

# SOA Issues and their Solutions through Knowledge Based Techniques – A Review

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## Summary

Service Oriented Architecture (SOA) is an evolution of Component Based Software Engineering (CBSE), which is truly a paradigm shift from typical Software Engineering (S.E) having more focus on reusability and flexibility of services. Due to its instant popularity and adaption in the recent decade, it seeks a lot of attention of practitioners and researchers. Knowledge Management (KM) has proved a powerful tool in resolving issues related to the requirement as well as software engineering. In this paper, we have extorted some major issues like service selection, service quality, service composition and coordination between different processes among web services etc. faced by the SOA community through KM techniques extensive literature study. The end product does not meet the user business requirements exactly. To minimize this gap between the requirements provided by the user and web services available to build a software system, knowledge management techniques can prove to be helpful. We have also suggested a mechanism of minimizing the effect of issues in SOA with the effective appliance of KM techniques.

### Keywords:

SOA, Knowledge Repository, Ontology, Semantic Analysis, Service Selection, Service Composition, Quality of Service.

## 1. Introduction

### 1.1 Service Oriented Architecture (SOA)

The research community has done a lot of efforts to develop a software system in an effective but faster and economical way. Among these efforts, Component Based Software Engineering (CBSE) has become a popular and widely acknowledged software engineering approach due to the benefits of component and code reuse (software artifacts). It is a paradigm shift from traditional software development. However, due to the limitations like platform independence, heterogeneity of protocol and locating system components against system requirements, there was another paradigm shift towards Service Oriented

Architecture (SOA). Service Oriented Architecture (SOA) is a paradigm shift and is a widely acknowledged approach in the past decade or so. SOA is a way of reorganizing software infrastructure into a set of interacting services [2][3]. Services Oriented Software Engineering (SOSE) provides engineering patterns based on SOA which has addressed most of the issues faced by CBSE and becomes reference architecture for distributed computing [1]. Web services provide a complete set of functionality, implemented as interface and are available over the internet [4]. Web services are mostly available in the form of standard XML messaging format known as Web Service Definition Language (WDSL). Universal Description, Discovery, and Integration (UDDI), is a central repository in which services are been published by the service provider and explored by the service requester. Service level agreement (SLA) made between the provider and requester after the selection of required service [4]. The advantages achieved by Software Industry through SOA are heterogeneous, platform independence, loose coupling, minimizing cost and time, reusability and collaboration [5]. In spite of these advantages, there are some new challenges faced by the SOA community due to quick adaption and growth of services over the web. [4][6]

### 1.2 Knowledge Management (KM)

The objective of software engineers is to build products/software in less possible time. Reuse of existing knowledge can minimize cost and time [1], which exactly is a motivation behind the concept of creating software with existing web services. Therefore during the course of development, developers need existing/available knowledge as quickly as possible, to take swift and accurate decisions.

Different knowledge management techniques have been proposed for this purpose. From these techniques, "Knowledge Repository" is among the best tactical knowledge management practices for storing knowledge

[7]. Once knowledge repository is created, it becomes easy to retrieve required knowledge when required. A number of other advantages can be achieved by organizing knowledge like improvement in product quality, time-saving, discovering required items etc. [8].

Knowledge related to the domain in which services are being provided also plays an important part for fulfilling domain understanding. For this purpose "Ontology" plays a vital role [9]. Ontology is basically a common specification of shared conceptual knowledge. It helps to extract knowledge from knowledge base due to its common set of rules and shared understanding regarding specified domain [10]. Ontology can be used for knowledge extraction and also have the potential for understanding rules related to a particular domain [10].

For extraction of knowledge in its true spirit and meanings, it should be analyzed in a syntactical as well as a semantic way [10]. Once information regarding existing information is managed properly and knowledge extraction techniques are applied to get accurate information timely, it becomes easier to find services that are exactly required to fulfill user needs.

## 2. Related Work

Service Oriented Architecture (SOA) is not a new paradigm which is widely acknowledged and accepted by the software industry. In spite of its worldwide recognition, it is also facing some serious challenges explored by the research community. A number of extensive and systematic reviews has been performed in this regard. Below we have highlighted some of these findings.

SLR from the year 2003-08 has been conducted by Qing GU in 2009 to identify challenges and issues in the field of Service Oriented System Engineering (SOSE). 45 issues have been enlisted and their yearly occurrence has been shown. Some important issues that have more significance are service quality, discovery/ selection, testing, verification and validation, modeling and composition. Author has categorized SOSE challenges under Product-related SOSE challenges and Process-related SOSE challenges. There are mainly eight types of challenges described in the paper, that are characteristics, artifacts, Quality Attributes, artifacts, service operation, SOSE activity, techniques, cross-cutting concerns and business related. It is also identified that the empirical work in this field is not sufficient and needs further attention [6].

Another review has been performed in 2011 in which challenges of SOSE were divided into four main phases, including Specification (Planning) issues, Discovery (Functional and Nonfunctional) issues, Composition issues and Management issues (Including Knowledge Mgmt.). The research hypothesis was that "Better management of

knowledge will improve requirement engineering phase of service oriented software engineering". It was discussed that the number of tools and techniques were presented to cater the highlighted issues in the past but there are no similarities among them and problematic areas still exist. Knowledge Management techniques proved to be helpful in conventional software engineering. So they can be helpful for finding the solution of existing problems of Service oriented software engineering. A framework has been presented in which the author has extracted three out of seven knowledge management techniques. That is Creation, Retrieval and Storage of Knowledge. These techniques are then merged with four phases of SOSE challenges. The limitation of the paper is that author has only presented the abstract method and no industrial evaluation of empirical study has been given to show the significance of the model or improvement from its implementation [4].

In 2012, a review paper was written that shows growing trends and adaption of SOA in the industry. The review was performed from 2001-2011. It highlights that the ultimate goal of SOA is the alignment of IT/Technical capabilities with business requirements. Business requirements/demands changes frequently. So in order to meet that demands technology should raise level without affecting the business architecture of an organization. Therefore business process can be used as loosely coupled smart services. SOA has the advantage to meet the business agility due to its loosely coupled nature. Adaption of open standards in SOA has minimized integration cost. SOA adaption trends have been shown in developers, companies and higher management perspective. At the end some factors that restrict companies/industry of adaption of SOA were also highlighted, which includes Integration of Business and IT, Challenges in Understanding scope, Governance issues, change, and risk management [14].

In 2013, a survey paper was presented that highlights the advantages of SOA and growing trends to adopt web services. It also discussed the evolution of service orientation from component based software engineering and object-oriented software development [16].

In 2017, a systematic literature review was published that show comprehensive overview of work done so far in the areas of Component Based Software Engineering (CBSE), Semantic based solutions on web service selection and discovery and ontology based repository [38].

In 2018, another comprehensive literature survey was presented. Review comprised of comparative analysis among different knowledge discovery techniques based on ontology, knowledge modeling, and information retrieval through semantic based Web Ontology Language (OWL-S) [33].

Some common challenges regarding SOA that has been highlighted from the above mentioned literature surveys are service selection, collaboration among different processes among web services, service composition, semantic gap, finding complex web services that meets user functional as well as non-functional requirements and insufficient information in UDDI [6] [4] [9] [11] [12] [15] [33] [37] [38] [47]. In this paper, we have specifically conducted a systematic literature review to bring to light that what all solutions have been proposed so far to address these issues based on the existing knowledge. We have further enhanced our discussion that which of the knowledge management technique is most suitable for catering SOA's highlighted issues. To streamline the existing KM solutions and to cope web service development with KM we have provided concrete guidelines which will serve as a foundation for resolving key SOA issues highlighted in the literature.

### 3. Methodology

In this study, we have followed the principles of Systematic Literature Review (SLR) [17]. A systematic literature review is a mean of recognizing, estimating and understanding entire accessible research related to a certain research query, topic domain or case of attention. Activities lie in SLR are categorized under three phases named planning phase, conducting phase and reporting phase [18] which is shown in (Fig.1). Distinct studies that aid in the systematic review are known as primary studies, but a systematic review itself is a form of secondary study. Most common reasons for conducting this systematic review are:

- To collect and analyze existing literature evidence relevant to KM techniques for resolving issues in SOA.
- To find out any research gaps in existing research to enhance and improve suggested parts for additional investigation.
- To propose an analysis for placing new innovation to be taken place in research activities.

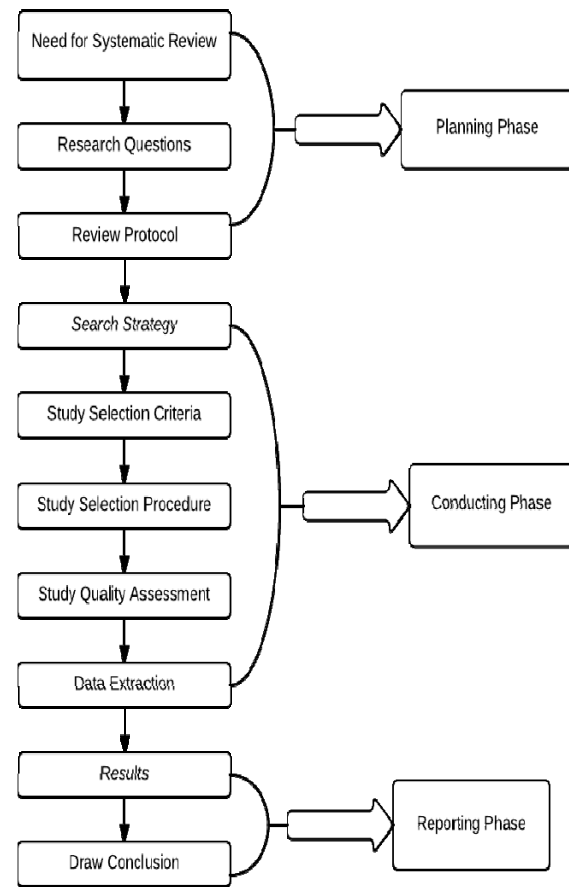


Fig. 1 SLR Process

#### 3.1 Research Questions

Challenges in SOA lies under different categories and different perspectives. For example, they can be categorized under the umbrella of specification, discovery, composition and management related issues [4]. They can also be segregated among project and product based challenges [6]. In this paper we have formulated our research questions with the aim to find solution of SOA issues by applying KM techniques. Keeping in view the link between issues in SOA and techniques related to KM to address these issues, we have formalized following research questions:

**RQ1.** How many research studies have used Knowledge Management (KM) as a technique to address issues in Service Oriented Architecture (SOA)?

**RQ2.** What sort of challenges in SOA are addressed by Knowledge Management?

**RQ3.** What are KM techniques used to address SOA issues?

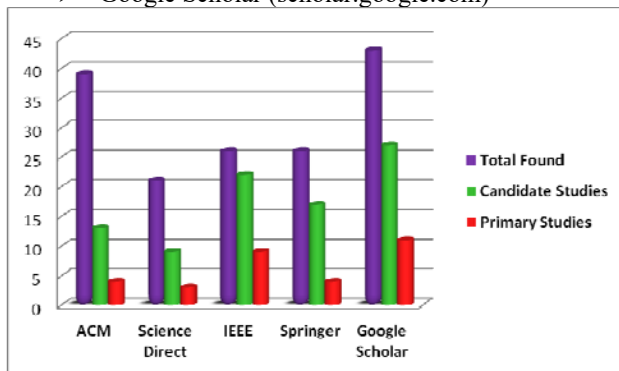
### 3.2 Review Protocol

Before the execution of a comprehensive literature review, a review protocol was planned. It is necessary to design a review protocol because it eliminates the biasness from a researcher point of view. The description of complete plan regarding selection and searching of relevant studies against pre-defined research questions was given. Components of review protocol consist of data sources, search strategy, study selection strategy, data extraction according to the scope and to synthesize data. The initial three components classify the scope of the study and elaborate the inspiration behind it. Whereas the last two components portray how the results are being concluded.

### 3.3 Data Sources

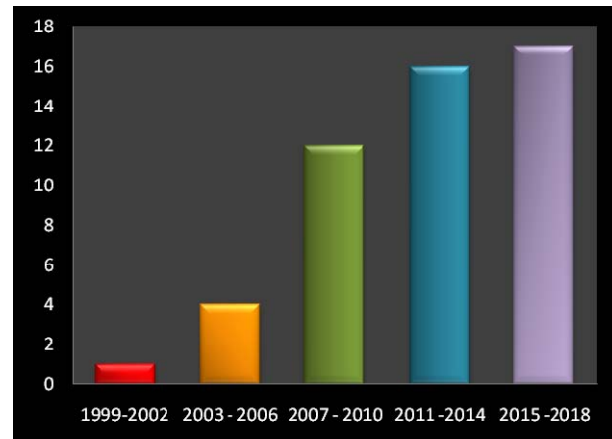
The electronic databases shown in (Fig.2) that we have included to search relevant material related to knowledge management solutions for eliminating SOA issues are:

- ACM Digital Library (portal.acm.org)
- ScienceDirect– Elsevier (www.sciencedirect.com)
- IEEE Xplore (ieeexplore.ieee.org)
- Springer Link (www.springerlink.com)
- Google Scholar (scholar.google.com)



Graph. 1 Number of results per sources

Year wise graph shown below indicates that more recent work is included for our study. It also shows that the research trend towards ontology based knowledge repository and ontology based on semantics is growing in the market and researchers are having more focus towards finding a commendable solution for service selection and discovery due to its usage and significance.



Graph. 2 Year wise distribution of papers

### 3.4 Search Strategy

The search strategy was designed on the basis of Research Questions. To find out “Knowledge Management existing techniques to address SOA issues” will be required for the answer of RQ1, similarly “Existing SOA issues resolved through KM strategies” for answering RQ2 and “List of KM strategies for addressing SOA issues” to answer RQ3. Using Boolean “AND” for connecting two key terms and “OR” for allowing synonyms, the following keywords have been searched. (“SOA” OR “Service Oriented Architecture” OR “SOA Orientation” OR “SOA Limitations”) AND (“Web Service Selection” OR “Service Oriented Requirement Engineering” OR “Ontology based Approach for Web Services” OR “Knowledge Management in SOA”) AND (“issues” OR “problems”) AND (“Knowledge Management for web services”).

### 3.5 Publication Selection & Screening Procedures

We further refined the studies resulting from an automatic search using a manual search step. The goal of this step is to identify the primary studies that are directly related to our studies. Therefore, we defined the following inclusion/exclusion criteria:

- ✓ **Inclusion criterion 1:** We included studies which employ some terminologies related to service oriented architecture and the issues SOA is currently facing, as well as in KM with a special focus on resolving SOA limitations.
- ✓ **Inclusion criterion 2:** Papers of journals having good impact factors and well-known conferences have been included, that gives sufficient material on the domain.

✓ **Inclusion criterion 2:** Papers were written in good English and published after the year 2000.

✗ **Exclusion criterion 1:** Short papers in which much relevant information was not provided are excluded while doing this study.

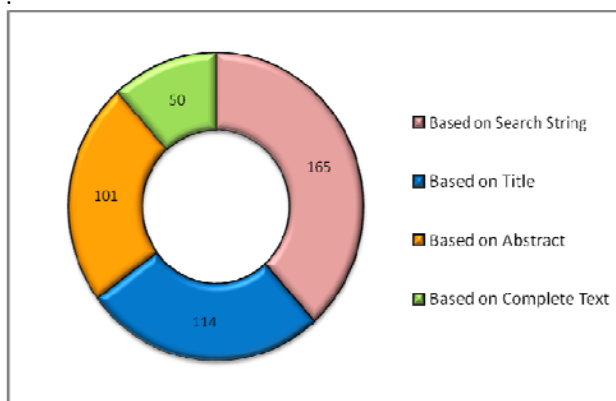
✗ **Exclusion criterion 2:** We mainly focus on SOA issues resolved through different techniques of KM and excluded all the papers that have highlighted other issues of Service orientation that was not solved through KM techniques.

✗ **Exclusion criterion 3:** Some studies that contain the keywords that are matching to our research studies but they were not answering our research questing were also excluded.

✗ **Exclusion criterion 4:** Redundant studies and papers that were published before 2000.

### 3.5 Study Quality Assessment

Quality of level of our studies is shown through quality assessment. Very less percentage found that is relevant to the research questions that we have formulated. We have eliminated only those papers that exactly answer our RQs. Refinement of papers is also done by applying inclusion and exclusion criteria. The basic aim of the quality assessment is to identify most suitable and relevant studies that form part of SLR. By applying search string total 165 papers were identified. Screening has been performed on selected papers. 114 papers left after screening of title, 101 papers left after abstract screening and at the end 50 papers left after screening of complete text as shown in the graph2



Graph. 2 Selection Criteria Overview

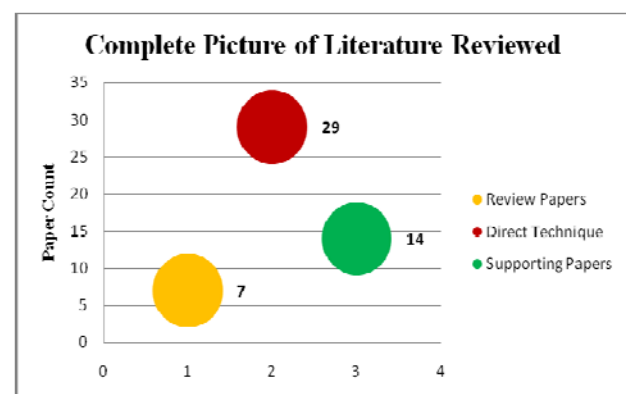
### 3.6 Data Synthesis

We have maintained a spreadsheet for recording issues extracted from the literature. In order to synthesise data according to research questions that we have formulated,

we have eliminated SOA challenges in a broader perspective and merge minor issues that come under each major issue. We have further synthesized our results by using “Reciprocal Translation” according to the suggestions of Kitchenham [17]. For example, if we have recognized three different challenges: (1) dynamic composition of web service, (2) Composition of services at runtime and (3) Automatic web-service composition. After applying reciprocal translation, all these issues merge under the category of Dynamic Service Composition. Similarly, we have applied a reciprocal translation to all challenges in an iterative manner to eliminate similarities in challenges and to combine minor challenges into a major challenge.

## 4. Overview of Comprehensive Literature Study

According to the results of our review, 7 review papers are selected that have already performed literature surveys on the issues that SOA is facing, but their reviews are not from the perspective of knowledge management. 29 papers of direct techniques have been found in which any solution based on existing knowledge has been proposed for catering SOA issues. Techniques include ontology based architectures, semantic analysis based solutions including natural language processing techniques and Web Ontology Language (OWL) based repositories. Proposed solutions were addressing SOA solutions of web service selection and discovery, service management and interoperability, service composition, and service modeling and orchestration. Whereas 14 papers contain supporting information directly related to knowledge management techniques, the role of ontology in SOA, improvement through the semantic environment or systematic literature review guidelines have become part of Literature as depicted in the Graph3.



Graph. 3 Finalized Picture of Literature Extracted

### 5. Results and Analysis

Answer of RQ 1:

Through deep investigation of previous research studies, we have illustrated the fact that Knowledge Management (KM) proved to be a powerful when it comes to addressing issues in Service Oriented Architecture (SOA) [4] [11] [13] [14] and [23]. Some other useful techniques have been proposed to minimize issues in services orientation like “Need of a powerful requirement engineering process for SOA” [27] [28], “Requirement Change Management Mechanism in SOA” [1] [4], “Automatic Service Composition and Discovery Process” [14] [25] [26] [47] [48] etc. But all of the highlighted issues are interlinked and research community has admitted the fact that existing knowledge of web services that are already used is important for organizational and domain prospective. Efficient use of existing knowledge can minimize the gap between requirements and available web services, enhance reusability factor that is a trade mark of SOA and also resolved existing SOA issues up to some extent [4] [7]. In order to answer to RQ1, we have conducted a detailed analysis to assist our findings (see table 1). 15 studies are specifically considered for analysis; the foundation of considering studies in this particular review is that only those studies are considered which provide any knowledge based technique, method, principal, a framework for integrating knowledge management in SOA for addressing issues in web services. Knowledge Management has been proved successful in improving software engineering as well as in requirement engineering processes [29]. This hypothesis has laid a foundation that it can also be helpful in solving service oriented software engineering issues.

Answer of RQ 2:

We have maintained the list of challenges addressed by applying different techniques of Knowledge Management (KM) in each paper. It is interesting to notice that there is a number of minor challenges that come under the umbrella of some major challenges that SOA or SOSE is facing currently in the industry, like “Service Composition” or “Service Discovery”, so we have extracted these challenges in their broader perspective. And we have eliminated the challenges after examination if we find that one challenge is a part of or sub-challenge of another challenge. For answering RQ2 we have identified the is list of SOA challenges for which knowledge management in its any form has been proposed as a solution, namely Web Service Specification (Planning) Discovery Web Services (That meets users functional and non-functional requirements), Web Service Composition, Service Modeling (Modeling Related requirements in specified form), Service Management, Collaboration of dynamic processes among web services,

Quality of Service, UDDI issues (Grammatical Search, Inconsistency and Discovering services according to requirements) and Service Selection .

Table 1: Challenges of SOA addressed through KM in each paper

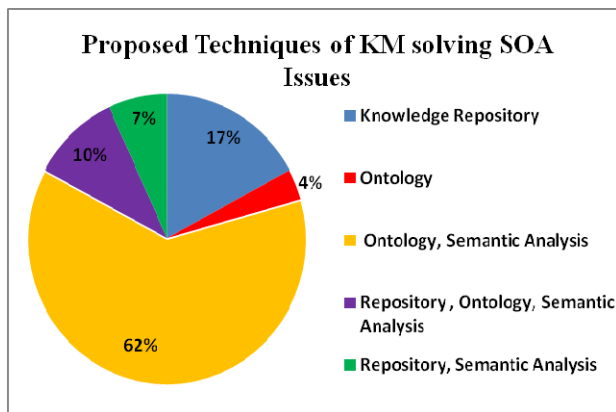
SOA Issues addressed by KM	Description	References
Web Service Specification	Planning Issues and details regarding the requirements and specification of services.	[4], [6]
Discovery Web Services	Discovering such types of services that meet functional and non-functional requirements of users. Automated Discovery Process is also missing.	[4], [6], [9], [13], [15], [19], [23], [24], [30], [33], [39], [40], [42], [43], [45], [47], [48]
Web Service Composition	Automated service composition mechanism, Service interoperability.	[4], [6], [13], [15], [19], [20], [21], [24]
Web Service Modeling	Modeling user requirements in specified form.	[6], [11], [13], [33], [37], [38], [40], [41]
Management of Web Services	It includes managing the meta-data of web services, services management itself and also managing the Knowledge regarding web services so that it can be utilized (reused) in future.	[4], [6], [11], [12], [35]
Service Collaboration	Dynamic Process collaboration among web services.	[6], [9], [13], [36], [49]
Quality of Service (QoS)	Services quality always needs improvement. Service that accurately matches user requirements enhances the quality of the overall software system.	[6], [13], [19], [20], [24], [46]
Issues regarding UDDI	Universal Description Discovery and Integration (UDDI) is XML based registry that is accessible over the internet world-wide. Grammatical based search and some inconsistencies in UDDI is reported as a limitation of SOA.	[6], [9], [11], [15], [22], [24], [49]
Web Service Selection	Lack of Automated service selection process. Improved selection mechanism.	[6], [13], [20], [21], [26], [39], [50]

Answer of RQ 3:

Most of the challenges illustrated through literature study are inter-related. Therefore the solution proposed so far are also interlinked. Knowledge Management (KM) proved to be a powerful tool for catering SOA issues. Different knowledge management techniques are applied, for example “Organizational Knowledge Base” [8], “Knowledge Based Web Services Repository” [11],



“Ontology based Knowledge Management” [12], [13], [15], [33], [37], [40]. In order to minimize the gap between requirements and available web services and to address existing UDDI issues, some researchers have proposed semantic gap analysis based on existing knowledge or information in combination with building ontology related to the particular domain, as a solution. [12], [13], [15], [19], [20], [21], [22], [23], [24], [25], [38], [39], [41] [42] [43] [44]. Percentage of existing techniques of KM proposed for resolving SOA issues is expressed in Graph4.



Graph. 4 Finalized Percentage of proposed Knowledge Based Techniques

From Graph 4, we can overview the percentage of all the techniques proposed so far based on existing knowledge. It is interesting that most of the researchers have recommended the combination of Ontology and Semantic gap analysis as a proposed solution. On contrary, very few studies have been found that have proposed only ontology as a solution and none of the studies have suggested only semantic gap analysis as a complete solution for resolving concerned areas highlighted. That indicates that combination of these techniques proved to be more fruitful rather than using them separately. In Table 2 we have given paper wise details of the proposed techniques, the methodology they have adapted and SOA issues they have addressed. We have categorized proposed solutions into Ontology oriented approach; Knowledge Repository based solution and Semantic Gap Analysis separately.

## 5. Discussion

Keeping in view the results of Systematic Literature Study shown in Table2, we have illustrated the fact that combination of knowledge based techniques or frameworks are also used to address multiple SOA issues.

18 out of 29 researchers have proposed a combination of Ontology and Semantic Gap Analysis as a solution for issues like service collaboration, service composition, and discovery, semantic search instead of grammatical search, improvement in service quality and modeling user requirements regarding the requirements of web services. It is a point of concern that in spite of all these proposed solutions; SOA community is still facing hurdles. Only 10% of our primary studies have proposed all three techniques that are Semantic Gap Analysis based on requirements, Building ontology on existing knowledge and Knowledge based repository as a solution for the resolution of issues. The proposed solutions also have limitations:

- One of them has used knowledge base in the business logic layer for maintaining business requirements and quick access to them within an organization instead of using it in the data access layer. [11] Whereas the actual purpose of the repository is to store information regarding available services used within an organization as well as to maintain their meta-data. So real purpose cannot be achieved by using a repository for improving business logic instead of data access layer.
- One more attempt has been made to offer a solution combining these three Knowledge Based techniques. But the limitation of the proposed approach was that it does not handle user's functional and non-functional requirements at the same time [13]. Rather than addressing functional requirement, the proposed solution should also meet non-functional requirements at the same time.

Other than 2 out of total 29 studies of direct technique no one else has given any solid framework for addressing major issues in SOA. From the detailed analysis of selected studies we have elicited that application of Knowledge Repository results in organizational satisfaction [16], improving services composition, discovery as well as selection mechanism [11], [13] and addressing services management issues [4]. Ontology helps in Inter-Process collaboration among web services [9], resolving services communication issues [13], composition and discovery issues of services [19], [20], [21], [25], [27], [47] improving services quality [12] [21] and formalization of requirements from user [22]. Whereas Semantic Gap Analysis improves UDDI inconsistencies [15], [46], [48] as UDDI offers grammatical search rather than searching the actual meanings of user requirements [9], [11]. Therefore we came to the conclusion that a comprehensive and detailed framework is needed for fixing existing issues of SOA that consists of all three techniques (Repository, Ontology and Semantic Analysis). That solution might enhance the complexity of work a little but it will provide accurate

services from the repository based on existing knowledge inside Organizational Knowledge Base and also enhance services quality as the existing services will be those that are already used and tested. In the case of service not found in the repository that matches user requirements, traditional mechanism of SOA should be followed.

## 6. Conclusion

SOA has gained the attention of industrial and research community due to the number of advantages it offers like loosely coupled web service architecture, Reusing of services, platform independence, and flexibility in its architecture. In spite of its world wide recognition and adaptation in the industry, SOA is facing different challenges that have restricted a part of software industry towards total conversion in services based environment. Some common challenges include web service selection and discovery, services collaboration among each other, composition of services, inter-process communication among web services, semantic gap between requirements and available web services due to grammatical based search in UDDI etc. In order to fill the existing gap between business requirements and available web services, these issues should be resolved. Efforts have been made so far to address these issues by managing existing knowledge and utilizing it at the time of decision making. Different researchers have suggested different approaches e.g. ontology based solution, knowledge-oriented repository, semantic gap analysis etc. to eliminate existing SOA issues, but they are unable to share any common grounds and up till now the issues in SOA exist.

## 7. Future Work

To address these issues there is a need of a comprehensive solution. In future, we are planning to provide an end-to-end solution consisting of knowledge management strategies that address major issues SOA community is facing currently. Starting from requirement gathering and prioritization till selection of required service from a repository based on existing knowledge. The proposed framework will be a combination of all three techniques (Ontology, Knowledge based Repository and Semantic Gap Analysis) that is lacking in the existing work included in this review. And SOA issues like service selection and discovery based on existing knowledge, semantic search, management of already used services, service modelling etc. highlighted in our review will be addressed.

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**Anx - A**

Table 2: Selected Studies Analysis

Title	Year of Publication	Journal / Conference	Ontology	Knowledge based repository	Semantic Analysis	Framework/ Principle	Methodology	Domain	SOA Issues Addressed in each paper
KM-SORE: knowledge management for service oriented requirements engineering [4]	2011	International Conference on Software Engineering Advances ICSEA	No	Yes	No	Framework	Exploratory	SOA	Service Specification (Planning), Service Discovery (Meeting Function and Non Functional Requirements), Composition and Management Issues.
Ontology-based Dynamic Process Collaboration in Service-Oriented [9]	2007	IEEE International Conference on Service-Oriented Computing and Applications (SOCA'07)	Yes	No	No	Framework (ODPC)	Case Study (Online Shopping Service)	SOA	Dynamic Process Collaboration among web services. Web Service Discovery and limitations of UDDI.
Knowledge Repository Supported SOA Application in Collaborative MRO Planning [11]	2012	International Journal of Digital Content Technology and its Applications (JDCTA)	Yes	Yes	Yes	Framework / Architecture	Exploratory (Use of repository in BLL)	SOA	Management issues. Web Service Modeling and limitations of UDDI (Grammatical based search).
Ontology-Based Knowledge Management in Service-Oriented Systems [12]	2011	Journal of Information and Organizational Sciences	Yes	No	No	Architectural Framework (OWL based Organizational Knowledge Management)	Case Study (Product Resale Domain)	SOA + Business Process Management	Organizational Knowledge Management, Gap between Requirements and Available services, Requirement Completeness.
Service Composition in Knowledge-based SOA Systems [13]	2012	Ohmsha, Ltd. and Springer	Yes	Yes	Yes	Framework (Meeting Functional or Non functional Requirements at a time)	Case Study (Telecom)	SOA, SOKU	Services Composition (Complex Services) and Mapping, Service Communication, QoS, User Requirements and Service Discovery (Functional and Non functional requirements), Service Selection and Modeling.
An Ontology-based Multi-dimensional Organization and Management Model for Web Services [15]	2012	Chinese National Institute of Metrology	Yes	No	Yes	Architectural Model	Experimental Evaluation	SOA	Web Service Discovery and Composition. Inconsistency in UDDI (Only classify web services but not consider it's functionality and attributes)
Ontology-Driven Web Services Composition Platform [19]	2005	Springer-Verlag	Yes	No	Yes	Architectural Framework	Experiment	SOA + Networks	Discovery and Composition of Complex Web Services, Quality of Service.

Design guidelines for software processes knowledge repository development [8]	2011	Elsevier - Information and Software Technology	No	Yes	No	Knowledge Management Framework	Case Study (Knowledge Based Process Library)	KM + Agile	Organizational Knowledge Management.
Aligning ontology-based development with service oriented systems [20]	2013	Elsevier - Future Generation Computer Systems	Yes	No	Yes	Framework	Case Study (Mobile Banking Application)	SOA + Distributed Computing	Web Service Selection, Web Service Composition, Quality of Service
Artificial intelligence in service-oriented software design [21]	2016	Elsevier - Engineering Applications of Artificial Intelligence	Yes	No	Yes	Principles	Exploratory	SOA + AI	Web Service Selection, Web Service Composition, Quality of Service
Semantic Web-Based Software Engineering by Automated Requirements Ontology Generation in SOA [22]	2014	International Journal of Web & Semantic Technology (IJWesT) Vol.5, No.2	Yes	No	Yes	Layered Architecture	Experimental Analysis	SOA + UML	Gap between requirements and available web services, Requirement incompleteness.
Bootstrapping Ontologies for Web Services [23]	2010	IEEE TRANSACTIONS ON SERVICES COMPUTING	Yes	No	Yes	Algorithm / Model	Experimental Analysis	SOA	Web Service Discovery, Service Oriented Relationship Modeling.
Process model-based atomic service discovery and composition of composite semantic web services using web ontology language for services (OWL-S) [24]	2012	ACM - Enterprise Information Systems Vol. 6, No. 4, November 2012, 445-471	Yes	No	Yes	Algorithm / Model (Ontology Based)	Case Study (Micro Finance Institution)	SOA + Finance	Web Service Discovery and Composition of Semantic Web Services, Quality of Service.
Web Service Matching By Ontology Instance Categorization [25]	2008	IEEE International Conference on Services Computing	Yes	No	Yes	Process / Algorithm (OnExCat)	Experiment (Web Service Matching Scheme)	SOA	Web Service Matching, Service Identification and Selection
Toward an integrated ontology for Web services [26]	2009	IEEE - Fourth International Conference on Internet and Web Applications and Services	Yes	No	Yes	Algorithm	Experiment	SOA	Automatic web Service Discovery and Composition, Semantic Gap.
An Architecture of a Multi Agent Enterprise Knowledge Management System Based on Service Oriented Architecture [33]	2012	IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 2, No 3, March 2012	No	Yes	No	Architecture	Experiment	SOA + Enterprise Systems	Organizational Deficiencies of Enterprise system, Organizational Complexity.
A web service based on RESTful API and JSON Schema/JSON Meta Schema to construct knowledge graphs [32]	2018	Cornell University Library	No	Yes	Yes	Architecture	Experiment	SOA + JSON Schema	Web service collaboration. Inter-service communication. Re-using of existing knowledge

The use of Ontologies for Effective Knowledge Modeling and Information Retrieval [33]	2018	Elsevier	Yes	Yes	Yes	SLR	Review / Comparison	SOA / Knowledge Modeling	Web service modeling. Reusability of existing services. Service selection and discovery
Towards a sustainable interoperability in food industry small and medium network enterprise: Distributed service-oriented enterprise resources planning [34]	2018	Elsevier	No	Yes	Yes	Architecture / Framework	Comparative Analysis / Tool	SOA + ERP Modeling Systems	Inter-service collaboration and communication. Management of services in distributed environment.
Clinical Decision Support Based on OWL Queries in a Knowledge-as-a-Service Architecture [41]	2018	Springer	Yes	No	Yes	Architecture	Case Study	SOA + Ontology + KaaS	Semantic Gap Analysis. Service Modeling. Re-use of existing knowledge.
A Semantic Similarity Measure Integrating Multiple Conceptual Relationships for Web Service Discovery [30]	2017	Elsevier	Yes	No	Yes	Semantic Similarity Principle	Comparative Analysis	SOA	Service selection and discovery. Semantic search.
SPARKLIS: An Expressive Query Builder for SPARQL Endpoints with Guidance in Natural Language [31]	2017	Journal of Semantic Web	Yes	No	Yes	Architecture	Tool	SOA + NLP	Management of web services. Service selection and retrieval according to requirements.
"Towards Self-Manageable and Adaptive Industrial Cyber Physical Systems with Knowledge-Driven Automatic Service Management [35]	2017	IEEE	No	Yes	No	Architecture	Case Study	SOA	Service selection and discovery. Management of web services. Reusability based on existing knowledge
Semantic Based Service Orchestration in IoT [36]	2017	ACM - SAICSIT'17	Yes	No	Yes	Framework	Simulation	SOA + IoT	Service Orchestration, Semantic search. Service selection.
Ontology development for run-time safety management methodology in Smart Work Environments using ambient knowledge [37]	2012	IJCSI	No	Yes	No	Architecture	Experiment	SOA + Enterprise Systems	Service collaboration and management. Service modeling. Knowledge management
Software component and	2017	Elsevier	Yes	No	Yes	SLR	Literature Review	CBSE + SOA +	Component based software

the semantic Web: An in-depth content analysis and integration history [38]								Semantic Web	engineering, Semantic analysis. Software re-use.
Extraction of web service build on Annotated Capability Specifications [39]	2017	IJARCS	Yes	No	Yes	Framework	Comparitive Analysis	SOA	Service selection and discovery. UDDI inconsistencies.
Ontology for development-time SOA Service Repository having services implemented using varying technologies [40]	2017	IBM	Yes	No	Yes	Architecture	Case Study	SOA + Ontology	Service modeling, Service management.