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Abstract

Enterprises depend on business-critical systems that have been developed over the last three decades or more, also known as legacy systems. They have several well-known disadvantages (e.g., inflexible, domain unspecific, and hard to maintain), and this is recognized by both the vendors and customers of these software systems. Both vendors and customers of these systems are well aware that better and cheaper customer specific solutions can be created following the service-oriented paradigm. Hence, momentum is growing within enterprises to evolve legacy systems towards Service-Oriented Architecture (SOA). The evolution to SOA is favored because of various advantages including well established sets of open standards, platform and language independent interfaces, clear separation of service interface and implementation, and loose-coupling among services.

Over a decade there have been significant developments in legacy to SOA evolution and that has resulted in a large research body of which there exists no comprehensive overview. This chapter provides an historic overview, focusing on the methods and techniques used in a legacy to SOA evolution. We conducted a systematic literature review to collect legacy to SOA evolution approaches reported from 2000 to August 2011. To this end, 121 primary studies were collected and evaluated using an evaluation framework. This report presents the evaluation results of the systematic literature review.

1. INTRODUCTION

Recently, many enterprises have focused on increasing their business flexibility and achieving cross-enterprise collaboration to remain competitive in the market, and to meet their business objectives. Enterprises are especially challenged by constant changes in the business environment and changes in the supporting information technology (IT) infrastructures that hinder the overall success of enterprises (van Sinderen, 2008). Furthermore, most enterprises still rely on so called legacy system- software developed over the previous decades using 3GL programming languages like COBOL, RGP, PL/I. Despite the well-known disadvantages, such as being inflexible and hard to maintain, legacy systems are still vitally important to the enterprises as they support complex core business processes; they cannot simply be removed as they implement and store critical business logic. Unsurprisingly, the knowledge contained in these systems is of high value to an enterprise. On the other hand, proper documentation, skilled manpower and resources to evolve these legacy systems are scarce. Therefore, momentum is growing to evolve and reuse those legacy systems within new technological environments – Service-Oriented Architecture (SOA) being the most promising one (Bisbal, Lawless, Wu, & Grimson, 1999; Lewis, Morris, O'Brien, Smith, & Wrage, 2005).

SOA has emerged as an architectural style that enables the reuse of existing legacy assets within a new paradigm that facilitates loose coupling, abstraction of underlying logic, flexibility, reusability and discoverability (Papazoglou, 2008). The evolution from legacy to SOA can be beneficial from both economical and technical perspectives. From an economical perspective, legacy to SOA evolution fosters

change management including intra-organizational changes, and changes in enterprises (Khadka, Sapkota, Pires, Sinderen, & Jansen, 2011; Papazoglou, Traverso, Dustdar, & Leymann, 2007). From a technical perspective, seamless enterprise collaboration through service composition (Khadka & Sapkota, 2010) and reduction in maintenance cost are claimed as long term benefits (Papazoglou, et al., 2007; Schelp & Aier, 2009). Motivated by these benefits, there has been significant research in legacy to SOA evolution. However, there is no systematic overview of legacy to SOA evolution, particularly focusing on the techniques, methods and approaches used to evolve legacy systems to a SOA environment. In the systematic literature review conducted by Razavian (Razavian & Lago, 2010), an overview of SOA migration families is reported. It focuses on classifying the SOA migration approaches into eight distinct families. The classification is inspired by the reengineering horseshoe method (Bergey, Smith, Weiderman, & Woods, 1999) rather than giving a historical overview of SOA migration methods. Also, a brief overview of legacy to SOA evolution is reported by Almonaies (Almonaies, Cordy, & Dean, 2010) that divides the legacy to SOA evolution approaches into four categories: replacement, redevelopment, wrapping and migration. The legacy to SOA evolution approaches reported in this research were not based on any systematic literature review process, so a complete, historical overview of the legacy to SOA evolution approaches is still lacking.

We have conducted a Systematic Literature Review (SLR) of the existing literature of legacy to SOA evolution and is reported in Khadka et al. (Khadka, Saeidi, Idu, Hage, & Jansen, 2012). In this report, we provide the evaluation results of the SLR along with the research questions and evaluation criteria used for the review.

The report is structured as follows: Section 2 presents the research questions and evaluation criteria, Section 3 presents the evaluation results in a form inventory table in which methods and techniques used in legacy to SOA evolution research papers are presented, and Section 4 provides the conclusion of this report.

2. RESEARCH QUESTIONS AND EVALUATION CRITERIA

In order to achieve our objective of creating an overview of legacy to SOA evolution approaches, we have formulated the following research questions:

i. *How can a legacy to SOA evolution method be systematically defined?*
ii. *What methods and techniques are used to facilitate such a systematic legacy to SOA evolution method?*
iii. *What are the existing research issues and what should be the future research agenda in legacy to SOA evolution?*

In order to answer these research questions, we have developed an evaluation framework for legacy to SOA evolution (Khadka, et al., 2012). Based on the evaluation framework, Table 1 depicts the evaluation criteria and Table 2 presents the description of the judgment scale used in the evaluation criteria. Furthermore, Table 3 provides the details findings of our SLR, consisting of 121 primary studies that report legacy to SOA evolution. Table 3 provides the inventory of methods and techniques used in legacy to SOA evolution process for each primary study.

Table 1. The evaluation criteria based on the evaluation framework.

Stage	Phase	Evaluation question	Answer
Evolution planning	Legacy system understanding	Does the solution include legacy system understanding?	Yes/No
		Which technique(s) is used for legacy system understanding?	Narrative
		To what extent are those techniques used?	Scale
		Is there any tool support for legacy system understanding?	Yes/No
	Target system understanding	Does the solution include target system understanding?	Yes/No
		What criteria/factors are included for target system understanding?	Narrative
		To what extent are those criteria/factors used?	Scale
	Evolution feasibility determination	Does the solution include evolution feasibility assessment?	Yes/No
		What technique(s) is used for evolution feasibility assessment?	Narrative
Evolution implementation & management	Candidate service identification	Does the solution include candidate service identification?	Yes/No
		What technique(s) is used for identifying candidate services?	Narrative
		Is there tool support for candidate service identification?	Yes/No
	Implementation	Does the solution provide any implementation technique for evolution?	Yes/No
		What technique(s) is used for implementation?	Narrative
		Is there tool support for the implementation?	Yes/No
	Deployment & provisioning	Does the solution provide deployment & provisioning of the services?	Yes/No
Case study		What empirical evidence (industrial/experiment) is provided?	Narrative
		In which language is the legacy system developed?	Narrative

Table 2: The judgment scale to assess the support of techniques/ method used

Scale point	Scale Definition	Representation
No support	The specified technique is not mentioned.	-
Implicitly discussed	The specified technique is mentioned.	+
Explicitly discussed	The specified technique is mentioned and discussed but no detailed information is given.	++
Explicitly discussed with evidence of use	The specified technique is mentioned, discussed and there is empirical evidence of its usability.	+++

3. EVALUATION RESULTS

Table 3: Evaluation table of Legacy to SOA Evolution SLR

Reference	Evolution Planning									Evolution Implementation and Management							Case Study	
	Legacy System Understanding				Target System Understanding			Evolution Feasibility		Candidate Service Identification			Implementation			Deploy and Provisioning		
	Y / N	Technique	Scale	Tool supp.	Y / N	Technique	Scale	Y / N	Technique	Y / N	Technique	Tool supp.	Y / N	Technique	Tool supp.		Exp. / Ind.	Language
(Ricca & Marchetto, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Manual	N	Y	Wrapping	N	N	Exp.	N/A
(B. Zhang, Bao, Zhou, Hu, & Chen, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	N/A
(Rabhi, Dabous, Yu, Benatallah, & Lee, 2004)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	N	N	Ind.	N/A
(Cuadrado, García, nas, & Parada, 2008)	Y	Reverse Engineering, Architectural Recovery, Documentation, User's Manual, Static Analysis, Dynamic Analysis, Abstraction	++	Y	Y	Specific Architecture Selection, Specific Architecture Selection	+	Y	Technology Interoperability	Y	Manual	N	Y	Refactoring	N	N	Ind.	Java
(Salama & Aly, 2008)	Y	Source Code Analysis	+	Y	N	N/A	-	Y	Filtration, Organizational Assessment, Cost Benefit Analysis	N	N/A	N	N	N/A	N	N	N/A	N/A
(Feng Chen, Yang, Qiao, & Chu, 2006)	Y	Reverse Engineering	+	Y	N	N/A	-	N	N/A	N	N/A	N	Y	Model Transformation, Abstraction, Code Translation, Program Transformation	Y	N	Exp.	Assembly

(H. Y. Huang, Tan, Zhu, & Zhao, 2008)	Y	System Deconstruction, Documentation, Dynamic Analysis	++	N	N	N/A	-	N	N/A	Y	Dependency Analysis	N	Y	Packaging, Interface Generation	N	N	Ind.	EJB (Enterprise JavaBeans)
(Khadka, Reijnders, Saeidi, Jansen, & Hage, 2011)	Y	Technical Analysis, Functional Analysis, Documentation, Interviewing	+++	N	Y	Service Requirements Identification	-	Y	Cost Benefit Analysis	Y	Concept Analysis	N	Y	Concept Slicing	Y	Y	Ind., Exp.	COBOL, C++
(Guzmán, Polo, & Piattini, 2006)	Y	Reverse Engineering, Model Transformation	+++	N	N	N/A	-	N	N/A	N	Pattern Matching	N	Y	Code Generation	N	N	Ind.	SQL-92
(Lu, Huang, Xu, & Yu, 2005)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Middleware	N	N	Exp.	N/A
(Alahmari, Roure, & Zaluska, 2010)	Y	Reverse Engineering, Model Transformation, Interviewing, Questionnaires, Portfolio Analysis, Process Modelling	+++	Y	N	N/A	-	N	N/A	Y	Manual	N	N	N/A	N	N	Exp.	Java
(Hoyer, et al., 2009)	Y	Reverse Engineering, Program Understanding	+	N	N	N/A	-	N	N/A	N	N/A	N	Y	Model Transformation, Adaptors	Y	N	Ind.	N/A
(X. Li, 2010)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Agentification	N	N	Ind.	N/A
(Bertani-Carrera, Alor-Hernandez, Juarez-Martinez, & Posada-Gomez, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Encapsulation, Multi-Layered Architecture	N	N	Ind.	Visual Basic 6, Microsoft Access
(Parsa & Ghods, 2008)	Y	Reverse Engineering	+	Y	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	Y	Ind.	Pascal
(Harry M. Sneed, 2009)	N	N/A	-	N	N	N/A	-	Y	Code Complexity, Reusability Assessment	Y	Manual	N	Y	Code Stripping, Wrapping	Y	N	Exp.	Cobol

(Lammer, Eggert, & Gronau, 2008)	Y	System Deconstruction	+	N	N	N/A	-	N	N/A	Y	Self-Diagnosis	N	Y	Wrapping	N	N	Ind.	ERP System: Microsoft Dynamics NAV ECM System: Optimal Systems OS.5|ECM
(Zhuo Zhang, Zhou, Yang, & Zhong, 2010)	Y	Dynamic Analysis	++	N	N	N/A	-	N	N/A	Y	Pattern Discovery, Pattern Anaylsis, Data Mining	N	N	N/A	N	N	Ind.	N/A
(Alahmari, Zaluska, & De Roure, 2010)	Y	Reverse Engineering, Model Transformation, Interviewing, Questionnaires, Portfolio Analysis, Process Modelling	+	Y	N	N/A	-	N	N/A	Y	Manual	N	N	N/A	N	N	Exp.	Java
(Z. Zhang, Yang, Zhou, & Zhong, 2010)	Y	Reverse Engineering, Domain Analysis	++	N	Y	Domain Business Logical Model	++	N	N/A	Y	Matching Algorithm	N	Y	Wrapping, Code Modification, Redevelopment	N	N	Exp.	Java
(Z. Li, Anming, Naiyue, Jianbin, & Zhong, 2009)	Y	Documentation, Portfolio Analysis	+	N	N	N/A	-	N	N/A	Y	Manual	N	Y	Wrapping	N	N	N/A	N/A
(Mínguez, Jakob, Heinkel, & Mitschang, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Adaptors, Middleware	N	N	Ind.	N/A
(Balis, Bubak, & Wegiel, 2005)	N	N/A	-	N	Y	Specific Architecture Selection, Scenarios	++	N	N/A	Y	Manual	N	Y	Middleware, Multi-Layered Architecture, Encapsulation, Code Generation	Y	N	N/A	N/A
(De Lucia, Francese, Scanniello, Tortora, & Vitiello, 2006)	Y	Business Analysis, Documentation, Source Code Analysis, Interviewing,	+++	N	Y	Specific Technology Selection, Specific Architecture Selection	+	Y	System Decomposability, System Complexity	N	N/A	N	Y	Wrapping, Restructuring, Interface Generation	Y	N	Exp.	Cobol

(X. Y. Li & Qian, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping, Agentification	N	N	Ind.	N/A
(Gerardo Canfora, Fasolino, Frattolillo, & Tramontana, 2008)	Y	Reverse Engineering, Static Analysis, Dynamic Analysis	++	N	N	N/A	-	N	N/A	Y	Business Value, Technical Quality Assessment, Use Cases	N	Y	Wrapping, Finite State Automaton Specification	N	Y	Ind.	N/A
(Masahide Nakamura, Tanaka, Igaki, Tamada, & Matsumoto, 2006)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Multi-Layered Architecture, Wrapping	N	N	Ind.	Infrared Remote Control API
(Gonzalez, Penalvo, Guerrero, & Forment, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Adaptors, Wrapping	N	N	Ind.	N/A
(Nasr, Gross, & Deursen, 2010)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Middleware	N	N	Ind.	J2EE, .NET
(R. Liu, Chen, Yang, Chu, & Lai, 2004)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Agentification	N	N	N/A	N/A
(Guzman, Polo, & Piattini, 2007)	Y	Reverse Engineering	++	Y	N	N/A	-	N	N/A	Y	Pattern Matching	N	Y	Pattern Matching	N	Y	Ind.	Oracle, SGBB
(Del Grosso, Di Penta, & de Guzman, 2007)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Dynamic Analysis, Formal Concept Analysis	Y	N	N/A	N	N	Exp.	Java
(Al Belushi & Baghdadi, 2007)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Knowledge Mining, Reverse Engineering	Y	Y	Forward Engineering, Wrapping	N	N	N/A	N/A
(Lee, Kim, & Yang, 2004)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Code Translation	Y	N	N/A	N/A
(Lewis, Morris, & Smith, 2006)	Y	Documentation , Interviewing, Interviewing, Source Code Analysis, Architectural Reconstruction	+++	Y	Y	SOA Environment Details, Functional Specification	+++	Y	Code Complexity, Dependency Analysis, Risk Analysis, Cost Benefit Analysis	Y	Manual	N	N	N/A	N	N	Ind.	C++
(T. Haase & Nagl, 2011)	Y	Reverse Engineering, Code Transformation	++	Y	N	N/A	-	N	N/A	N	N/A	N	Y	Code Generation	N	N	Exp.	N/A
(Heckel, et al., 2008)	Y	Reverse Engineering, Code Annotation	+++	N	N	N/A	-	N	N/A	N	N/A	N	Y	Redesign, Forward Engineering, Graph Transformation	N	N	Exp.	Java

(Kapsalis, Charatsis, Georgoudakis, & Papadopoulos, 2003)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	N/A	N/A
(Bissyandé, Réveillère, Bromberg, Lawall, & Muller, 2010)	Y	Code Transformation	++	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	z2z, Janus
(S. Li, Yang, & Zhou, 2004)	Y	Reverse Engineering	+	N	Y	N/A	+	N	N/A	N	N/A	N	Y	Abstraction, Restructuring, Refinement	N	N	Ind.	N/A
(Kouamou, 2009)	Y	Reverse Engineering	+++	N	Y	Functional Specification, SOA Environment Details	++	N	N/A	N	N/A	N	Y	Multi-Layered Architecture, Wrapping, Adaptors	Y	N	Ind.	J2EE
(Arcelli, Tosi, & Zanoni, 2008)	Y	Design Pattern Detection	++	N	N	N/A	-	N	N/A	Y	Design Pattern Detection	N	N	N/A	N	N	N/A	N/A
(H.M. Sneed, 2008)	N	N/A	-	N	N	N/A	-	Y	Code Complexity, Reusability Assessment	Y	Manual	N	Y	Code Stripping, Wrapping	Y	N	Ind.	COBOL
(Ferber, Rauber, & Hunold, 2010)	Y	Source Code Analysis	++	Y	Y	Component Specification	+++	N	N/A	N	N/A	N	Y	Middleware, Wrapping	N	N	Exp.	Java
(M. Nakamura, Tanaka, Igaki, Tamada, & Matsumoto, 2008)	N	N/A	-	N	Y	N/A	+	N	N/A	Y	Manual	N	Y	Wrapping	N	N	Exp.	C++
(Grechanik, Conroy, & Swaminathan, 2007)	N	N/A	-	N	Y	Specific Technology Selection	++	N	N/A	Y	Manual	Y	Y	Wrapping	Y	Y	Exp.	N/A
(H. Sneed & Sneed, 2003)	Y	Function Mining	+++	Y	Y	Functional Specification	N/A	N	N/A	Y	Function Mining	Y	Y	Wrapping	Y	N	Ind.	COBOL, COBOL-CICS, C
(Feng, Cheng, & Zhao, 2006)	N	N/A	-	N	Y	Functional Specification, Specific Technology Selection	+++	N	N/A	N	N/A	N	Y	Agentification	N	N	Ind.	N/A
(Alor-Hernandez, Juarez-Martinez, Posada-Gomez, Chavez-Trejo, & Rocha-Aragon, 2009)	N	N/A	-	N	Y	Specific Architecture Selection	+++	N	N/A	Y	Information Discovery	N	Y	Wrapping	N	Y	Ind.	Visual Basic 6

(G. Liu, 2010; Millard, et al., 2006)	Y	Scenarios, Use Cases	+	N	Y	Specific Architecture Selection	+	N	N/A	N	N/A	N	Y	Wrapping	N	N	Ind.	N/A
(Millard, et al., 2006)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Application of Design Patterns	N	Y	Wrapping	N	N	Exp.	.Net
(De Lucia, Francese, Scanniello, & Tortora, 2008)	Y	Interviewing, Documentation, Source Code Analysis, Reverse Engineering	+++	Y	Y	Specific Platform Selection, Specific Architecture Selection	+++	N	N/A	N	N/A	N	Y	Wrapping	Y	Y	Ind.	COBOL
(Lewis & Smith, 2007)	Y	Interviewing, Documentation, Program Understanding, Source Code Analysis, Architectural Reconstruction	++	N	Y	SOA Environment Details, Specific Standards Selection, Specific Technology Selection	++	N	N/A	Y	N/A	N	N	N/A	N	N	N/A	N/A
(Shimin Li & Tahvildari, 2008)	Y	Architectural Recovery, Source Code Modelling	++	Y	N	N/A	-	N	N/A	Y	Source Code Analysis	Y	N	N/A	N	N	Exp.	Java
(Erradi, Anand, & Kulkarni, 2006)	Y	Portfolio Analysis, Interviewing, Source Code Analysis	+++	Y	Y	Decision Making Criteria	+++	Y	Multi Criteria Decision Making	N	N/A	N	N	N/A	N	N	Ind.	N/A
(Jandl, Alber, Radinger, & Goeschka, 2004)	N	N/A	-	N	Y	Specific Technology Selection	++	N	N/A	N	N/A	N	Y	Wrapping	N	N	N/A	N/A
(Zhuopeng Zhang, Yang, & Chu, 2006)	Y	Source Code Analysis	+++	N	N	N/A	-	Y	Options Analysis for Re-engineering	Y	Formal Concept Analysis	Y	Y	Program Slicing, Wrapping	N	N	Exp.	Java
(Bao, Yin, He, Ge, & Chen, 2010)	Y	Dynamic Analysis	-	N	N	N/A	N/A	N	N/A	Y	Use Cases, Manual	N	Y	Program Slicing, Modularization	Y	Y	Exp.	Java
(M. Nakamura, Igaki, Kimura, & Matsumoto, 2009)	Y	Reverse Engineering, Data Flow Analysis	-	N	N	N/A	-	N	N/A	Y	Dependency Analysis	N	Y	Wrapping	N	N	Exp.	C
(Baker, Lamb, Taleb-Bendiab, & Al-Jumeily, 2010)	N	N/A	-	N	Y	Specific Standards Selection, Specific Technology Selection	+	N	N/A	Y	N/A	N	Y	Wrapping, Model Transformation	Y	N	Exp.	N/A
(Feng Chen, Li, & Chu, 2005)	Y	Feature Location Technique	+	Y	Y	Specific Standards Selection	+	N	N/A	Y	Feature Analysis	Y	Y	Wrapping	Y	N	Exp.	N/A

(Marchetto & Ricca, 2009)	Y	Documentation, Reverse Engineering, Use Cases, Test Cases	++	N	N	N/A	-	N	N/A	Y	Functionality Analysis, Database Analysis, Cross-cutting Functionality Analysis, Test Cases	N	Y	Wrapping, Rewriting	N	Y	Exp.	Java
(Nguyen, van den Heuvel, Papazoglou, de Castro, & Marcos, 2009)	Y	Service Schema Specification	+++	N	Y	Service Schema Specification	+++	N	N/A	Y	Process Structure Tree	N	N	N/A	N	N	Exp.	Java, SAP
(Lamprecht, et al., 2008)	Y	Documentation	+	N	Y	Specific Architecture Selection	+++	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Ind.	C
(Vemuri, 2008)	Y	Test Cases, Feature Analysis	+++	N	N	N/A	-	Y	Return of Investment	Y	Feature Analysis	N	Y	Wrapping, Rewriting, Refactoring, COTS, Declarative Rule Engine	N	N	Ind.	N/A
(Zhuopeng Zhang & Yang, 2004)	Y	Reverse Engineering	+++	Y	Y	Specific Architecture Selection	+++	N	N/A	Y	Domain Analysis, Agglomerative Clustering	N	Y	Wrapping	N	Y	Ind.	C++
(Woollard, Mattmann, & Medvidovic, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	N	N	Ind.	Fortran, C
(Harry M. Sneed, 2006)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Business Rule and Value Analysis	N	Y	Code Stripping, Wrapping	Y	N	Ind.	COBOL
(Andal, Habiba, & Hakima, 2010)	N	N/A	-	N	Y	Specific Architecture Selection	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	COBRA
(Feldhorst, Libert, Hompel, & Krumm, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Multi-Layered Architecture	Y	N	Ind.	N/A
(Balderrama, Montagnat, & Lingrand, 2010)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	Y	Ind.	N/A
(Qu, Bollig, & Erlebacher, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	Y	Exp.	TCL

(Zhou, Zhang, Chee, & Chen, 2010)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Domain Analysis, Goal-Service Modeling, Business Process Decomposition	Y	N	N/A	N	N	N/A	N/A
(Cetin, et al., 2007)	Y	N/A	+	N	Y	BPMN	++	N	N/A	Y	Manual	N	Y	Wrapping, Code Customization, COTS, Screen Scraping	N	Y	Ind.	N/A
(El-Ramly, Stroulia, & Samir, 2009)	Y	Reverse Engineering	+	N	Y	Functional Specification	+	N	N/A	N	N/A	N	Y	Wrapping	N	N	N/A	N/A
(M. Li & Qi, 2004)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	Cobol
(Sindhgatta & Ponnalagu, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Information Retrieval	Y	N	N/A	N	N	Exp. Ind.	Java
(Koschel, Kleiner, & Astrova, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Integration	Y	N	Ind.	Natural, ADABAS DB
(Yürekten, Dinçer, Akar, Sungur, & Özbudak, 2006)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Model Transformation	Y	N	Ind.	N/A
(G. Canfora, Fasolino, Frattolillo, & Tramontana, 2006)	Y	Reverse Engineering	+	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	Y	Exp.	N/A
(Webster, et al., 2011)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	N	N	Ind.	N/A
(Alahmari, Zaluska, & Roure, 2010)	Y	Reverse Engineering, Portfolio Analysis, Documentation, Process Modeling	+++	Y	N	N/A	-	N	N/A	Y	Manual	N	N	N/A	N	N	Exp.	Java
(Millham, 2010)	Y	Reverse Engineering	+	Y	N	N/A	-	N	N/A	Y	Shared File Usage Analysis, Domain Analysis	N	Y	Wrapping	N	N	Ind.	COBOL
(Kroculick, 2011)	N	N/A	-	N	Y	Quality Attributes, Open Architecture Assessment	++	Y	DSDR 11 (DoD)	N	N/A	N	Y	N/A	N	N	N/A	N/A
(Aversano, Cerulo, & Palumbo, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	Y	XML Comparison to WSDL, Information Retrieval, Kokash	Y	N	N/A	N	N	Exp.	PHP, Java

											Algorithm							
(Fuhr, Horn, Riediger, & Winter, 2011)	Y	Code Parsing, Model Transformation	++	Y	N	N/A	-	N	N/A	Y	Graph Query	Y	Y	Graph Transformation	Y	N	Exp.	Java
(Ilk, Zhao, & Hofmann, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Ontology Modelling, Ontology Mapping	N	N	N/A	N	N	Exp.	ABAP
(Del Castillo, García-Rodríguez, & Caballero, 2009)	Y	Interviewing, Database Model Recovery	-	N	Y	Interviewing	-	N	N/A	Y	Model Driven Pattern Matching	Y	Y	Model Driven Program Transformation	Y	Y	Ind.	ASP/.NET
(Umar & Zordan, 2009)	Y	Strategic Analysis	++	N	N	N/A	-	Y	Strategic Analysis, Architecture Analysis, Cost Benefit Analysis	N	N/A	N	N	N/A	N	N	Ind.	N/A
(Y. Liu, Wang, Zhuang, & Zhu, 2008)	Y	Reverse Engineering	+	N	N	N/A	-	N	N/A	Y	Manual	N	Y	Wrapping	N	Y	N/A	N/A
(Tangjianfeng, Zhangxianing, & Wangjicheng, 2009)	N	N/A	-	N	Y	Specific Architecture Selection	++	N	N/A	N	N/A	N	Y	Adapt Transition Approach	Y	N	Ind.	Mainframe
(Zhao & Wang, 2010)	Y	Reverse Engineering	+++	N	Y	Specific Architecture Selection	+++	N	N/A	N	N/A	N	Y	Wrapping	N	N	Ind.	.Net, J2EE
(Pena, Correal, & Hernandez, 2010)	Y	Portfolio Analysis	+++	Y	Y	Specific Architecture Selection, System Ecosystem, Service Portfolio, SOA Domain Specific Language	+++	Y	Risk Analysis, Model Comparison	Y	Correspondence Analysis	N	N	N/A	N	N	Exp.	N/A
(van Geet & Demeyer, 2010)	Y	Reverse Engineering, Interviewing, Source Code Visualization, Feature Location Technique	-	N	N	N/A	-	N	N/A	Y	Reverse Engineering, Interviewing, Source Code Visualization, Feature Location Technique	N	N	N/A	N	N	Ind.	COBOL, Assembly

(Baghdadi, 2006)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Reverse Engineering, Application of CRUD Operations Patterns, Application of Transformation Patterns	Y	Y	Forward Engineering, Code Generation	N	N	N/A	N/A
(Bouras, Alexandrou, Pardalis, & Gouvas, 2010)	N	N/A	-	N	Y	Specific Architecture Selection	++	N	N/A	N	N/A	N	Y	Wrapping, Semantic Enrichment	N	Y	N/A	N/A
(Pieczykolan, Kryza, & Kitowski, 2006)	N	N/A	-	N	N	N/A	N/A	N	N/A	N	N/A	N	Y	Adaptors	Y	N	N/A	PL/SQL
(Z. Zhang, Liu, & Yang, 2005)	Y	Options Analysis for Reengineering (OAR), Architectural Recovery, System Decomposition	++	Y	Y	Functional Specification	+	N	N/A	Y	Concept Analysis, Feature Location Technique, Cluster Analysis	N	Y	Dependency Analysis, Refinement	N	Y	Ind.	N/A
(F. Chen, Zhang, Li, Kang, & Yang, 2009)	Y	Source Code Analysis, Documentation	+	N	Y	Application Domain Analysis	+	Y	Legacy System Assessment	Y	Ontology Mapping, Static Analysis, Dynamic Analysis	N	Y	Program Slicing	N	N	Ind.	C++
(Th. Haase & Nagl, 2008)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping, Model Driven Transformation, Adaptors	Y	N	N/A	N/A
(Lewis, Morris, Smith, & O'Brien, 2005)	Y	Interviewing, Documentation	++	N	Y	Interviewing, Reference Models, SOA Environment Details	++	Y	Cost Benefit Analysis, Code Complexity	Y	Manual	N	N	N/A	N	N	Ind.	C++
(Chung, Won, Baeg, & Park, 2009)	Y	Reverse Engineering, 5W1H	+++	Y	N	N/A	-	N	N/A	Y	Pattern Recognition	N	N	N/A	N	N	Exp.	C#
(Chung, An, & Davalos, 2007)	Y	Reverse Engineering	+	N	Y	Service-Oriented Forward Software Engineering Process	+	N	N/A	N	N/A	N	Y	Forward Engineering	Y	N	Ind.	N/A

(Balasubramaniam, Lewis, Morris, Simanta, & Smith, 2008)	Y	Service Migration Interview Guide, Architectural Reconstruction, Documentation	+++	N	Y	SOA Environment Details, Specific Standards Selection, Specific Technology Selection, Guidelines for Service Implementation, QoS of Target System	+++	Y	Migration Feasibility Decision Point	Y	Manual	N	N	N/A	N	N	Ind.	C++, C#, Managed C++
(Kavianpour, 2007)	Y	Enterprise Architecture and Application Portfolio, Architectural Recovery, Model Repository, Documentation	-	Y	Y	Architecture Driven Modernization, Feature Gap Analysis	-	Y	Portfolio Analysis, Cost Benefit Analysis	N	N/A	N	Y	Wrapping, Replacement	N	N	N/A	N/A
(Bhallamudi & Tilley, 2011)	Y	Requirements Analysis, Architectural Recovery, Program Understanding	+++	N	N	N/A	N/A	Y	Migration Feasibility Decision Point	N	N/A	N	N	N/A	N	Y	Ind.	N/A
(G. Huang, 2009)	N	N/A	-	N	Y	Specific Architecture Selection	++	N	N/A	N	N/A	N	Y	Wrapping	N	N	N/A	N/A
(Liam & Brien, 2005)	Y	Architectural Reconstruction, Program Understanding	+++	Y	Y	Interviewing, Documentation, Requirements	+++	Y	Options Analysis for Re-engineering	N	N/A	N	N	N/A	N	N	Ind.	C++
(Mudiam, Gannod, & Lindquist, 2006)	N	N/A	−	N	N	N/A	−	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	N/A
(Zillmann, et al., 2011)	Y	Reverse Engineering, Documentation, Test Cases, Static Analysis, Dynamic Analysis	+++	N	Y	Specific Architecture Selection	-	Y	Technical Feasibility	Y	Business Process Mapping	N	Y	Code Transformation	Y	Y	Ind.	Java
(J. Zhang, Chang, Zhang, & Hung, 2007)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	N	Y	Ind.	N/A
(Streekmann & Hasselbring, 2008)	N	N/A	−	N	Y	Specific Architecture Selection	+	N	N/A	N	N/A	N	Y	Wrapping	N	N	N/A	N/A

(Djelloul, Mimoun, & El Kader, 2009)	Y	Reverse Engineering	++	Y	N	N/A	-	N	N/A	N	N/A	N	Y	Code Transformation	Y	N	Ind.	N/A
(Jiang & Stroulia, 2004)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Pattern Mining	Y	Y	Wrapping	Y	N	Ind.	N/A
(Marchetto & Ricca, 2008)	Y	Reverse Engineering, Documentation, Functional Requirements	+	N	N	N/A	-	N	N/A	Y	Business Rule Recovery, Architectural Recovery	N	Y	Program Slicing, Wrapping	Y	Y	Exp.	Java
(Petcu & Baltat, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Exp.	C++
(Di Lorenzo, Fasolino, Melcarne, Tramontana, & Vittorini, 2007)	Y	Manual, Execution Scenarios	-	N	N	N/A	-	N	N/A	Y	Dynamic Analysis	N	Y	Wrapping	Y	N	Exp.	Web application
(Gimnich, 2009)	N	N/A	-	N	N	N/A	-	N	N/A	Y	Manual	N	Y	Wrapping	N	Y	Ind.	Cobol, PLI, Assembler
(Zou & Kontogiannis, 2000)	N	N/A	–	N	N	N/A	–	N	N/A	N	N/A	N	Y	Wrapping	N	N	N/A	N/A
(Xu, Duan, & Yang, 2005)	Y	Architectural Components Understanding	+	N	N	N/A	–	N	N/A	N	N/A	N	Y	Transformation	Y	N	Exp.	Java
(Guo, Guo, Chen, & Yang, 2005)	N	N/A	–	N	N	N/A	–	N	N/A	N	N/A	N	Y	Wrapping	Y	N	Ind.	N/A

4. CONCLUSION

In this report, we presented the evaluation result of a SLR for legacy to SOA evolution. We presented the research questions and evaluation criteria of the SLR and inventoried the tools and techniques used in legacy to SOA evolution research papers.

REFERENCES

Al Belushi, W., & Baghdadi, Y. (2007). *An Approach to Wrap Legacy Applications into Web Services.* Paper presented at the International Conference on Service Systems and Service Management.

Alahmari, S., Roure, D. d., & Zaluska, E. (2010). *A Model-Driven Architecture Approach to the Efficient Identification of Services on Service-Oriented Enterprise Architecture*. Paper presented at the The 2010 14th IEEE International Enterprise Distributed Object Computing Conference Workshops.

Alahmari, S., Zaluska, E., & De Roure, D. (2010). *A Service Identification Framework for Legacy System Migration into SOA*. Paper presented at the 2010 IEEE International Conference on Services Computing.

Alahmari, S., Zaluska, E., & Roure, D. D. (2010, 2010-06). *Migrating Legacy Systems to a Service-Oriented Architecture with Optimal Granularity.* Paper presented at the 12 International Conference on Enterprise Information Systems.

Almonaies, A. A., Cordy, J. R., & Dean, T. R. (2010). *Legacy system evolution towards service-oriented architecture.* Paper presented at the Interrnational Workshop on SOA Migration and Evolution (SOAME 2010), Madrid, Spain.

Alor-Hernandez, G., Juarez-Martinez, U., Posada-Gomez, R., Chavez-Trejo, A. M., & Rocha-Aragon, J. S. (2009). *Defining an SOA for Stock Quote Management*. Paper presented at the 2009 Mexican International Conference on Computer Science.

Andal, H. F., Habiba, D., & Hakima, M. (2010). *Integrating legacy systems in a SOA using an agent based approach for information system agility.* Paper presented at the International Conference on Machine and Web Intelligence (ICMWI), 2010.

Arcelli, F., Tosi, C., & Zanoni, M. (2008). *Can design pattern detection be useful for legacy systemmigration towards SOA?* Paper presented at the The 2nd international workshop on Systems development in SOA environments.

Aversano, L., Cerulo, L., & Palumbo, C. (2008). *Mining candidate web services from legacy code.* Paper presented at the 10th International Symposium on Web Site Evolution, 2008 (WSE'08)

Baghdadi, Y. (2006). Reverse engineering relational databases to identify and specify basic Web services with respect to service oriented computing. *Information Systems Frontiers, 8*, 395-410.

Baker, T., Lamb, D., Taleb-Bendiab, A., & Al-Jumeily, D. (2010). *Facilitating Semantic Adaptation of Web Services at Runtime Using a Meta-Data Layer.* Paper presented at the Developments in E-systems Engineering (DESE), 2010.

Balasubramaniam, S., Lewis, G. A., Morris, E., Simanta, S., & Smith, D. (2008). *SMART: Application of a Method for Migration of Legacy Systems to SOA Environments.* Paper presented at the 6th International Conference on Service-Oriented Computing, Berlin, Heidelberg.

Balderrama, J. R., Montagnat, J., & Lingrand, D. (2010). *jGASW: a service-oriented framework supporting HTC and non-functional concerns.* Paper presented at the 2010 IEEE International Conference on Web Services.

Balis, B., Bubak, M., & Wegiel, M. (2005). A Solution for Adapting Legacy Code as Web Services. In V. Getov & T. Kielmann (Eds.), *Component Models and Systems for Grid Applications* (pp. 57-75): Springer US.

Bao, L., Yin, C., He, W., Ge, J., & Chen, P. (2010). *Extracting reusable services from legacy object-oriented systems.* Paper presented at the IEEE International Conference on Software Maintenance (ICSM'10).

Bergey, J., Smith, D., Weiderman, N., & Woods, S. (1999). *Options Analysis for Reengineering (OAR): Issues and Conceptual Approach* (No. CMU/SEI-99-TN-014): SEI.

Bertani-Carrera, J. C., Alor-Hernandez, G., Juarez-Martinez, U., & Posada-Gomez, R. (2009). *A Multi-layered SOA for Management of Inventories Flow Control*. Paper presented at the 2009 International Conference on Electrical, Communications, and Computers.

Bhallamudi, P., & Tilley, S. (2011). *SOA migration case studies and lessons learned.* Paper presented at the IEEE International Systems Conference (SysCon'11)

Bisbal, J., Lawless, D., Wu, B., & Grimson, J. (1999). Legacy information systems: Issues and directions. *Software, IEEE, 16*(5), 103-111.

Bissyandé, T., Réveillère, L., Bromberg, Y. D., Lawall, J., & Muller, G. (2010). *Bridging the Gap between Legacy Services and Web Services*. Paper presented at the Middleware 2010.

Bouras, T., Alexandrou, D., Pardalis, C., & Gouvas, P. (2010). *Semantic service-oriented integration of healthcare IT systems.* Paper presented at the 2010 10th IEEE International Conference on Information Technology and Applications in Biomedicine (ITAB).

Canfora, G., Fasolino, A. R., Frattolillo, G., & Tramontana, P. (2006). *Migrating Interactive Legacy Systems To Web Services*. Paper presented at the European Conference on Software Maintenance and Reengineering.

Canfora, G., Fasolino, A. R., Frattolillo, G., & Tramontana, P. (2008). A wrapping approach for migrating legacy system interactive functionalities to Service Oriented Architectures. *J. Syst. Softw., 81*, 463-480.

Cetin, S., Ilker Altintas, N., Oguztuzun, H., Dogru, A. H., Tufekci, O., & Suloglu, S. (2007). *Legacy migration to service-oriented computing with mashups.* Paper presented at the International Conference on Software Engineering Advances

Chen, F., Li, S., & Chu, W. C.-C. (2005). *Feature Analysis for Service-Oriented Reengineering*. Paper presented at the 12th Asia-Pacific Software Engineering Conference.

Chen, F., Yang, H., Qiao, B., & Chu, W. C.-C. (2006). *A Formal Model Driven Approach to Dependable Software Evolution.* Paper presented at the 30th Annual International Computer Software and Applications Conference - Volume 01, Washington, DC, USA.

Chen, F., Zhang, Z., Li, J., Kang, J., & Yang, H. (2009). *Service identification via ontology mapping.* Paper presented at the 33rd Annual IEEE International Computer Software and Applications Conference (COMPSAC'09) Seattle. Washington.

Chung, S., An, J. B. C., & Davalos, S. (2007). *Service-Oriented Software Reengineering: SoSR*. Paper presented at the 40th Annual Hawaii International Conference on System Sciences.

Chung, S., Won, D., Baeg, S.-H., & Park, S. (2009). *Service-oriented reverse reengineering: 5W1H model-driven re-documentation and candidate services identification.* Paper presented at the 2009 IEEE International Conference on Service-Oriented Computing and Applications (SOCA).

Cuadrado, F., García, B., nas, J. C. D., & Parada, H. A. (2008). *A Case Study on Software Evolution towards Service-Oriented Architecture*. Paper presented at the 22nd International Conference on Advanced Information Networking and Applications - Workshops.

De Lucia, A., Francese, R., Scanniello, G., & Tortora, G. (2008). Developing legacy system migration methods and tools for technology transfer. *Software: Practice and Experience, 38*(13), 1333-1364.

De Lucia, A., Francese, R., Scanniello, G., Tortora, G., & Vitiello, N. (2006). *A strategy and an Eclipse based environment for the migration of legacy systems to multi-tier web-based architectures.* Paper presented at the International conference on software maintenance.

Del Castillo, R. P., García-Rodríguez, I., & Caballero, I. (2009). *PRECISO: a reengineering process and a tool for database modernisation through web services*. Paper presented at the 2009 ACM symposium on Applied Computing.

Del Grosso, C., Di Penta, M., & de Guzman, I. G. R. (2007). *An approach for mining services in database oriented applications.* Paper presented at the 11th European Conference on Software Maintenance and Reengineering.

Di Lorenzo, G., Fasolino, A. R., Melcarne, L., Tramontana, P., & Vittorini, V. (2007). Turning web applications into web services by wrapping techniques, *14th working conference on reverse engineering* (pp. 199-208).

Djelloul, B., Mimoun, M., & El Kader, M. A. (2009). Towards Reengineering Web Applications to Web Services. *The international Arab Journal of Information Technology, 6*(4), 359-364.

El-Ramly, M., Stroulia, E., & Samir, H. (2009). Legacy Systems Interaction Reengineering. In A. Seffah, J. Vanderdonckt & M. C. Desmarais (Eds.), *Human-Centered Software Engineering* (pp. 316-333): Springer London.

Erradi, A., Anand, S., & Kulkarni, N. (2006). *Evaluation of Strategies for Integrating Legacy Applications as Services in a Service Oriented Architecture.* Paper presented at the IEEE International Conference on Services Computing(SCC'06).

Feldhorst, S., Libert, S., Hompel, L. T., & Krumm, H. (2009). *Integration of a legacy automation system into a SOA for devices.* Paper presented at the 14th IEEE international conference on Emerging technologies & factory automation.

Feng, Z., Cheng, Q., & Zhao, F. (2006). *CRUTCH: An Integration Framework forWeb Service and MAS*. Paper presented at the IEEE International Conference on e-Business Engineering.

Ferber, M., Rauber, T., & Hunold, S. (2010). *Combining Object-Oriented Design and SOA with Remote Objects over Web Services.* Paper presented at the 2010 Eighth IEEE European Conference on Web Services.

Fuhr, A., Horn, T., Riediger, V., & Winter, A. (2011). Model-driven software migration into service-oriented architectures. *Computer Science - Research and Development*, 1-20.

Gimnich, R. (2009). Using Existing Software Assets in SOA Design, *Software Maintenance and Reengineering, 2009. CSMR'09. 13th European Conference on* (pp. 309-310).

Gonzalez, M. A. C., Penalvo, F. J. G., Guerrero, M. J. C., & Forment, M. A. (2009). *Adapting LMS Architecture to the SOA: An Architectural Approach.* Paper presented at the 2009 Fourth International Conference on Internet and Web Applications and Services, Washington, DC, USA.

Grechanik, M., Conroy, K. M., & Swaminathan, K. S. (2007). *Creating Web Services From GUI-Based Applications.* Paper presented at the the IEEE International Conference on Service-Oriented Computing and Applications.

Guo, H., Guo, C., Chen, F., & Yang, H. (2005). Wrapping Client-Server Application to Web Services for Internet Computing, *Parallel and Distributed Computing, Applications and Technologies, 2005. PDCAT 2005. Sixth International Conference on* (pp. 366 - 370).

Guzman, I., Polo, M., & Piattini, M. (2007). *An ADM Approach to Reengineer Relational Databases towards Web Services*. Paper presented at the 14th Working Conference on Reverse Engineering (WCRE'07).

Guzmán, I. d., Polo, M., & Piattini, M. (2006). A Methodology for Database Reengineering to Web Services. In A. Rensink & J. Warmer (Eds.), *Model Driven Architecture ? Foundations and Applications* (Vol. 4066, pp. 226-240): Springer Berlin / Heidelberg.

Haase, T., & Nagl, M. (2008). Service-Oriented Architectures and Application Integration. In M. Nagl & W. Marquardt (Eds.), *Collaborative and Distributed Chemical Engineering. From Understanding to Substantial Design Process Support* (pp. 727-740): Springer Berlin / Heidelberg.

Haase, T., & Nagl, M. (2011). Application integration within an integrated design environment. *Computers & Chemical Engineering, 35*(4).

Heckel, R., Correia, R., Matos, C., El-Ramly, M., Koutsoukos, G., & Andrade, L. (2008). Architectural Transformations: From Legacy to Three-Tier and Services, *Software Evolution* (pp. 139-170).

Hoyer, P., Gebhart, M., Pansa, I., Link, S., Dikanski, A., & Abeck, S. (2009). *A Model-Driven Development Approach for Service-Oriented Integration Scenarios*. Paper presented at the 2009 Computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns.

Huang, G. (2009). *Study and design of enterprise information-based system based on SOA*. Paper presented at the 4th International Conference on Computer Science Education.

Huang, H. Y., Tan, H. F., Zhu, J., & Zhao, W. (2008). *A Lightweight Approach to Partially Reuse Existing Component-Based System in Service-Oriented Environment.* Paper presented at the 10th international conference on Software Reuse: High Confidence Software Reuse in Large Systems, Berlin, Heidelberg.

Ilk, N., Zhao, J. L., & Hofmann, P. (2008). *On Reuse of Source Code Components in Modernizing Enterprise Systems.* Paper presented at the IEEE Symposium on Advanced Management of Information for Globalized Enterprises.

Jandl, M., Alber, M., Radinger, W., & Goeschka, K. M. (2004). *Experiences in Integration and Reuse of CORBA-Interfaced Software with Directory Services and Web Services.* Paper presented at the 37th Annual Hawaii International Conference on System Sciences (HICSS'04)

Jiang, Y., & Stroulia, E. (2004). *Towards reengineering Web sites to Web-services providers*. Paper presented at the 8th European Conference on Software Maintenance and Reengineering (CSMR'04)

Kapsalis, V., Charatsis, K., Georgoudakis, M., & Papadopoulos, G. (2003). *Architecture for Web-based services integration.* Paper presented at the 29th Annual Conference of the IEEE Industrial Electronics Society.

Kavianpour, M. (2007). *SOA and Large Scale and Complex Enterprise Transformation.* Paper presented at the 5th international conference on Service-Oriented Computing, Berlin, Heidelberg.

Khadka, R., Reijnders, G., Saeidi, A., Jansen, S., & Hage, J. (2011). *A Method Engineering based Legacy to SOA Migration Method*. Paper presented at the 27th IEEE International Conference on Software Maintenance (ICSM'11).

Khadka, R., Saeidi, A., Idu, A., Hage, J., & Jansen, S. (2012). Legacy to SOA Evolution: A Systematic Literature Review. In A. D. Ionita, G. Lewis & M. Litoiu (Eds.), *Migrating Legacy Applications: Challenges in Service Oriented Architecture and Cloud Computing Environments*: IGI Global (in press).

Khadka, R., & Sapkota, B. (2010). *An evaluation of dynamic web service composition approaches.* Paper presented at the 4th International Workshop on Architectures, Concepts and Technologies for Service Oriented Computing (ACT4SOC 2010).

Khadka, R., Sapkota, B., Pires, L. F., Sinderen, M., & Jansen, S. (2011). *Model-Driven Development of Service Compositions for Enterprise Interoperability*. Paper presented at the 3rd International IFIP Working Conference on Enterprise Interoperability (IWEI'11). Retrieved from http://dx.doi.org/10.1007/978-3-642-19680-5_15

Koschel, A., Kleiner, C., & Astrova, I. (2009). *Mainframe Application modernization Based on Service-Oriented Architecture.* Paper presented at the 2009 computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns.

Kouamou, G. E. (2009). *Building a Service-Oriented ERP from an Open Source Software.* Paper presented at the 2009 Fourth International Conference on Software Engineering Advances.

Kroculick, J. B. (2011). *Migration strategies for service-enabling ground control stations for unmanned systems.* Paper presented at the Defense Transformation and Net-Centric Systems 2011.

Lammer, A., Eggert, S., & Gronau, N. (2008). A Procedure Model for a SoA-Based Integration of Enterprise Systems. *IJEIS, 4*(2), 1-12.

Lamprecht, A.-L., Margaria, T., Steffen, B., Sczyrba, A., Hartmeier, S., & Giegerich, R. (2008). GeneFisher-P: variations of GeneFisher as processes in Bio-jETI. *BMC Bioinformatics, 9*, 1-15.

Lee, R., Kim, H.-K., & Yang, H. S. (2004). *An Architecture Model for Dynamically Converting Components into Web Services.* Paper presented at the 11th Asia-Pacific Software Engineering Conference.

Lewis, G., Morris, E., O'Brien, L., Smith, D., & Wrage, L. (2005). *SMART: The Service-Oriented Migration and Reuse Technique* (No. CMU/SEI-2005-TN-029): Software Engineering Institute.

Lewis, G., Morris, E., & Smith, D. (2006). *Analyzing the Reuse Potential of Migrating Legacy Components to a Service-Oriented Architecture*. Paper presented at the 10th European Conference on Software Maintenance and Reengineering (CMSR'06).

Lewis, G., Morris, E., Smith, D., & O'Brien, L. (2005). Service-Oriented Migration and Reuse Technique (SMART), *13th IEEE International Workshop on Software Technology and Engineering Practice* (pp. 222-229). Washington, DC, USA: IEEE Computer Society.

Lewis, G., & Smith, D. B. (2007). *Developing realistic approaches for the migration of legacy components to service-oriented architecture environments.* Paper presented at the 2nd international conference on Trends in enterprise application architecture.

Li, M., & Qi, M. (2004). Leveraging legacy codes to distributed problem-solving environments: a Web services approach. *Software: Practice and experience, 34*(13), 1297-1309.

Li, S., & Tahvildari, L. (2008). *E-BUS: a toolkit for extracting business services from java software systems.* Paper presented at the Companion of the 30th international conference on Software engineering.

Li, S., Yang, H., & Zhou, H. (2004). *Building a Dependable Enterprise Service Assembly Line (ESAL) for Legacy Application Integration.* Paper presented at the 2004 International Conference on Cyberworlds.

Li, X. (2010). *A multi-Agent based legacy information system integration strategy.* Paper presented at the Networking and Digital Society (ICNDS), 2010 2nd International Conference on.

Li, X. Y., & Qian, Y. (2009). *A web service based enterprise information integration model.* Paper presented at the Computer Science Education, 2009. ICCSE '09. 4th International Conference on.

Li, Z., Anming, X., Naiyue, Z., Jianbin, H., & Zhong, C. (2009). *A SOA Modernization Method Based on Tollgate Model.* Paper presented at the 2009 International Symposium on Information Engineering and Electronic Commerce.

Liam, O., & Brien, D. S. (2005). *Supporting migration to services using software architecture reconstruction.* Paper presented at the 13th IEEE International Workshop on Software Technology and Engineering Practice (STEP'05).

Liu, G. (2010). *Design of medical management information system based on SOA.* Paper presented at the 2nd IEEE International Conference on Information Management and Engineering

Liu, R., Chen, F., Yang, H., Chu, W. C., & Lai, Y. B. (2004). *Agent-Based Web Services Evolution for Pervasive Computing.* Paper presented at the 11th Asia-Pacific Software Engineering Conference.

Liu, Y., Wang, Q., Zhuang, M., & Zhu, Y. (2008). *Reengineering Legacy Systems with RESTful Web Service.* Paper presented at the Annual IEEE International Computer Software and Applications Conference.

Lu, F., Huang, H., Xu, Z., & Yu, H. (2005). *A Middleware for legacy application wrapper.* Paper presented at the 1st International Conference on Semantics, Knowledge and Grid, Washington, DC, USA.

Marchetto, A., & Ricca, F. (2008). *Transforming a java application in an equivalent web-services based application: toward a tool supported stepwise approach.* Paper presented at the 10th International Symposium on Web Site Evolution (WSE'08).

Marchetto, A., & Ricca, F. (2009). From objects to services: toward a stepwise migration approach for Java applications. *International Journal on Software Tools for Technology Transfer (STTT), 11*(6), 427-440.

Millard, D. E., Howard, Y., Chennupati, S., Davis, H. C., Jam, E.-R., Gilbert, L., et al. (2006). *Design Patterns for Wrapping Similar Legacy Systems with Common Service Interfaces.* Paper presented at the European Conference on Web Services.

Millham, R. (2010). *Migration of a Legacy Procedural System to Service-Oriented Computing Using Feature Analysis.* Paper presented at the 2010 International Conference on Complex, Intelligent and Software Intensive Systems.

Mínguez, J., Jakob, M., Heinkel, U., & Mitschang, B. (2009). *A SOA-based approach for the integration of a data propagation system.* Paper presented at the 10th IEEE international conference on Information Reuse & Integration, Piscataway, NJ, USA.

Mudiam, S. V., Gannod, G. C., & Lindquist, T. E. (2006). Synthesizing and integrating legacy components as services using adapters. *Science of Computer Programming, 60*(2), 134-148.

Nakamura, M., Igaki, H., Kimura, T., & Matsumoto, K.-I. (2009). *Extracting service candidates from procedural programs based on process dependency analysis.* Paper presented at the IEEE Asia-Pacific Services Computing Conference.

Nakamura, M., Tanaka, A., Igaki, H., Tamada, H., & Matsumoto, K.-i. (2006). *Adapting Legacy Home Appliances to Home Network Systems UsingWeb Services.* Paper presented at the IEEE International Conference on Web Services, Washington, DC, USA.

Nakamura, M., Tanaka, A., Igaki, H., Tamada, H., & Matsumoto, K. (2008). Constructing Home Network Systems and Integrated Services Using Legacy Home Appliances and Web Services. *International Journal of Web Services Research (IJWSR), 5*(1), 82-98.

Nasr, K. A., Gross, H.-G., & Deursen, A. v. (2010). *Adopting and Evaluating Service Oriented Architecture in Industry*. Paper presented at the 2010 14th European Conference on Software Maintenance and Reengineering.

Nguyen, D., van den Heuvel, W. J., Papazoglou, M., de Castro, V., & Marcos, E. (2009). GAMBUSE: A gap analysis methodology for engineering SOA-based applications. *Conceptual Modeling: Foundations and Applications*, 293-318.

Papazoglou, M. (2008). *Web services: principles and technology*: Addison-Wesley.

Papazoglou, M., Traverso, P., Dustdar, S., & Leymann, F. (2007). Service-oriented computing: State of the art and research challenges. *Computer, 40*(11), 38-45.

Parsa, S., & Ghods, L. (2008). *A new approach to wrap legacy programs into web services.* Paper presented at the 11th International Conference on Computer and Information Technology.

Pena, Y., Correal, D., & Hernandez, T. (2010). *Reusing legacy systems in a service-oriented architecture: a model-based analysis.* Paper presented at the Proceedings of the 2010 international conference on Advances in conceptual modeling: applications and challenges, Berlin, Germany.

Petcu, D., & Baltat, A. (2009). Transforming an Interactive Expert Code into a Statefull Service and a Multicore-Enabled System. *Intelligent Systems and Technologies,* pp. 137-159.

Pieczykolan, J., Kryza, B., & Kitowski, J. (2006). Semi-automatic Creation of Adapters for Legacy Application Migration to Integration Platform Using Knowledge. In V. Alexandrov, G. v. Albada, P. Sloot & J. Dongarra (Eds.), *Computational Science ? ICCS 2006* (pp. 252-259): Springer Berlin / Heidelberg.

Qu, Y., Bollig, E. F., & Erlebacher, G. (2008). KWATT: a toolkit for automatic web service generation. *Visual Geosciences, 13*(1), 59-69.

Rabhi, F. A., Dabous, F. T., Yu, H., Benatallah, B., & Lee, Y. K. (2004). *A Case Study in Developing Web Services for Capital Markets.* Paper presented at the 2004 IEEE International Conference on e-Technology, e-Commerce and e-Service Washington, DC, USA.

Razavian, M., & Lago, P. (2010). A Frame of Reference for SOA Migration. In E. Di Nitto & R. Yahyapour (Eds.), *Towards a Service-Based Internet* (Vol. 6481, pp. 150-162): Springer Berlin / Heidelberg.

Ricca, F., & Marchetto, A. (2009). *A quick and dirty meet-in-the-middle approach for migrating to SOA*. Paper presented at the joint international and annual ERCIM workshops on Principles of software evolution (IWPSE) and software evolution (Evol) workshops.

Salama, R., & Aly, S. G. (2008). *A Decision Making Tool for the Selection of Service Oriented-Based Legacy Systems Modernization Strategies.* Paper presented at the The International Conference on Software Engineering Research and Practice, Las Vegas, USA.

Schelp, J., & Aier, S. (2009). *SOA and EA-sustainable contributions for increasing corporate agility.* Paper presented at the 42nd Hawaii International Conference on System Sciences.

Sindhgatta, R., & Ponnalagu, K. (2008). *Locating components realizing services in existing systems.* Paper presented at the IEEE International Conference on Services Computing.

Sneed, H., & Sneed, S. (2003). *Creating Web services from legacy host programs.* Paper presented at the 5th IEEE International Workshop on Web Site Evolution.

Sneed, H. M. (2006). *Integrating legacy Software into a Service oriented Architecture.* Paper presented at the European Conference on Software Maintenance and Reengineering.

Sneed, H. M. (2008). *COB2WEB a toolset for migrating to web services.* Paper presented at the 10th International Symposium on Web Site Evolution (WSE'08)

Sneed, H. M. (2009). A pilot project for migrating COBOL code to web services. *Int. J. Softw. Tools Technol. Transf., 11*, 441-451.

Streekmann, N., & Hasselbring, W. (2008). Towards Identification of Migration Increments to Enable Smooth Migration. *Model-Based Software and Data Integration,* pp. 79-90.

Tangjianfeng, Zhangxianing, & Wangjicheng. (2009). *Research of Mainframe Application Transition to SOA Environment.* Paper presented at the International Conference on Computational Intelligence and Software Engineering.

Umar, A., & Zordan, A. (2009). Reengineering for service oriented architectures: A strategic decision model for integration versus migration. *Journal of Systems and Software, 82*(3), 448-462.

van Geet, J., & Demeyer, S. (2010). Reverse Engineering on the Mainframe: Lessons Learned from In Vivo Research. *IEEE Software, 27*(4), 30-36.

van Sinderen, M. (2008). Challenges and solutions in enterprise computing. *Enterprise Information System, 2*(4), 341-346.

Vemuri, P. (2008). *IEEE TENCON - 2008 Modernizing a legacy system to SOA - Feature analysis approach.* Paper presented at the TENCON 2008 - 2008 IEEE Region 10 Conference.

Webster, D., Liu, L., Russell, D., Venters, C., Luo, Z., & Xu, J. (2011). Migrating Legacy Assets through SOA to Realize Network Enabled Capability. In A. Vakali & L. Jain (Eds.), *New Directions in Web Data Management 1* (Vol. 331, pp. 311-346): Springer Berlin / Heidelberg.

Woollard, D., Mattmann, C., & Medvidovic, N. (2009). *Injecting software architectural constraints into legacy scientific applications.* Paper presented at the 2009 ICSE Workshop on Software Engineering for Computational Science and Engineering.

Xu, Y., Duan, Q., & Yang, H. (2005). Web-Service-Oriented Customer Relationship Management System Evolution, *Software Technology and Engineering Practice, 2005. 13th IEEE International Workshop on* (pp. 39 -48).

Yürekten, Ö., Dinçer, K., Akar, B., Sungur, M., & Özbudak, E. (2006). Migrating a Hierarchical Legacy Database Application onto an XML-Based Service-Oriented Web Platform. In A. Levi, E. Savas, H. Yenigün, S. Balcisoy & Y. Saygin (Eds.), *Computer and Information Sciences ? ISCIS 2006* (Vol. 4263, pp. 645-654): Springer Berlin / Heidelberg.

Zhang, B., Bao, L., Zhou, R., Hu, S., & Chen, P. (2008). *A Black-Box Strategy to Migrate GUI-Based Legacy Systems to Web Services*. Paper presented at the International Sympoisum on Service-oriented system engineering.

Zhang, J., Chang, C. K., Zhang, L. J., & Hung, P. C. K. (2007). Toward a service-oriented development through a case study. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 37*(6), 955-969.

Zhang, Z., Liu, R., & Yang, H. (2005). *Service identification and packaging in service oriented reengineering*. Paper presented at the 7th International Conference on Software Engineering and Knowledge Engineering (SEKE).

Zhang, Z., & Yang, H. (2004). *Incubating Services in Legacy Systems for Architectural Migration.* Paper presented at the 11th Asia-Pacific Software Engineering Conference.

Zhang, Z., Yang, H., & Chu, W. C. (2006). *Extracting Reusable Object-Oriented Legacy Code Segments with Combined Formal Concept Analysis and Slicing Techniques for Service Integration.* Paper presented at the 6th International Conference on Quality Software.

Zhang, Z., Yang, H., Zhou, D., & Zhong, S. (2010). *A SOA Based Approach to User-Oriented System Migration.* Paper presented at the 2010 10th IEEE International Conference on Computer and Information Technology (CIT 2010).

Zhang, Z., Zhou, D.-D., Yang, H.-J., & Zhong, S.-C. (2010). A service composition approach based on sequence mining for migrating e-learning legacy system to SOA. *Int. J. Autom. Comput., 7*, 584-595.

Zhao, J., & Wang, X. (2010). *Research on Legacy System Reuse in Ningxia Public Business Information Services Platform.* Paper presented at the International Conference on Computational Intelligence and Software Engineering.

Zhou, N., Zhang, L. J., Chee, Y. M., & Chen, L. (2010). *Legacy Asset Analysis and Integration in Model-Driven SOA Solution.* Paper presented at the 2010 IEEE International Conference on Services Computing.

Zillmann, C., Winter, A., Herget, A., Teppe, W., Theurer, M., Fuhr, A., et al. (2011). *The SOAMIG Process Model in Industrial Applications.* Paper presented at the 15th European Conference on Software Maintenance and Reengineering (CSMR'11)

Zou, Y., & Kontogiannis, K. (2000). Web-based specification and integration of legacy services, *Proceedings of the 2000 conference of the Centre for Advanced Studies on Collaborative research* (pp. 17).