Semantic Enterprise Application Integration at Service Layer: A Systematic Mapping

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Abstract. Organizations use several applications to support their business processes and activities. These applications should be integrated to provide a better support and meet the organizations' needs. Moreover, to properly support the processes, Enterprise Application Integration (EAI) should address the service integration layer. EAI must cope with semantic conflicts that often arise when integrating applications due to the heterogeneity of the applications. In this paper, we present a systematic mapping that investigated EAI initiatives that address semantic aspects and cover the service integration layer. Our main interest is to investigate the approaches adopted to integrate services and the use of ontologies in this context. The results provide a panorama of research in this area.

Keywords: Enterprise Application Integration, Service Integration, Semantic Integration, Ontology, Systematic Mapping.

1 Introduction

There are a lot of information systems to support the business processes of companies, non-profit organizations, and governmental organizations [14]. Enterprise Application Integration (EAI) is one of the solutions which provide the ability to integrate many applications running in an enterprise [2], and a promising way for unhindered information flow, resolving the problem of "islands of information" [7]. However, EAI has been one of the main challenges faced by organizations [6].

The applications[1] to be integrated are usually developed by different groups that, many times, do not have any concern with integration. As a result, these applications, almost all, are heterogeneous, autonomous and distributed [11]. Thus, multiple technical, syntactical and semantic conflicts can arise when integrating applications [11]. Nowadays, technical and syntactical aspects of application integration are relatively well-established, but semantic aspects have still been challenging [12].

Semantic integration, which is based on meaning, is more reliable than syntactical integration, which is based only on the processing of strings and union of schemes [21]. In semantic EAI, a common understanding of the handled terms and services exchanged

[1] In this paper, *application* and *system* are used as synonymous.

by applications is shared [4]. In this context, ontologies can be used to establish a common understanding about the domain of interest, serving as an interlingua to provide communication between applications [4] and promoting integration at different layers (data, message/service, and process) [16]. In other words, ontologies can be used as a reference model to map concepts and services used by the different enterprise applications [4]. In Computer Science, ontology is considered an explicit concrete artifact representing a model of consensus within a community and a universe of discourse, aimed at supporting semantic interoperability in its various forms (e.g., model integration, service interoperability, knowledge harmonization, and taxonomy alignment) [10].

Among the reasons for interest in service layer integration, we found that enterprises are getting away from tight application-to-application interfaces and are adopting more service-oriented, loosely coupled, message-based, and asynchronous techniques [19]. The notion of business services and Service Oriented Architecture (SOA) provides a view of integrated components to be dealt with as encapsulated and reusable high-level services. Also, an integration scenario is composed of one or more processes, and processes consist of services, links connecting services and rules defining operations on process data or service execution order [15]. Services can then address integration problems and also create new capabilities on existing application services. A composed process can, e.g., offer a reusable complex functionality which can be adopted in further composed processes as a single service [15].

Considering the relevance of service integration and the challenges of semantic integration, we decided to investigate semantic EAI initiatives with focus on the service layer. By that, we aim to provide an overview of this research topic by means of a mapping study. A mapping study is a secondary study designed to give a panorama of a research area/topic through a systematic method and, using a well-defined classification for selecting and analyzing the works focus of interest. From that, it also aims to identify available evidence about the interest topic contributing for pointing out issues to be addressed in future researches [13] [17].

This mapping study refines and updates two studies previously performed by some of the authors of this paper. First, [16] investigated semantic EAI initiatives in general, analyzing aspects such as business application domain, addressed integration layers (data, message/service, process) and ontology use. Next, [6] updated the study by [16] and, after that, analyzed in deep the semantic EAI initiatives addressing the process layer. In [6], Cerqueira et al. investigated how semantic integration has been performed at the process layer and the use of ontologies in this context. In our study, we updated the study by [6] with regard to the semantic EAI initiatives in general. Thus, we investigated in deep the semantic EAI initiatives addressing the service layer, by analyzing how semantics has been assigned to services and the use of ontologies in these service integration initiatives.

It is important to clarify some terminological aspects used along this paper. Despite the definitional differences/interrelations between *integration* (as the act of incorporating components into a complete set in a way to form a new system constituting a whole and creating synergy [11]), and *interoperability* (as the ability of applications/components to exchange data and services preserving the constituent parts as they are [19]), these terms are often used indistinctively [16]. In this paper, therefore, the term "integration" is adopted in a broader sense, covering both integration and interoperability meanings.

We present our mapping study in this paper, which is organized as follows: Section 2 provides the background for the paper, talking briefly about EAI, services and ontologies; Section 3 presents the research protocol used in the study; Section 4 presents the obtained results; Section 5 discusses the findings that emerge from the results; Section 6 describes the limitations of this work; and, finally, Section 7 presents our final considerations.

2 Background

EAI is crucial for organizations, since applications increasingly need to work together to support business processes. According to [7], EAI is the integration of applications enabling information sharing to efficient operations and flexible delivery of business services to the customer, considering current or legacy applications.

To integrate enterprise applications, it is necessary to create a coherent information system architecture in which the various business processes, information storages and systems are integrated so that they appear seamless for the user. It is necessary, thus, to define an integrated system as a collection of subsystems that interact to form a whole, and whose properties emerge due to the interaction of its subsystems [19] [22].

Nonetheless, enterprise applications many times have trouble to interoperate with others because their structure and design did not consider interoperability needs. According to [11], these are HAD (heterogeneous, autonomous, and distributed) applications. Heterogeneous means that each enterprise application implements its own data and process model. Autonomous means that enterprise applications may run independently of any other application. Distributed means that applications locally implement their data model, which they generally do not share with other enterprise applications. This, therefore, contributes to make EAI a difficult and complex task.

EAI can cover different layers [11]: data, message/service, and process. Data integration deals with moving or federating data between multiple data stores. Integration at this layer assumes bypassing the application logic and manipulating data directly in the database, through its native interface. Message (or service) integration addresses messages exchange between the integrated applications. Process integration views enterprises as a set of interrelated processes and it is responsible for handling message flows, implementing rules and defining the overall process execution [11]. In this paper, we are particularly interested in service integration.

According to [11] a service is defined as the realization of a business functionality via software that anyone can use to compose new applications by using these services in the context of new or modified processes. Service integration provides loosely coupled integration and has played an important role in EAI. Moreover, there is a strong connection between process integration and service integration, since process integration may occur from connections among services [6].

Semantic conflicts can arise in any of the integration layers, whenever applications are built with different conceptualizations. To avoid them, the meaning of the interchanged information and shared functionalities/tasks has to be understood across the applications. Ontologies have been employed for the establishment of common understanding to explain implicit and hidden knowledge, contributing to solving semantic conflicts [16].

Considering their generality level, ontologies can be classified as: top-level ontologies (so-called foundational ontologies), which describe general concepts like, time, space, event, object, etc., and are independent of particular domains or tasks; domain ontologies, which describe concepts related to a generic domain (e.g., Electrocardiogram); task ontologies, which describe the conceptualization related to a generic task or process (e.g., Diagnosis); and application ontologies, which deal with concepts related to a particular application (e.g., a medical ontology for heart diseases built on Diagnosis and Electrocardiogram ontologies). Ideally, domain and task ontologies should be defined from top-level ontologies and application ontologies should be based on domain and task ontologies [9].

3 The Research Protocol

The study was conducted following the approach defined in [13][17], which involves: planning, when the research protocol is defined; conducting, when occurs the execution of the protocol, data extraction, analyze and record; and reporting, when the results are recorded and made available to possible interested parties. Next, we present the main parts of the protocol used in the study.

The study **goal** was to investigate EAI initiatives that address semantic aspects and the service layer. By "address the service layer" we mean that the integration occurs by the exchange of information through messages. For achieving the goal, we defined nine **research questions,** which are shown bellow with their rationale:

RQ1. *When and in which type of vehicle (journal/ conference/ symposium/ workshop) have the studies been published?*: Aims at giving an understanding on when and where publications about semantic EAI initiatives addressing the service layer have been published.

RQ2. *Which types of research (considering the classification defined by [20]), have been done?:* Investigates which type of research is reported in each selected publication. This question is useful to evaluate the maturity stage of the research topic.

RQ3. *What are the business application domains addressed in the EAI initiatives?:* Identifies the business applications domains that have been supported by semantic EAI initiatives addressing the service layer and verifies if there is predominance of any of them.

RQ4. *Have ontologies been adopted in the EAI initiatives? If so, what the purpose of using them?:* Verifies if ontologies have been used in semantic EAI initiatives and the identifies the purpose of using them.

RQ5. *What kinds of ontologies (considering their generality level) have been used?:* Identifies the kinds of ontologies used in semantic EAI initiatives addressing the service layer and verifies if there is a predominance of some kind.

RQ6. *Which languages/formalisms have been used to create the ontologies?:* Identifies how ontologies have been represented in semantic EAI initiatives.

RQ7. *How has service integration been addressed in the EAI initiatives?:* Investigates the technological strategies and integration approaches used to perform semantic integration at the service layer.

RQ8. *How is semantics assigned to services?:* Investigates which techniques and methods have been used to assign semantics to services in semantic EAI initiatives addressing the service layer.

RQ9. *Have systematic approaches been used to conduct the EAI initiatives?:* Verifies whether the initiatives have been followed by systematic approaches to performing semantic integration at service layer. This question helps identify if there has been a concern with providing clear guidance for users to perform semantic EAI addressing the service layer.

Since this study updates previous studies, we applied the same **search string** used in [16] and [6]. The search string has two groups of terms joined in conjunction with the AND operator. The first group includes terms to capture studies related to integration/interoperability of enterprise applications. The second aims at capturing studies that deal with semantic aspects. Within each group, the OR operator was used to allow for synonyms. The search string used in this study is: *("application integration" OR "application interoperability" OR "enterprise system integration" OR "enterprise system interoperability" OR "integration of information system" OR "interoperability of information system" OR "integration of application" OR "interoperability of application" OR "interoperability of enterprise application" OR "interoperability of enterprise system" OR "integration of enterprise application" OR "integration of enterprise system" OR "interoperability of business application" OR "interoperability of business system" OR "integration of business application" OR "integration of business system" OR "integration of heterogeneous system" OR "integration of heterogeneous application" OR "interoperability of heterogeneous system" OR "interoperability of heterogeneous application" OR "interoperability of information system" OR "integrated application" OR "interoperable application" OR "integrated enterprise system" OR "interoperable enterprise system" OR "information system integration" OR "information system interoperability" OR "enterprise system integration" OR "enterprise system interoperability" OR "business system integration" OR "business system interoperability") AND (semantic OR semantics OR semantically).*

The search was performed in the following six **sources**: IEEE Xplore), ACM Digital Library, Scopus, Science Direct, Engineering Village, and Web of Science. These sources are the same searched in [16] and [6]. They were selected based systematic reviews in the Software Engineering area and on other studies conducted by members of our research group.

Publication selection was performed in four steps: *In Preliminary Selection and Cataloging (S1),* the search string was applied in the search mechanism of each digital library (we limited the search scope to the title, abstract and keywords metadata fields).

After that, we identified publications indexed by more than one digital library and removed the duplications. *In Selection of Relevant Publications – 1st filter (S2)*, the abstracts of the selected publications were analyzed considering the following inclusion (IC) and exclusion (EC) criteria: (IC1) the study addresses an EAI initiative that considers semantic aspects; (EC1) the publication does not have an abstract; (EC2) the publication is an abstract only; (EC3) The publication is not written in English; (EC4) the publication is an older version or a publication already selected; (EC5) the publication is a secondary study, a tertiary study, an editorial or a summary. In *Selection of Relevant Publications – 2nd filter (S3)*, the full text of the publications selected in S2 was read and analyzed considering the cited inclusion and exclusion criteria. Publications whose full text was not available were also excluded (EC6). With the publications selected in S3 we updated the study reported in [16] and [6]. Then, to focus on publications presenting EAI initiatives addressing the service layer, in *Selection of Relevant Publications – 3rd filter (S4)*, we applied an additional inclusion criterion: (IC2) the publication presents a semantic EAI initiative addressing the service layer, to the publications selected in S3 and also to all the publications addressing semantic EAI initiatives selected in [16] and [6]. As a result, we obtained the publications object of the study described in this paper.

The publications returned in the publication selection steps were cataloged and stored in spreadsheets. We defined an id for each publication and recorded the publication title, authors, year, and vehicle of publication. Data from the publications returned in S4 were extracted and organized into a data extraction form oriented to the research questions. The spreadsheets and form produced during the study can be found in http://bit.ly/SEIA-SLM-Spreadsheet. Publication selection and data extraction were performed by the first author and reviewed by the second, third and fourth authors. Discordances and possible biases were discussed in meetings.

4 Data Synthesis

This study considered publications until December 31st, 2017. In S1, we searched for studies published from 2016, since [6] selected studies published until December 31st, 2015. We obtained 140 publications as result of S1. After duplications removal 113 publications remained. 32 of them were selected in S2. In S3, five publications were selected. In S4 we applied IC2 to the five publications selected in S3. All of them were also selected in S4. Moreover, we applied IC2 to the publications selected in [16], resulting in 40 publications, and to publications selected in [6], which resulted in five publications. After all these steps, we have selected 50 publications presenting semantic EAI initiatives that address the service layer. Figure 1 illustrates the process followed and the number of publications selected in each step. Due to space limitation, we do not provide in this paper the list of selected publications. It can be found in http://bit.ly/SEIA-SLM-Publications.

Analyzing the 50 publications selected in the final selection stage, we noticed that some of them refer to a same work and report different parts of that work. In these cases, we decided to analyze together the set of publications referring to a same work and count them as only one study, since they refer to the same work. As a result, we identified 45 different approaches (instead of 50). Next, we present the data synthesis for each research question.

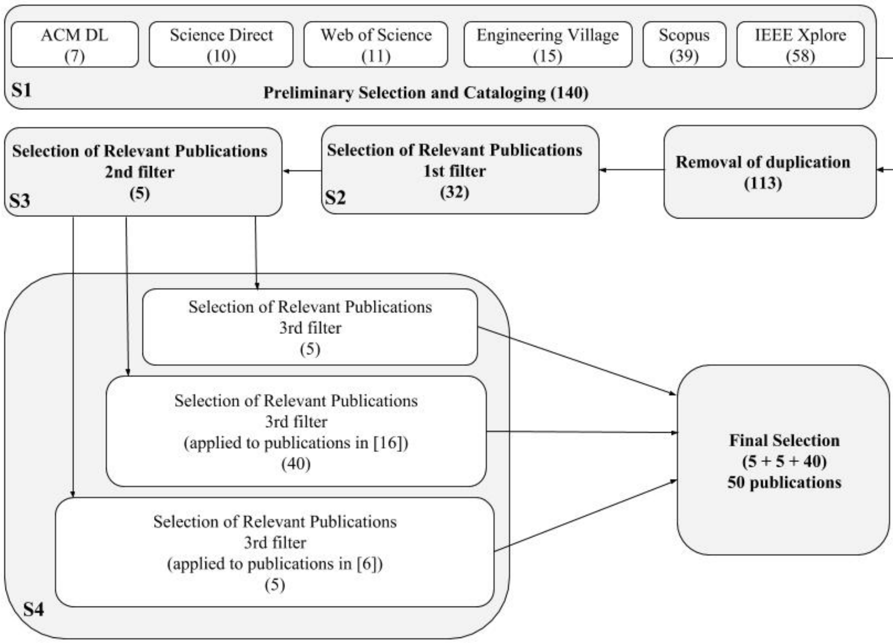

Fig. 1. – Publication Selection Process

RQ1 - When and in which type of vehicle have the studies been published?

Figure 2 shows the distribution of studies per year. Regarding the type of vehicle, twenty-one studies (47%) were published in conferences, sixteen studies (36%) in journals, six (13%) studies in symposiums, one study (2%) in workshop, and one study (2%) was published as a book chapter. The years of 2015 and 2016 have no publications of studies about semantic EAI addressing the service layer.

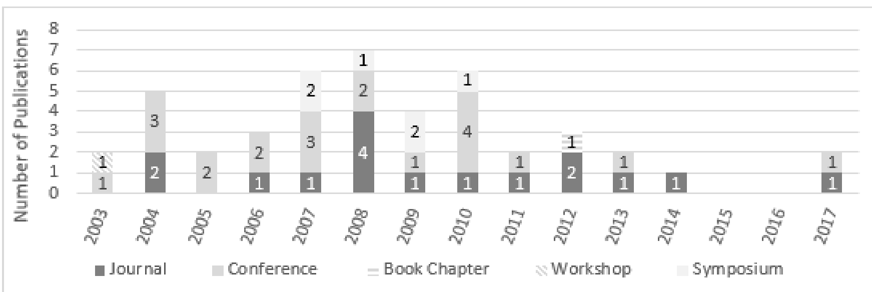

Fig. 2. – Distribution of selected studies over the years

RQ2 - Which types of research have been done?

Following the classification by [20], thirty-three (73%) of the analyzed studies are *Proposal of Solution*. From these, ten (22%) are also *Validation Research* (i.e., they use a proof of concept, experiment, prototype or similar to evaluate the proposal) and two (4%) are also *Evaluation Research* (i.e., the proposal was evaluated in practice). Nine proposals (20%) do not propose a solution, but address some kind of evaluation. Three (7%) of them are *Validation Research* and six (13%) are *Evaluation Research*. Three (7%) studies were classified as *Experience Paper*.

RQ3 - What are the business application domains addressed in the EAI initiatives?

Most of the investigated semantic EAI initiatives (ten studies, 22%) are independent of the application domain. Nine studies (20%) concern E-Business and E-Commerce domains. Three studies (7%) regard Educational and Medical domains each. Financial, Manufacturing, Product Development, and Supply Chain were application domains addressed in two studies (4% per domain) each. Accounting, Construction Industry, Digital Asset Management, E-Gov, Emergency Management and Geographical Information, Management and Maintenance Decision of Electric Equipment, Multimedia Content, Oil Industry, Power Marketing, Process Management, Production Process Simulation, Software Engineering are application domains in only one study (2%) each.

RQ4 - Have ontologies been adopted in the EAI initiatives? If so, what is the purpose of using them?

Ontologies are adopted in thirty-seven studies (82%). Eleven studies (24%) use ontologies to *Data Description*, one study (2%) to *Service Description*, seventeen studies (38%) to *Data and Service Description*, one study (2%) to *Data and Process Description*, and four studies (9%) to *Data, Service and Process Description*. Two studies (4%) use ontologies as *Reference Model* and one study (2%) use to *Framework Description*. Eight studies (18%) do not use ontologies.

RQ5 - What kinds of ontologies (considering their generality level) have been used?

Table 1 presents the quantity and percentage of studies per kind of ontologies. "Unspecified" refers to studies that use ontologies, but they do not specify their kinds, and it was not possible to identify them.

Table 1. – Kinds of Ontologies used in the Studies

Kind of Ontologies	Quantity of Studies	Percent of Studies (%)
Domain Ontology	26	58%
Domain Ontology and Application Ontology	5	11%
Domain Ontology and Foundational Ontology	1	2%
Domain Ontology, Application Ontology and Foundational Ontology	1	2%
Unspecified	4	9%
Do not use Ontology	8	18%

RQ6 - Which languages/formalisms have been used to create the ontologies?

The studies adopt several languages/formalisms to represent ontologies, ranging from Semantic Web languages to simpler data representation techniques. The following languages/formalisms were identified: OWL (six studies, 13%), RDF (four studies, 9%), OWL-DL (one study, 2%), OWL-S (three studies, 7%), XML (three studies, 7%) and WSMO (two studies, 4%). Considering studies that adopt more than one language/formalism, there are six studies (13%) using OWL, four (9%) using XML, five (11%) using OWL-S, and one (2%) using RDF. Finally, two studies (4%) use a language proposed in the own study, and seven studies (16%) propose the use of ontologies, but do not make commitment to any specific language/formalism.

RQ7 - How service integration is addressed in the EAI initiatives?

The studies use diverse technologies for integration. With the focus on just one technology, we found eleven studies (24%) using *Web Services*, eleven studies (24%) using *Semantic Web Services*, ten (20%) using *Mediators*, three (7%) using *Workflow*, two studies (4%) using *Model-Driven Architecture*, one study (2%) using *Agent-Based Paradigm*, one study (2%) using *Middleware*, one study (2%) using *Event-Based-Paradigm*, and one study (2%) applying *Dictionary Inference Rules*. Among studies that combine technologies for service integration, two studies (4%) use *Mediator and Web Services*, one study (2%) use *SOA and Workflow*, and one study use *Mediator and Semantic Web Services*.

RQ8 - How is semantics assigned to services?

As pointed out in RQ4, most of the studies (82%) use ontologies. In the service context, ontologies are used to assign semantics to structural aspects of the services, describing the types of inputs, outputs, preconditions, and postconditions. The semantic descriptions of services are used to ease the search in the services registers architecture, where agents can search for descriptions using the same concepts of the services announced. Transformations from the types of messages to be exchanged are performed using ontologies to stablish semantic to existing data in the messages and make them compatible among the integrated services. The use of Domain Ontologies is predominant for assigning semantics to services. Semantic Web strategies and standard web technologies (OWL-S, OWL, WSMO, WSDL, RDF, RDFS, XML) are predominant among strategies to implement semantics in services. The eight (18%) studies that do not use ontologies have some common vocabulary defining involved data, except for two studies that do not focus on data description.

RQ9 - Have systematic approaches been used to conduct the EAI initiatives?

Forty-one studies (91%) do not follow a systematic approach or method to guide the semantic EAI initiative. Thus, only four studies (9%) use approaches guiding the steps to be followed in the integration.

5 Discussion

Considering the distribution of studies along the years, as shown in Fig. 2, we point out the period between 2006 and 2010. In 2006, we notice the start point in the increase number of the published studies, achieving the peak in 2008. From that, the number of published studies decreases gradually, passing through 2010 until 2017. This tendency seems to correspond, in terms of Gartner Hype Cycle, to the "Technology Trigger" phase (specially by adoption and standardization of semantic web technologies), achieving the "Peak of Inflated Expectations" until the "Trough of Disillusionment" and some level of stability.

Looking at the vehicles where the analyzed studies have been published (RQ1), 64% of these studies were published in scientific events (conferences, symposiums and workshops), whereas 36% were published in journals. Considering that journals usually require more mature works, we can say that the topic addressed in this mapping has been explored and discussed with relative degree of maturity by the research community. By the analysis of RQ3, we can see that the analyzed studies have taken place in diverse business domains, which points out that semantic EAI initiatives at service layer runs through several business domains. This indicates its applicability. On the other hand, analyzing the types of research (RQ2), only 8 studies (18%) reported evaluations in real scenarios (Evaluation Research). This indicates that, despite the (supposed) maturity degree presented by published studies, the research area lacks in reporting of real experiences.

Data obtained from RQ4, RQ5, and RQ6 reveal a predominance of the use of *Domain Ontologies* to *Data and Service description*. The use of domain ontologies to semantically describe service information is used in the analyzed publications to establish a common understanding of the service inputs, outputs, preconditions, and postconditions. The service description is then mapped to ontology concepts, which provides the common vocabulary for message exchanging among the integrated applications. As an example, in [14], a domain ontology is used to describe services inputs and outputs, creating a mapping between process and service information. OWL and XML are used as formalism to create ontologies, down-cast and up-cast transformations. In [3], in turn, domain ontology is used in mediation services to translate output information of one business activity into input information of another. The translation is made based on the semantic mapping between service parameters. All studies using *Domain Ontology* or *Service Ontology* use the ontology to *Data and Service description.* This is aligned to the necessity of data description to turn possible service description. Most of these studies use semantic web technologies (such as OWL, OWL-S, WMSO) to describe services. Also, all the studies that use ontologies to address semantics at service layer focus on structural aspects of service (services inputs and outputs). Only in [4] behavioral aspects are considered in the semantic service integration. The authors suggest mapping the applications structural aspects to a structural integration model and then looking for services and tasks (i.e., behavioral aspects) with the same semantics.

As for assigning semantics to services (RQ8), as we mentioned above, there is a predominance of assigning semantics to data that constitute the services (i.e., service structural aspects), mainly using domain ontologies for data description (inputs, outputs, preconditions, postconditions). Service ontologies (such as OWL-S) are used in some studies. OWL-S contemplates a service composition in the form of a process model composed of atomic and composite processes that have control constructs to define the interaction between client and services.

Concerning how semantic service integration has been addressed (RQ7), (*Semantic*) *Web Services* (24%), together with *Mediator* (22%) have been the most used approaches (46%). Web services, by principle, play an important role in many analyzed studies in providing a loosely coupled integration implementation. Semantic web services, in turn, are used towards filling semantic issues in web services, providing descriptions of services capabilities in a way to turn viable automatic or semi-automatic identification of services, for use in compositions. The use of Service Oriented Architecture (SOA) or the use of service register is common in studies involving (semantic) web services. They use service matching to find necessary services, usually to support business process and some choreographic or orchestration. Approaches that use a Mediator need more complex logic for semantic data conversions, service interconnection, services matching or technological compatibilizations. A common characteristic to the three cited categories is to take the business processes into account to organize the services. This is an important aspect to integrate services and there is still a gap between business process models and information system deployment [3].

Finally, just a few studies (9%) followed a systematic approach to carry out EAI (RQ9). In [18], the used approach focuses on creating associations between the conceptual models and the application logic using ontologies to create conceptual models and associate these models to the system resources. [4], in turn, uses a semantic integration approach independent of how the integration will be designed and implemented. The focus is on using ontologies to assign semantics at the conceptual level. The approach used in [1] uses an upper ontology to assign semantics to data, service and process. All these approaches have in common the use of conceptual models to assign semantics. By doing that, semantic aspects also addressed as independent of technological issues. Although a massive use of technologies is usually necessary to implement (semantic) service integration, it seems to exist a tendency towards a separation of concerns regarding conceptual and technological aspects. As such, as in Software Engineering research area, semantic EAI approaches should define semantic service integration at conceptual level and then devote to aspects such as platform, programming language and architectural design definitions.

6 Limitations of the Study

In general, researchers conducting mapping studies have to make a lot of decisions and exercise a lot of judgment. Depending on that, different sets of publications can be obtained and different conclusions can be reached [23].

Some of the challenges we experienced in this study regard to how to apply the inclusion/exclusion criteria in a consistent way, how to classify data, and how to interpret them. We carried out some actions aiming at minimizing the influence of these challenges on the results. Thus, publication selection and data extraction were initially performed by only one of the authors, which followed the procedures established in the research protocol. To reduce the subjectivity, the other three authors performed the same procedures over the previous analyzed publications. As such, each publication was analyzed by at least two researchers. Discordances and possible biases were discussed and addressed by the researchers.

The study considered six digital libraries as sources. Although this set of digital libraries represents a comprehensive source of publications, the exclusion of other sources and the fact that we did not perform snowballing may have left some valuable publications out of our analysis.

Another limitation is related to the classifications we made for categorizing data. We defined a classification schema for each research question. Some categories were based on classifications previously proposed in the literature (e.g., in RQ2 we followed the categorization defined by [20]). Others were established during data extraction, based on data provided by the analyzed studies (e.g., in RQ4 we created a categorization regarding the purpose of using ontologies). Determining the categories and how studies fit them involves a lot of judgment. For achieving a more consistent analysis, some studies classifications were discussed in meetings. Anyway, we cannot ensure that all results concerning the studies classification are fully repeatable.

7 Final Considerations

Organizations use several applications to support business processes. The execution of services of these applications supports implementing the business processes functions. Thus, to better support the business processes, applications should be integrated through the integration of their services, in a way that the integration scenario implements the supported business processes. The integration scenario consists of services, links connecting services and rules defining operations on process data or service execution order [15].

Integration at service layer can provide a loosely coupled way of application collaboration, and a semantic layer can improve service architectures like SOA for describing the services announced. Semantic issues arise in EAI integration whenever applications use different conceptualizations. In this context, ontologies can be used as an effective tool to conceptualization alignment and to cope with heterogeneity problems. At the service layer, ontologies can provide a shared understanding of data services and processes in the integration scenario and facilitate communication between the applications [4].

In this paper, we presented a mapping study that investigated semantic EAI initiatives addressing the service layer. The results of the mapping provide a panorama of research related to services integration in semantic EAI initiatives.

Considering the study results, we identified the following gaps in the investigated research topic: (i) lack of systematic approaches for guiding integration at the service layer; (ii) task ontologies have not been used to support service integration; and (iii) lack of a general conceptualization about enterprise application services. As for (i) only few EAI initiatives followed a systematic approach and systematic approaches are necessary to provide feasible methods to perform semantic EIA. With respect to (ii), we noticed a lack of concern with behavioral aspects of services. Most of the studies focus on structural aspects of service (input and output parameters) to assign semantics. However, behavioral aspects should also be taken into account. In this context, task ontologies can be useful to assign semantics to services, functionalities, activities, and their related information [5]. Concerning (iii), none of the analyzed publications provide a conceptualization about enterprise application service. Understanding what an enterprise application service is, as well as the concepts related to it is important to properly address semantic service integration. Moreover, it is necessary to understand the semantic relations among application services and business process activities [8] in order to provide integrated solution to better support the business processes.

Apart from the studies reported in [16] and in [6], which served as a starting point to our study, we did not find any other related work. There are similarities and differences between the studies performed by [16] and [6] and ours. As for similarities, the three studies investigated semantic EAI initiatives and the use of ontologies in this context. Concerning differences, we can highlight the study focus and the investigated aspects. [16] aimed to provide a panorama concerning semantic EAI in general. [6], in turn, focused on semantic EAI addressing the process layer. Our study is more interested in semantic EAI addressing the service layer. Thus, in our study, we analyzed in depth how integration initiatives have been addressing semantic integration at service layer, and how semantics has been assigned to services. Moreover, we extended the coverage of the studies by [16] and [6] until 2017.

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