Services for Legacy Software Rejuvenation: A Systematic Mapping Study

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Abstract— One of the promises of Service-Orientation and Service-Oriented Architecture (SOA) is the ability to revitalize legacy systems and gain a significant return of efforts and investments. SOA has gained significant attention from academic and industry as a promising architectural style enabling legacy applications to expose and reuse their functionalities. When a research area matures, there is a sharp increase in the number of searches and results available and it is important to summarize and provide a more comprehensive overview of this area. The goal of this work is to investigate the use of services in the modernization of legacy software, gathering information of rejuvenation techniques and technologies adopted. To achieve this goal, a systematic mapping study was performed covering papers recently published in journals, conferences, and workshops, available at relevant electronic databases. This study also presents the characteristics of the selected research divided into six research questions. As a result, 47 studies were selected presenting strategies and solutions for legacy rejuvenation. The results indicate that Java or Object-Oriented systems represent a significant number of legacy systems in operation today, which are adopted migration techniques to become more service oriented. The study also showed a growing number of validations with real use cases in enterprise environment.

Keywords- Systematic Mapping; SOA; Legacy Systems.

I. INTRODUCTION

Nowadays, many companies have systems that have been implemented for some time. These systems must interact with those that are developed nowadays requiring constant adjustment and maintenance to meet new needs and remain aligned with business rules [1].

One of the challenges faced by information technology today is the continuous adaptation and migration of legacy systems to more flexible and modern platforms [2]. With the fast development of business logic and information technology, today´s best solutions are tomorrow´s legacy systems [3].

The legacy systems or existing working systems of enterprise usually contain a mixture of different techniques and protocols which is hard to maintain and update. However, Legacy systems carry out the enterprise's most crucial business information together with business processes and many organizations have leveraged the value of their legacy systems by exposing parts of it as services [4]. Rapid changes in hardware and software technologies combined with the changing requirements require the use of

new methods that enable the evolution of these systems efficiently [5].

Service-Orientations and Service-Oriented-Architecture (SOA) are presented as alternatives to the modernization of legacy systems, recovering investments applied in these systems over the years. Almonaies *et al* [6] list some of the features that ease modernization of these systems, including loose coupling, the implementation of logical abstraction, agility, flexibility and reusability. Migrating legacy systems to services enables the reuse of software components already established, as well as its integration with new services to support changing business needs [1]. Modernizing legacy systems using Services may be accomplished in several ways which vary from the creation of intermediate layers for insertion of new features to the development of a completely new system [7]–[9].

When a research area matures there is a sharp increase in the number of search results available and thus it is important to summarize and provide a more comprehensive overview of this area [10]. Secondary studies as the Systematic Reviews and Mappings have been proposed and defended as the main methods of conducting reviews at primary studies and have become pillars in the practice of evidence-based research [11]. Based on this premise, in order to better understand the area and to identify the shortcomings on it, this paper presents a systematic mapping study of the use of Services to modernize legacy software.

The Mapping Study (MS) reported here follows the guidelines from Kitchenham [12], Petersen [10] and the process proposed by Biolchini *et al*. [13], in which the work was divided into three phases, namely, *i)* Planning, *ii)* Conducting, and *iii)* Reporting results. Its main focus is to identify and classify the techniques and legacy systems that are currently rejuvenated with SOA use. For that, it collects evidence on how research are structured according to modernization strategy, implementation technology, legacy system features, feasibility analysis and the main contribution of each study.

This paper is organized as follows: Section 2 presents the systematic mapping process undertaken in this study; Section 3 presents the main findings and analyzes them; Section 4 presents related works relevant to this research; Section 5 presents the conclusions as well as threats to validity of this research and directions for future works.

II. SYSTEMATIC MAPPING STUDY PLANNING

This section presents how the mapping study methodology has been planned, including the research

questions, search strategy, inclusion, exclusion and classification criteria used to provide a structure of the primary studies. Additional process details can be found at Silva Neto [14].

A. Research Questions

The goal of this study is to identify and classify primary research addressing the use of Service-orientation in legacy modernization by the following main question: "What are the approaches used in the adoption of Services to modernize legacy systems and how these approaches differ from each other?"

In [15], they recommend that as a research question has different focuses, it must be divided into sub questions in order to facilitate the mapping process. The overall goal and question are divided into the following research questions (RQ):

- **RQ1** - What modernization strategy is adopted? The main purpose of this question is to identify the modernization strategies used to choose SOA for legacy modernization.
- **RQ2** - What Service-orientation implementation technology is used? The purpose of this question is to identify which Service implementation technologies are used for the modernization of legacy software.
- **RQ3** – What is the type of modernized legacy system? This question has as objective to identify the type of legacy system modernized through Services.
- **RQ4** – Were there feasibility analysis? This question has as main objective to identify how feasibility analysis was carried out when selecting the use of Services to modernize legacy software. We intended to map the methodologies and techniques used in the feasibility analysis or the complete lack of this kind of activity.
- **RQ5** - What was the proposed contribution? This question has as objective to identify the type of contribution left by primary research, through which possible gaps and research areas still open on the subject can be mapped out.
- **RQ6** - How was the proposal validated? This question is intended to identify how primary research is being validated, the topics of interest are the research populations where the experiments were applied qualitatively and quantitatively.

B. Search Strategy

Considering the search questions, therea set of keywords was identified. The main keywords for search expression are *legacy*, *modernization* and *SOA* with the following related terms:

- **Service-Orientation and SOA:** Service-Oriented Architecture , Webservice, Web Service, RESTful.

- **Modernization:** Migration, Reengineering, re-engineering, evolution
- **Legacy System:** Legacy Software, Legacy Information

Thus, the following search expression was obtained after refinements:

((legacy AND (system OR software OR information)) AND (migration OR modernization OR evolution OR reegineering OR {re-engineering}) AND

(SOA OR webservice OR {web service} OR {Service-Oriented Architecture} OR RESTful))

In addition to research questions and search strategy, we stablished the search sources to find primary studies. In [15]–[20], relevant research bases in the areas of architecture and software engineering in general were found, so we used these works to choose the sources of research in this systematic mapping. Kitchenham[21] recommends including alternative sources of research manually to avoid biasing the research including, among others, a list of search results of the primary research and the Internet itself. Thus they added secondary research bases to perform manual search. Follow the databases chosen:

TABLE I. SELECTED SOURCES

Source	Address
IEEE Xplore	www.ieeexplore.ieee.org
Compendex	www.engineeringvillage.com
Web of Science	www.isiknowledge.com
Scopus	www.scopus.com
Public Domain	www.dominiopublico.gov.br
References	Reference List of primary Studies

The last two rows of Table 1, are secondary research bases to perform manual search.

C. Inclusion/Exclusion criteria

Criteria should be defined to exclude primary research that have no relevance to the research question, as well as ensuring that the relevant work is analyzed [10]. The search of primary studies was divided into three phases or stages, where only selection criteria for excluding non-relevant primary study to the research questions were adopted. The publications that do not fit in any of the exclusion criteria are automatically inserted in the next stages of evaluation.

We named each step and applied the selection criteria as follows on Table II:

- Step one (E1);
- Step two (E2);
- Step three (E3).

TABLE II. INCLUSION/EXCLUSION CRITERIA

Inclusion Criteria
1) Articles published in English from January 2010 to February 2014 for searches in primary research bases
2) Articles in English and Portuguese published from January 2006 to February 2014 for manual searches in the secondary research bases
3) Articles that focus on legacy modernization with services or SOA.
Exclusion Criteria
CS1: repeated publications or already cataloged.
CS2: Very short papers, less than 4 pages.
CS3: Publications that have no direct relation to the main research question and at least one (1) of the sub questions.
CS4: Secondary Studies
CS5: Folders, Books and Catalogues

It was also used the Kitchenham's [21] recommendation that in case of the existence of the same publication in more than one event,the latest one is cataloged.

Quality assessment criteria were defined for the selected studies after the application of exclusion and inclusion criteria. We followed the recommendations in [22], which the evaluation of quality was not used for purposes of exclusion or inclusion, quality assessment was carried out to enhance the quality of the assessed studies.

III.   SEARCH CONDUCTION AND CLASSIFICATION: OVERVIEW OF THE RESULTS

This section presents details of search conduction and classification of the studies.

A. Procedure Selection

As shown, the conduct of research was carried out in three steps :

Step one (E1): Selection and preliminary registration of publications using primary research bases with the application of the search expression.

Step two (E2): Selection of relevant publications based on the title and summary and application of the first filtering based on exclusion criteria.

Step three (E3): Selection of relevant publications based on their full text and application of the second filtering based on exclusion criteria.
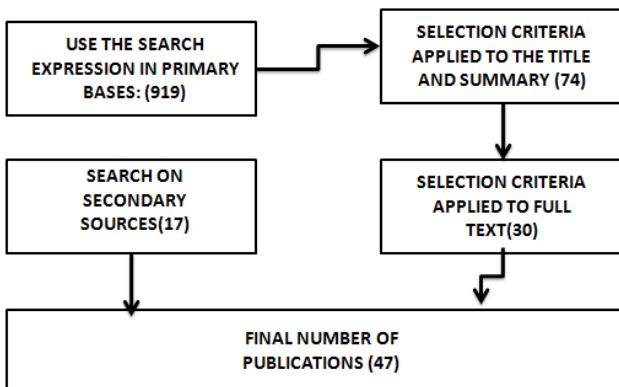

Figure 1. Conduction summary

Initially the search was executed expression in primary search bases selected publications passed through filters as E1, E2 and E3, finally, the search was performed on the secondary databases following the possible exclusion criteria for each base. In [14] there is the complete list of publications. The Appendix A presents Table IX with items chosen after the selection steps.

B. Overview of the results

The completion of the search gives an overview of the subject importance, the publications were classified according to each research question, we also obtained relevant data on authors, events and temporal distribution of publications.

The authors with highest number of selected publications are respectively: Khadka, Patricia Lago and Harry Sneed. We used the Scholar to survey the number of citations received by each publication selected. The most cited publication was the *S38: SOMA:A method for developing service-oriented solutions*.

In order to answer the research questions, there was the classification of selected publications for each research question separately.

RQ1: This research question investigates what strategy or modernization approach was used and heavily mentioned in the selected research. They used the classifications in [9] to group publications in three (3) main types of strategies: Redevelopment (i), Wrapping (ii) and Migration (iii).

The first category, Redevelopment, comprises a complete rewrite of the system in a new technology or language. The second category, encapsulation or Wrapping, also known as the integration is to maintain the legacy system with minimal changes to the source code where a new software layer is added to express the functionality through services. The third category, migration, operates in the restructuring and transformation of legacy systems to more flexible platforms keeping its data and key features, it resembles the first category but there is a less extreme character compared to the level of structural changes.

Table III summarizes the publications according to Q1.1, it used the classifier N/A (No Answer) to identify publications that lacked connection with this research question.

TABLE III. Q1.1 CLASSIFICATION

APPROACH	%	SELECTED PUB
REDEVELOPMENT	6,38%	S17;S30;S40
MIGRATION/ENCAPSULATION	2,12%	S15
MIGRATION ONLY	48,94%	S2;S5;S6;S7;S8;S10;S19;S25;S26;S35;S47;S23;S12;S22;S42;S1;S18;S29;S32;S34;S36;S39;S45
ENCAPSULATION ONLY	23,41%	S3;S14;S21;S31;S33;S37;S41;S11;S16;S20;S27
N/A	19.15%	S4;S9;S24;S44;S46;S43;S28;S13;S38

RQ2: This research question investigates which SOA implementation technology was used or heavily mentioned in research. Although SOA and the term "Services Oriented" are initially agnostic about the technology, they tried to sort through the analysis of primary studies the technology that

allowed the realization of SOA concepts and the modernization of legacy systems through service orientation.

Table IV summarizes the publications according to Q1.2, it used the classifier "N/A" (No Answer) to identify publications that lacked connection with this research question.

TABLE IV. Q1.2 CLASSIFICATION

TECHNOLOGY	%	SELECTED PUB
OSGi	2,12%	S1
SOAP	46,81%	S2;S3;S14;S5;S6;S7;S10;S15; S24;S33;S37;S41;S47;S42;S1 1;S16;S18;S20;S27;S30;S32; S45
RESTFul	4,26%	S19;S36
N/A	46,81%	S4;S8;S9;S17;S21;S25;S26;S 31;S35;S44;S46;S23;S12;S22; S43;S28;S13;S29;S34;S38;S3 9;S40

Regarding publications not receiving classification from the point of view of this question of search, they had focused on general aspects of legacy modernization SOA ranging from indication to migration aid of processes (S4), by comparing the level of maintainability between two approaches (S17), these publications did not address any implementation techniques and received for this reason the classification N / a (no Answer) for this research question.

RQ3: This research question investigates the main features of the legacy system that has undergone modernization, this information is relatively useful in decision making for new projects with similar characteristics to those presented here.

The main features of the rejuvenated systems were grouped according to the programming language when the author stressed to this feature, regarding the type of system in which such languages are grouped, for example: Web Applications (WEBAPP). We also used the general characteristic of the system when the author took black-box methods and language used in the original system was not addressed.

TABLE V. Q1.3 CLASSIFICATION

LEGACY FEATURE	%	SELECTED PUB
JAVA	23,41%	S14;S8;S9;S10;S33;S41;S23; S1;S18;S29;S45
ITERACTIVE/FORM BASED	2,12%	S27
FORTRAN	2,12%	S47
COBOL	21,28%	S5;S15;S24;S25;S26;S42;S16 ;S20;S30;S40
C++	4,26%	S11;S13
WEBAPP	17,02%	S2;S6;S19;S35;S37;S12;S22; S32
N/A	29,79%	S3;S4;S7;S17;S21;S46;S31;S 44;S43;S28;S34; S36;S38;S39

Regarding publications classified as N/A (No Answer) in Table V, they addressed these processes or methodologies in general or the type of system have not made clear who would be modernized, receiving so this classification.

RQ4: This research question investigates the feasibility analysis performed in the SOA option for legacy system

modernization. The goal here was to determine whether the projects or research that addressed legacy modernization SOA presented some technical or business justification. Justifying a project that involves major changes to existing software is an important task that usually involves the analysis of the software, the maintenance process and the business value that the application adds [23].

In Table VI, the studies were classified and grouped according to the practice or approach used to justify the project or indicative of an absence in any case. This research question has the particularity to make explicit that the absence of criteria or feasibility reasons for this fact in itself is relevant to this issue.

TABLE VI. Q1.4 CLASSIFICATION

METHODOLOGY	%	SELECTED PUB
SOMA	6,38%	S21;S33;S38
OWN METHOD	23,41%	S3;S14;S5;S8;S9;S10;S25;S3 5;S44;S1;S40
SAAM	2,12%	S17
INTERNAL COMITE	2,12%	S26
SMART	2,12%	S13
CODE INSPECTION	2,12%	S16
NOT USED	61,70%	S2;S4;S6;S7;S15;S19;S24;S3 1;S37;S41;S46;S47;S23;S12; S22;S43;S42;S28;S11;S18;S2 0;S27; S29;S30;S32;S34;S36;S39;S4 5

Publications that have proposed some kind of process in which there were steps or activities responsible for determining the feasibility received the rating OWN. Publications that showed no indications of feasibility analysis, whether technical or business, were classified as NOT USED. Approximately 61.7% of the publications fit into this category.

RQ5: This question is intended to identify and quantify the contributions provided by selected studies in order to provide information to those who wish to expand or contribute to them. For classification purposes, the works were grouped according to the characteristic that the authors have given greater emphasis to describe the contributions of their research.

TABLE VII. Q1.5 CLASSIFICATION

CONTRIBUITION	%	SELECTED PUB
OVERVIEW	6,38%	S15;S17;S43
PROCESS	40,43%	S2;S3;S4;S5;S6;S8;S9;S10;S2 5;S26;S35;S37; S44;S22;S1;S13;S36;S38;S40
ARCHITECTURE	6,38%	S14;S31;S47
METHODOLOGY	42,55%	S7;S19;S21;S24;S33;S41;S46 ;S23;S12;S42;S28;S18;S20;S 27;S29;S30;S32;S34;S39;S45
TOOL	4,26%	S11;S16

In the analysis of publications that contributed to some kind of methodology on table VIII, (S12 and S24) there are proposed methodologies for business rules extraction through legacy code (S41 and S42) they have proposed methodologies for generation or improvement of the extracted services. In (S7 and S39), the focus of the methodology was the extraction of information that would

help the process of modernization. In (S32, S34, S45, S29, S18, S28, S46 and S19) they have proposed methodologies to identify services from legacy systems, and (S28) emphasized the need to identify the "right" services that actually represent value for Business. Finally, still in relation to methodologies, in publications (S30, S27, S20, S23, S33 and S21), methods or techniques that help the legacy modernization processes have been proposed.

RQ6: This question is intended to identify how the publications were validated and where the study was applied. These ratings on Table VIII are useful to researchers who wish to extend the study area to new research**.**

TABLE VIII. Q1.6 CLASSIFICATION

VALIDATION	%	SELECTED PUB
BUSINESS ENVIRONMENT	51,06 %	S1;S3;S14;S7;S9;S15;S17;S25;S26;S35;S37;S41;S44;S47; S23;S12;S42;S13;S16;S20;S30;S34; S38;S40
ACADEMIC	36,17 %	S2;S4;S5;S6;S8;S10;S19;S24; S33;S46;S22;S11;S18;S27;S29;S32;S45
THEORETICAL	12,77 %	S21;S31;S43;S28;S36;S39

For classification purposes, the names "business environment" and "academic environment" where adopted for primary studies that used cases studies. The first term was used in studies that validated their experiments in companies or through business experiences. The second term joins studies that were validated in academic environments, through simulation or implementation in a highly controlled environment. Studies that confirmed its assumptions based on literature with no explicit use of cases of use were classified as theoretical.

IV.   RELATED WORK

There are others researches addressing the modernization of legacy systems using SOA or services. In a domain where a number of systematic reviews exist already it may be possible to conduct a tertiary review, in order to answer wider research questions [21]. Although this is not the focus of this paper, this section briefly introduces some of these works.

Laguna *et al* [18], conducted a systematic mapping addressing the evolution of software product lines ranging from legacy systems to reengineer product line. The work was conducted in three stages and conducted by two experts. The first step occurred in 2010, the second and third in 2011 and 2012 respectively. At the end of the research they got 74 selected primary studies which were classified regarding the following perspectives: Focus of research, type of contribution and type of validation. These classifications assisted in the formulation of research questions used in the systematic mapping subject of current research.

Razavian and Lago [24], conducted a systematic review addressing the migration of legacy systems to service-oriented systems. The main objective of the review was the

classification of the main migration strategies existing in this area , which they called *SOA Migration Families*.

Khadka *et al* [25], also conducted a systematic review addressing the evolution of legacy systems through SOA. They investigate primary studies produced from 2000 to 2011 getting 121 selected primary studies for classification. The focus of the research took place in the identification and classification methodologies, techniques and approaches relevant to the evolution of legacy to SOA. A framework to guide the rejuvenation process was also developed and used as a guide in their review.

Comparing the work proposed here with the ones already conducted, they were driven around the validation or proposal of a migration process or order to classify the approaches in general. The approach proposed in this systematic mapping aims to present an updated classification based on academic and technological aspects. To achieve this purpose the research questions were adapted to encompass both aspects. A more detailed comparison can be made in a tertiary study.

V.   CONCLUSIONS AND FUTURE WORK

The aim of this study was to classify and give an overview of SOA use in the rejuvenation of legacy software. 919 primary studies obtained in search databases widely used in the field of Software Engineering were analyzed. 17 other publications were obtained through manual searches on a reference list in conjunction with conducting searches on Brazilian Public Domain Portal.

From 936 publications found, 47 were selected for analysis which were classified according to six research questions to establish technical and scientific overview updated of the use of SOA in legacy modernization.

The results indicate that migration strategies are the most commonly used, followed by encapsulation techniques. The results also showed that in studies that addressed migration the predominant theme in the studies is to propose processes or methodologies that support or guide the migration projects.

Regarding the type of system or language in which the modernized system was developed, most publications that presented this information were related to systems developed in the Java programming language, the second largest representation was developed in COBOL systems, followed by legacy web. This may indicate the difficulty in disposing of old COBOL systems, justifying the investment in its rejuvenation.

On the feasibility analysis in research involving rejuvenating legacy systems using SOA, it was found that approximately 23.4% of publications used a process or method owned by the author to perform feasibility studies indicating a concern with these activities. However, a critical result is that approximately 61.70% of the total publications made no reference to analysis or feasibility study to choose SOA to modernize legacy software.

On the analysis of each contribution, the results show that the publications that contributed to some kind of process, prioritized guides for modernization tasks, being followed by publications to assist in decision-making on

technical feasibility and the identification of services from legacy systems, while publications that contributed methodologies have mostly focused on identifying services.

Regarding the validation of each study, the results showed that those who used the business environment to implement the use cases, chose majoritary banking and financial sectors while the experimental validations dominates the use cases on open source projects in general.

The results showed that the applications in Java or object-oriented already represent a significant number of legacy systems in operation. Migration techniques are easily applied to make this systems service oriented.

The following itens are the main threats to the validity of the results of this study:

(i) Although recommended, manual searches depend on too the opinion of mapping drivers and may lead to biased results.

(ii) A decrement factor in the validity of the research lies in the limitations imposed by the search engines of digital research sources that limiting the replication for future work.

The related studies have shown the presence of other secondary studies on similar topics. Thus, it is proposed for future work, to conduct a tertiary review to take a more global result of the use of services in the rejuvenation of legacy systems.

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APPENDIX A. PRIMARY STUDY

TABLE IX. SELECTED PAPERS

ID	PUBLICATION
S1	Cuadrado, Félix, et al. "A case study on software evolution towards service-oriented architecture." *Advanced Information Networking and Applications-Workshops, 2008. AINAW 2008. 22nd International Conference on*. IEEE, 2008.
S2	Almonaies, Asil A., et al. *A framework for migrating web applications to web services*. Springer Berlin Heidelberg, 2013.
S3	Baghdadi, Youcef, and Wisal Al-Bulushi. "A guidance process to modernize legacy applications for SOA." *Service Oriented Computing and Applications*9.1 (2015): 41-58.
S4	Razavian, Maryam, and Patricia Lago. "A lean and mean strategy for migration to services." *Proceedings of the WICSA/ECSA 2012 Companion Volume*. ACM, 2012.
S5	Khadka, Ravi, et al. "A method engineering based legacy to SOA migration method." *Software Maintenance (ICSM), 2011 27th IEEE International Conference on*. IEEE, 2011.
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