexander, M.; Kerr, G. The IBM telecommunications service delivery platform. *IBM Systems Journal*, v. 47, n. 3, p. 433–443, 2008.

Reiff-Marganiec, S.; Truong, H.-L.; Casella, G.; Dorn, C.; Dustdar, S.; Moretzky, S. The incontext pervasive collaboration services architecture. In: *ServiceWave'08*, Madrid, Spain: Springer-Verlag, 2008, p. 134–146 (LNCS v. 5377).

Schroth, C. Global industrialisation of information-intensive services: A reference architecture for electronic business media. *International Journal of Product Lifecycle Management*, v. 3, n. 2-3, p. 191–210, 2008.

Shan, T. Practical SOA. In: *ICSOFT'07*, Barcelona, Spain, 2007, p. 31.

Shaw, M.; Clements, P. The golden age of software architecture. *IEEE Software*, v. 23, n. 2, p. 31–39, 2006.

Shaw, M.; Garlan, D. *Software architecture: Perspectives on an emerging discipline*. Prentice Hall, 1995.

Yang, L.; Zuo, C.; Wang, Y.-G. Research and implementation of service oriented architecture for knowledge discovery. *Jisuanji Xuebao/Chinese Journal of Computers*, v. 28, n. 4, p. 445–457, 2005.

Zheng, Q. H.; Dong, B.; Tian, F.; Chen, W. A service-oriented approach to integration of e-learning information and resource management systems. In: *CSCWD'08*, Xian, China, 2008, p. 1047–1052.

Zimmermann, O.; Kopp, P.; Pappe, S. Architectural knowledge in an SOA infrastructure reference architecture. In: *Software Architecture Knowledge Management*, Springer-Heidelberg, p. 217–241, 2009.

Zirpins, C.; Emmerich, W. A reference model of virtual service production networks. *Service Oriented Computing and Applications*, v. 2, n. 2-3, p. 145–166, 2008.