Are Model-driven Techniques Used as a Means to Migrate SOA Applications to Cloud Computing?

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Abstract: In recent years, cloud computing has emerged as an option to use computing resources as a solution for the global economic crisis, namely, a cheaper way to have IT resources. Thus, many companies have started to migrate their systems to cloud infrastructures, without the required support to carry out this process. In this position paper, we provide an overview of the current state of research on cloud computing migration. To understand this subject, we conducted a systematic mapping. The results suggest that research into cloud computing migration is still in its early stages. We identify research gaps and provide general recommendations about how these gaps may be addressed as well as future research directions that may have potential impact on this research field.

1 INTRODUCTION

Cloud computing has become a topic of tremendous interest as organizations struggle to improve their IT performance. Cloud computing is described by (Feuerlicht, 2010) as follows: it involves making computing, data storage, and software services available via the Internet.

The main characteristics of cloud services are: on-demand self-service, ubiquitous network access, location independent resource pooling, rapid elasticity, and measured service (Mell and Grance, 2011). Cloud computing is classified into service models as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). And their deployment models as public, private, community and Hybrid (Mell and Grance, 2011).

The use of cloud services enables companies to pay only for what they use with regard computing and network resources, rather than having to invest in IT resources, and the requisite staff to support all the hardware and software.

Cloud computing has associated benefits and also challenges. One of these challenges are related to is adoption, more specifically, the migration of existing application to cloud computing.

There are few studies as reported in (Mohagheghi and Sæther, 2011; Pace et al., 2010) that present the evaluation of different cloud platforms for performance indicators. Nevertheless, there is not sufficient literature available to support on process for migrating existing applications to cloud.

In this position paper, we present a systematic mapping study for summarizing how researchers and practitioners migrate their applications to cloud environments.

Our paper is organized as follows: Section 2, presents the protocol we defined. Section 3, described the results obtained. Finally, section 4 presents our conclusions and suggest areas for further investigation.

2 RESEARCH METHOD

We have performed a systematic mapping study by considering the guidelines that are provided in works as those (Budgen et al., 2007; Kitchenham and Charters, 2007; Petersen et al., 2008). A systematic mapping study is a means of categorizing and summarizing the existing information about a research question in an unbiased manner.

Our systematic mapping study was performed in three stages: Planning, Conducting, and Reporting. The activities concerning the planning and conducting stages of our systematic mapping study

are described in the following sub-section and the reporting stage is presented in Section 4.

Planning Stage. During the planning stage, we performed the following activities in order to establish a review protocol: establishment of the research question; definition of the search strategy, selection of primary studies, quality assessment, definition of the data extraction strategy, and selection of synthesis methods.

Research Question. The goal of our study is to examine the current use of strategies of migration of SOA applications to Cloud Computing environments from the point of view of the following research question: *"How researchers and practitioners migrate their SOA applications to Cloud Computing environments and which is the effect on the quality?"*. Since our research question is too broad, it has been decomposed into more detailed sub-questions (see Table 1) in order for it to be addressed.

Table 1: Research sub-questions.

Research sub-questions	Motivation
RQ1: Which strategies are used to migrate Service-Oriented Architecture applications to Cloud computing environments?	To discover which are the most frequently used migration strategies in the process to migrate SOA applications to Cloud Computing environments.
RQ2: Which are the consequences of migration on product quality?	To discover which quality characteristics have been affected in the migration process.

Search Strategy. The main digital libraries that were used to search for primary studies were: IEEEXplore, ACM Digital Library, Science Direct, and Springer Link. We also manually searched the following conference proceedings: CLOUD COMPUTING and IEEE CLOUD.

In order to perform the automatic search of the selected digital libraries, we used a search string (see Table 2) consisting of three parts: Migration, Services and Cloud. The period reviewed included studies published from 2006 to 2013 (inclusive). This starting date was selected because 2006 was the year in which Amazon Inc. officially launched *Amazon Web Services*.

Selection of Primary Studies. Each study was evaluated by the three authors in order to decide whether it should be included or not, by considering its title, abstract and keywords. The studies that met at least one of the following inclusion criteria were included:

- Research papers presenting migration strategies SOA applications to Cloud Computing environments.
- Research papers presenting examples or any empirical studies (e.g. study cases, experiments), about migration strategies to Cloud Computing environments.

Table 2: Search string applied.

Concept	Alternative terms or Synonyms
Migration	(migra* OR evolv* OR adopt* OR reus* OR mov*) AND
Services	(soa OR service*) AND
Cloud	cloud

* The asterisk symbol "*" signifies any character whose purpose it is to include any word variation of each search term (e.g., the search term "migra*" includes the following words: migrate OR migrating OR migration OR…).

The studies that met at least one of the following exclusion criteria were excluded:

- Introductory papers for special issues, books and workshops.
- Duplicate reports of the same study in different sources.
- Short papers with less than five pages.
- Paper not written in English.

Quality Assessment. In addition to general inclusion/exclusion criteria, it is considered critical to assess the "quality" of primary studies. A three-point Likert-scale questionnaire was designed to provide a quality assessment of the selected studies. The questions were:

- The study presents strategies to migrate SOA applications to Cloud Computing environments.
- The study has been published in a relevant journal or conference.
- The study has been cited by other authors.

The possible answers to these questions were: "I agree (+1)", "Partially agree (0)", and "I do not agree (-1)".

Data Extraction Strategy. It was based on providing the set of possible answers for each research sub-question that had been defined. The possible answers to each research sub-question are explained in more detail as follows.

With regard to RQ1 (Strategies used), a paper can be classified in one of the following answers:

- C1: Migration strategies.
  a) *Conventional*: if it paper uses existing conventional migration strategy.
  b) *MDD*: if it paper uses strategies based on Model-Driven Development approach.
- C2: Migration approaches (Watson, 2012).

a) *Rehost:* if migration approach is specifically to move an application without changing its architecture.
b) *Refactor:* if migration approach is specifically to move applications to a different hardware environment and/or change the application infrastructure configuration without changing its external behavior.
c) *Revise:* if migration approach is specifically to modify or extend the existing code base to support legacy modernization requirements.
d) *Rebuild:* if migration approach is specifically to rebuild the solution, discard code for an existing application and re-architect the application.

- C3: Migration types (Andrikopoulos et al., 2012).
  a) *Replace components:* a migration type where one or more (architectural) components are replaced by Cloud services.
  b) *Partially migrate:* if migration type is specifically to change some of the application functionality to the Cloud, such as application layers, and architectural components.
  c) *Migrate the whole software stack:* if migration type is specifically to move the application that is encapsulated in VMs and run them on the Cloud.
  d) *Cloudify:* if migration type is specifically to make a complete migration of the application tasks.

With regard to RQ2 (C4: Quality aspects), a paper can be classified in one or more quality characteristics from the ISO/IEC 25010 standard SQuaRE (International Organization for Standardization, 2011).

Synthesis Method. We applied both quantitative and qualitative synthesis methods. The quantitative synthesis was based on: i) Counting the primary studies classified in each answer from our research sub-questions; and ii) Counting the number of papers found in each bibliographic source per year.

The qualitative synthesis is based on including several representative studies for each criterion by considering the results from the quality assessment.

Conducting Stage. The application of the review protocol yielded the following preliminary results (see Table 3): A total of 48 research papers were therefore selected in accordance with the inclusion criteria.

Table 3: Results of conducting stage.

Source	Potential Studies	Selected Studies
Automated search		
IEEEXplore (IEEE)	1026	29
ACM DL (ACM)	308	7
Science Direct (SD)	152	5
Springer Link (SL)	1187	2
Total	2673	43
Manual search		
CLOUD COMPUTING	8	1
IEEE CLOUD	7	4
Total	15	5
Overall results	2688	48

3 RESULTS

A summary of the results of our study is presented in Table 4. Table 5 includes the papers cited in this section. The complete list is available at: http://users.dsic.upv.es/~jagonzalez/Webist2014/references.htm

Table 4: Results of systematic mapping.

Criteria	Possible answer	Results	
		# Studies	Percentage (%)
C1: Migration strategies	Conventional	46	95,83
	MDD	2	4,17
C2: Migration approach	Rehost	20	44,44
	Refactor	18	40,00
	Revise	-	-
	Rebuild	7	15,56
C3: Migration types	Replace	-	-
	Partially migrate	7	14,89
	Migrate the whole software stack	15	31,91
	Cloudify	25	53,19
C4: Quality aspects	Performance efficiency	44	30,56
	Compatibility	14	9,72
	Reliability	31	21,53
	Security	35	24,31
	Maintainability	5	3,47
	Portability	15	10,42

3.1 Migration Strategies

With regard to criteria C1 (migration strategies) revealed that around 96% of the papers reviewed presented conventional strategy (e.g., Babar et al. on Table 5.S01, and Tran et al. on Table 5.S14).

Babar et al. (see Table 5.S01) reported their

Table 5: Excerpt of selected papers from the review.

S01. Babar MA, Chauhan MA. A tale of migration to cloud computing for sharing experiences and observations, SECLOUD, 2011.
S02. Beserra P V., Camara A, Ximenes R, Albuquerque AB, Mendonca NC. Cloudstep: A step-by-step decision process to support legacy application migration to the cloud, MESOCA, 2012.
S03. Cai B, Xu F, Ye F, Zhou W. Research and application of migrating legacy systems to the private cloud platform with cloudstack. ICAL, 2012.
S04. Chauhan MA, Babar MA. Towards Process Support for Migrating Applications to Cloud Computing, International Conference on Cloud and Service Computing, 2012.
S05. Chee Y-M, Zhou N, Meng FJ, Bagheri S, Zhong P. A Pattern-Based Approach to Cloud Transformation, International Conference on Cloud Computing, 2011.
S06. Gerhards M, Sander V, Belloum A. About the flexible Migration of Workflow Tasks to Clouds Combining on- and off-premise Executions of Applications, Cloud Computing, 2012.
S07. Guillen J, Miranda J, Murillo JM, Canal C. A service-oriented framework for developing cross cloud migratable software. NordiCloud, 2013.
S08. Guillen J, Miranda J, Murillo JM, Canal C. Developing migratable multicloud applications based on MDE and adaptation techniques, NordiCloud, 2013.
S09. Juan-Verdejo A, Baars H. Decision support for partially moving applications to the cloud, HotTopiCS, 2013.
S10. Lamberti F, Sanna A, Demartini C. How to move your own applications into the cloud by exploiting interfaces automation and accessibility features, International Conference on Cloud Computing and Intelligence Systems, 2011.
S11. Li J, Jia Y, Liu L, Wo T. CyberLiveApp: A secure sharing and migration approach for live virtual desktop applications in a cloud environment. Futur. Gener. Comput. Syst. 2013.
S12. Mohagheghi P, Sæther T. Software Engineering Challenges for Migration to the Service Cloud Paradigm: Ongoing Work in the REMICS Project, IEEE World Congress on Services, 2011.
S13. Suen C-H, Kirchberg M, Lee BS. Efficient Migration of Virtual Machines between Public and Private Cloud, Inter. Conf. on Cloud Computing Technology and Science, 2011.
S14. Tran V, Keung J, Liu A, Fekete A. Application migration to cloud, SECLOUD, 2011.
S15. Zhou L. CloudFTP: A Case Study of Migrating Traditional Applications to the Cloud, Inter. Conf. on Intelligent System Design and Engineering Applications, 2013.

experiences and observations gained from migrating an Open Source Software, Hackystat, to cloud computing. The aims of this job is to share their experiences and observations gained through this project and to analyze the literature with those research works who intend to migrate software systems in general and SOA based system in particular to cloud computing.

Tran et al. (see Table 5.S14) proposed a taxonomy of the migration tasks involved, and they showed the costs breakdown among categories of tasks, for a case-study which migrated a .NET n-tier application to Windows Azure. They determined how efforts are required for different types of Cloud as well as identified any missing tasks.

The remaining 4% of the studies reported the use of *MDD* strategy. MDD approaches rely on models as a means of abstracting the development process from the peculiarities of each cloud platform. These results may indicate that there are few studies that used this strategy to migrate existing system to cloud computing environment (e.g., Guillen et al. on Table 5.S08, and Mohagheghi et al. on Table 5.S12).

Guillen et al. (see Table 5.S08) proposed a framework MULTICLAPP. The framework follows a three-stage development process where applications can be modeled and coded without developers having to be familiar with the specification of any cloud platform.

Mohagheghi et al. (see Table 5.S12) presented a research project REMICS to define methodology and tools for model-driven migration of legacy applications to a SOA with deployment in the cloud. The project's main objective is to develop a set of model-driven methods and tools that support organizations with legacy systems to modernize them according to the "Service Cloud paradigm".

3.2 Migration Approaches

With regard to criteria C2 (migration approach) revealed that the most frequently used migration approach is *rehost*, with around 44% of the papers reviewed (e.g., Li et al. on Table 5.S11 and Zhou et al. on Table 5.S15). These results may indicate that most migrations are performed using this approach.

Li et al. (see Table 5.S11) proposed a flexible collaboration approach, CyberLiveApp, to enable live virtual desktop application sharing, based on a cloud infrastructure. This approach supports secure application sharing and on-demand migration among multiple users or equipment. To achieve the goals of live application sharing and migration between VMs, a presentation redirection approach based on VNC protocol and a VM cloning service based on the Libvirt interface are used.

Zhou et al. (see Table 5.S15) proposed migrating traditional applications - CloudFTP to the cloud. They implemented FTP service on Windows Azure Platform along with the auto-scaling cloud feature since CloudFTP follows the application model suggested for general Azure development.

Refactor account for around 40% of the papers reviewed (e.g, Beserra et al. on Table 5.S02, and Chee et al. on Table 5.S05).

Beserra et al. (see Table 5.S02) presented Cloudstep, a step-by-step decision process aimed at supporting legacy application migration to the cloud. The process relied on the creation of template-based profiles characterizing the organization, the target legacy application and candidate cloud providers.

Chee et al. (see Table 5.S05) proposed a pattern-based approach Cloud Transformation Advisor which helps users selecting appropriate enablement patterns from a knowledge base of best practices when planning the transformation. This knowledge base uses a structured representation to capture application information, cloud platform capability information, and enablement pattern information in order to facilitate pattern selection.

Rebuild account for around 16% of the papers reviewed, since this way focused on rebuilding the solution (e.g., Cai et al. on Table 5.S03).

Cai et al. (see Table 5.S03) presented the problems with Legacy Information Systems and proposed redevelopment, which rewrites existing applications providing new interfaces for a component, making it more easily accessible for other software components; and migration.

3.3 Migration Types

With regard to for criteria C3 (migration types) revealed that around 53% of the papers reviewed presented *cloudify* (e.g., Chauhan et al. on Table 5.S04, and Lamberti et al. on Table 5.S10).

Chauhan et al. (see Table 5.S04) presented a process framework for supporting migration to cloud computing based on their experiences from migrating an Open Source System (OSS), Hackystat, to two different cloud computing platforms (Amazon Web Services and Google App Engine). The main activities involved in this process include identification of requirements and potential cloud platforms, analyzing application compatibility with potential cloud environments, identification of potential architecture solutions, evaluation of cloud environments for cloud specific quality attributes, tradeoff analysis of potential architecture solutions, selection of architecture modifications to be incorporated and refactoring of the system to incorporate new architecture modifications.

Lamberti et al. (see Table 5.S10) presented a prototype implementation, which consists of a framework that allows today's applications to be put into the cloud by exploiting user interface automation and accessibility information embedded in modern window-based graphics toolkits. This framework organized as a three-tier architecture includes the particular remote program we want to move to the cloud, a server-side gateway and a web-based client.

Migrate the whole software stack account for around 32% of the papers reviewed (e.g., Suen et al. on Table 5.S13). Suen et al. (see Table 5.S13) proposed and evaluated techniques for both instance-based and volume-based storage in the public and private cloud infrastructure for efficient and effective transfer and storage of VM images. The main focus was on both the public and private cloud infrastructure and the movement of VMs between them.

Lastly, *partially migrate* account for around 15% of the papers reviewed (e.g., Gerhards et al. on Table 5.S06, and Juan-Verdejo et al. on Table 5.S09).

Gerhards et al. (see Table 5.S06) addressed the demand for a consistent framework that allows a mixture of on and off-premise calculations by migrating only specific parts to a Cloud. It used the concept of workflows to present how individual workflow tasks can be migrated to the Cloud whereas the remaining tasks are executed on-premise.

Juan-Verdejo et al. (see Table 5.S09) proposed a cloud migration framework to assist in the moving of the target application by following a local and cloud deployment model instead of an all-or-nothing approach. Besides this framework envisions that parts of the application are kept locally while others parts are migrated to cloud infrastructures.

3.4 Quality Aspects

With regard to criteria C4 (quality aspects) revealed that the most frequently quality aspects were *performance/efficiency* and *security* account for around 31% and 24% respectively (Guillen et al. (see Table 5.S07)) since on cloud environments the elasticity property of applications where quick and secure deployment is typically required. Others quality aspects as *maintainability* and *compatibility* account for around 3% and 9% respectively. This is because of quality aspects such as maintainability to play a minor role because the cloud providers are responsible of this partly on their platforms.

On the other hand, *reliability* and *portability* account with 21% and 10% respectively received less considerations (e.g., Babar et al. (see Table 5.S01)), where the authors stated that one example of such requirement is constrains on the geographic locations of data storage places. For some applications, it is required that data should not store outside a particular region. In IaaS clouds, data is

maintained at different location for reliability and cost effectiveness.

It is worthy to mention that the analysis of the number of research studies on cloud migration showed that there has been a growth of interest on this topic since 2009. Figure 1 shows the number of selected publications per year and source.

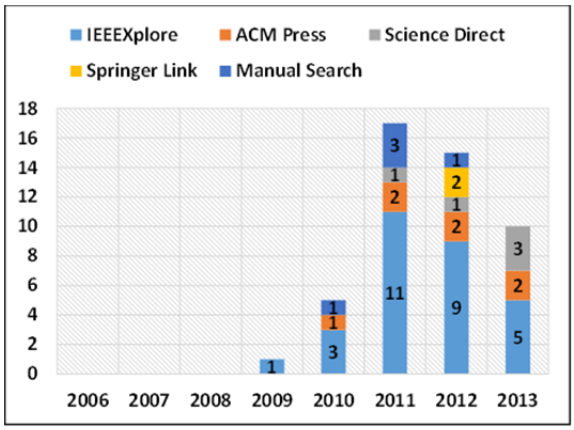

Figure 1: Number of publications by year and source.

4 CONCLUSIONS

The results suggest that research into cloud computing migration is still in its early stages. We identify research gaps and provide general recommendations about how these gaps may be addressed as well as future research directions that may have potential impact on the field.

Some of the gaps found are: i) MDD approach had been rarely used in the process to migrate SOA applications to Cloud environments; and ii) Some quality characteristics which we consider relevant in applications (reliability, maintainability, portability) had not received appropriate coverage.

Our results also confirmed some claims stated by other researchers according to the cloud migration: there is a lack of literature to support the migration process. We recommend the use of Model-Driven Development approach since it provides a higher abstraction level than traditional programming languages. We are also intended to address some of the research gaps discovered. For instance, addressing migrate SOA applications to Cloud environment through a migration framework using MDD techniques taking advantage of its benefits.

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