Tools to Support SMEs to Migrate to the Cloud: Opportunities and Challenges

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***Abstract*—The cloud computing paradigm represents a shift in the way companies deal with customizable and resourceful platforms to deploy software. It has been receiving increasing attention, partly due to its claimed financial and functional benefits. Cloud computing providers provide organizations with access to computing services without the need for those organizations to own the providing infrastructure. However, migration of legacy information systems to the cloud is not simple. This field is very dynamic and related technologies are rapidly evolving. For instance, Small and Medium Enterprises (SMEs) may not necessarily be well prepared to deal with issues such as multi-tenancy, elasticity, interoperability, and cloud services. With such issues in view, we searched for different types of tools referenced in the literature to support migration to the cloud and discussed related challenges and advantages of their use by SMEs.**

***Index Terms*—cloud computing; legacy systems; cloud migration; tools.**

I. Introduction

Cloud computing offers novel opportunities such as the economy of scale to SMEs. In exchange of having affordable access to sophisticated computers resources, SMEs must plan the migration of parts or the whole of their applications to the cloud. This entails expending efforts to understand existing legacy systems and in some cases redesign them. Considering that cloud related issues entail the analysis of various aspects such as economic, strategic risks and technological related issues [1], decision makers must have extensive judgment and insight to thoroughly comprehend the alternatives and the set of required choices towards the cloud adoption [2].

Migrating a legacy style application to the cloud is not a trivial task and arise several challenges. The size and the complexity of this task can be discouraging, especially in the cases of small and medium enerprises aiming at benefiting from the promised advantages of the cloud [3]. The issues to be addressed are still poorly understood and vary dynamically, due to the change of related technologies [3].

The cloud environment is characterized by a large amount of resources such as memory, CPU, network bandwidth and storage. These resources can be booked and released by service consumers, according to demand to optimize the usage in the case of workload variation[4].

Researchers have pointed out that empirical insights into cloud-sourcing decisions remains scarce [5]. For this reason, we decided to look for evidence in the literature about tools that have supported SMEs to migrate to the cloud.

The rest of this paper is organized as follows. The next section presents the context of this work. Section 3 describes the methodology of the study. Section 4 analyzes the results. Section 5 presents the conclusion and scope for future research.

II. Context of this Work

It is estimated that the worldwide cloud computing market will increase up to $241 billion by 2020 [6]. Academia and practitioners devoted research effort to this topic by focusing on technical solutions and also on the social and non-technical consequences of the cloud as a paradigm [7]. Moving large-scale legacy systems to the cloud is not as straightforward as it might first appear [4] as systems often precede the cloud era and in most cases were developed without considering its unique characteristics [7][8]. The complexity of migration is increased due to the development of legacy applications not considering requirements attributed to cloud environments such as elasticity, multi-tenancy, interoperability, and cloud service/platform selection [3][7]. Tools can support migration of legacy systems to the cloud, instead of carrying out such migrations in an ad-hoc manner. Such migrations may latter result in maintenance problems related to poor and non effective migrations [7].

The literature reports that SMEs have been facing challenges such as the classic lock-in effect towards the adoption of new cloud services [9]. Thus, before sourcing cloud services, companies have the option to use migration tools that account for various issues such as cost and risk factors.

Figure 1 was adapted from [7] and presents migration types from legacy systems to the cloud. We can identify types of tools that support activities related to each kind of migration presented as follows. **Type I** migration [7] relates to deploying the business logic tier of the legacy system in the cloud infrastructure through the *Infrastructure as a Service* (IaaS) model. In this case, the data tier remains in the local network of the company. Deploying an audio-processing component of an application in the cloud is an example of this type of migration. **Type II** migration [7] relates to the replacement of some components or the entire legacy application stack with a cloud service, by applying the service delivery model *Software as a Service* (SaaS). *Online Customer Relationship Management* (CRM) applications are a typical example of SaaS, which can be integrated with other applications via their available interfaces. **Type III** migration [7] relates to the deployment of a legacy database in a cloud data store provider through IaaS delivery service model. The components related to business logic tier are maintained in the local network of the company and the database is deployed in a public cloud data store. Amazon's Elastic Block Store (EBS), Amazon's *Simple Storage Service* (S3), and Dropbox are examples of public cloud data store serving this end. **Type IV** migration [7] relates to the conversion of the data, schema, and changing the data tier of the legacy application to a cloud native database such as e.g., Amazon DynamoDB [1] and Azure Cosmos DB [2]. Finally, **Type V** migration [7] relates to the deployment of the entire application stack in the cloud through IaaS. In this case, the legacy system is wrapped in a unique virtual machine (VM) to run in the cloud. Hosting a Web legacy system and the corresponding Web server using a virtual machine on Digital Ocean [3] is an example of this type of migration.

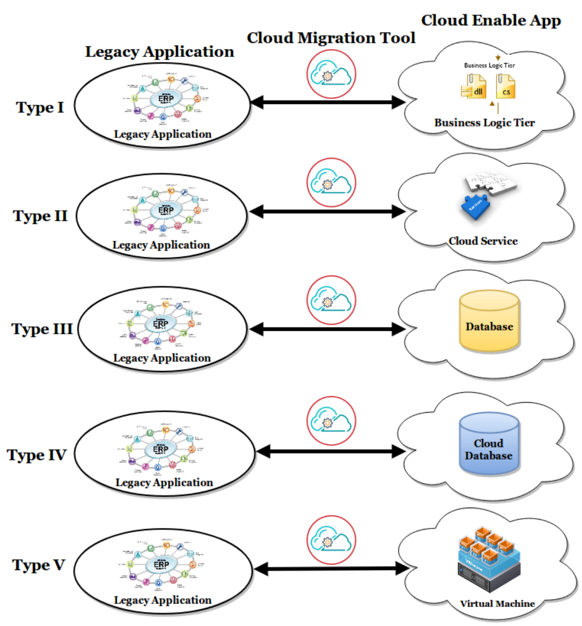

Fig. 1. Migration Types to the Cloud. Adapted from [7].

In addition to migration type, the migration process is another relevant issue that can be used to contextualize the role tools play in the migration to the cloud. The migration process can be summarized by the following phases [4]. **Phase I** (Plan phase) comprises tasks such as context analysis, migration requirement analysis, legacy systems identification and plan definition. Examples of work products of this phase include the legacy system model, the migration requirements and the migration plan. **Phase II** (Design phase) comprises tasks such as design of the cloud solution, choose the cloud service/platform, identify incompatibilities, and design principles. Examples of work products of this phase include the cloud solution architecture and the virtual machine specification. **Phase III** (Enable phase) comprises tasks such as resolving incompatibilities, deploying system components, configuring network, deploying and testing system. This phase has as the main work product the system template.

[1]https://aws.amazon.com/dynamodb/
[2]https://goo.gl/BQUqBZ
[3]https://www.digitalocean.com/

III. The Semi Systematic Literature Review

To collect data for this paper, we conducted a semi-systematic literature review [10] to identify studies that report the use of tools to support the migration to the cloud and associated challenges as well as difficulties to perform the migration. The review fulfills just part of the criteria of a systematic literature review (SLR) [10]. For this reason, it is considered a semi-systematic literature review, since this seems to be the most accurate description [11]. The fulfilled criteria include: (1) search strings applied to a dedicated digital library, (2) analysis of number of hits, (3) documenting the included papers, and (4) usage of explicit inclusion/exclusion criteria [11]. The SLR criteria that are not met include: (a) evaluation of papers by multiple authors and (b) a more rigorous quality assessment of the study, data extraction and data synthesis. Additionally, we included papers that were not found via our search string, which is not part of SLR process.

The literature review assessed two research questions as follows. **Research Question 1 (RQ1):** Which tools support the migration of legacy systems to the cloud? The results of the semi-systematic literature review show that there are no tools that fully support the whole migration of a legacy system to the cloud. However, there are tools that provide a fully-automated support for specific tasks during the migration.
Research Question 2 (RQ2): What are the main challenges and opportunities reported in the literature related to the migration of legacy systems to the cloud? Studies from the literature show that difficulties are related to the understanding of the scope of the transition to the cloud as not only a technological improvement of existing legacy systems. Moreover, studies also reported that practitioners usually struggle in issues related to lack of standards for development of cloud services.

We applied the following search string to analyze the two research questions: *"cloud migration"* and *"tools"* and *"legacy systems"* for papers published between 2012 and 2017. The search string was executed on October 16th, 2017. We conducted the search queries in the Science Directory digital library and the number of papers returned was *six*. Once we obtained the results of these queries, we applied the inclusion and exclusion criteria. To be included, papers needed to fulfill at least one of the following criteria: *Inclusion Criteria 1 (IC1)*: papers that report empirical studies focusing on the study topic; *Inclusion Criteria 2 (IC2)*: papers published from January 2012 to November 2017. *Exclusion Criteria 1 (EC1)*: papers that do not report empirical studies; *Exclusion*

Criteria 2 (EC2): papers not published from January 2012 to November 2017.

IV. Analyzing Data from the Selected Papers

In this section, we present the findings of this study, together with the appropriate references. Table I presents a list of selected papers returned from the query of the search string in the *Science Direct* digital library. By analyzing these papers, we identified the tools presented in Table II, as well as the migration phase they support.

Answers to RQ1: *Which tools support the migration of legacy systems to the cloud?*

Considering the tools listed in Table II, the distribution of tools per phase is as follows: one tool to support Phase 1, twenty-two tools to support Phase 2, and two tools to support Phase 3. In the following paragraphs, we briefly describe these tools with their main features.

Cloud Adoption Toolkit [12] provides support for cloud migration decision making, including Energy Consumption Analysis, Technology Suitability Analysis, Responsibility Modeling, Stakeholder Impact Analysis, and Cost Modeling.

The CloudGenius tool: also provides support to deal with the multi-criteria decision-making problems regarding the identification of an effective combination of a Cloud VM image and a Cloud infrastructure service. For this end, the tool uses a model and methods to determine a suitable combination of a Cloud VM image and the corresponding Cloud infrastructure service [13].

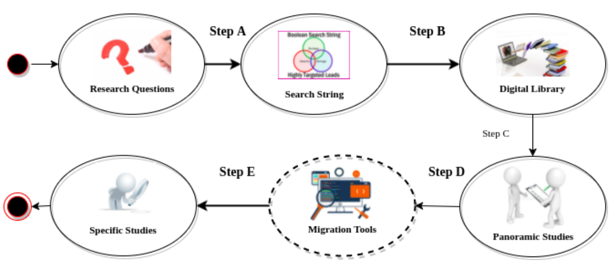

Fig. 2. Semi-Systematic Literature Review

TABLE I
Selected Primary Studies

ID	Title	Year
[4]	Challenges in migrating legacy software systems to the cloud — an empirical study	2017
[14]	Cloud migration process — A survey, evaluation framework, and open challenges	2016
[15]	Automated configuration support for infrastructure migration to the cloud	2016
[16]	White-box modernization of legacy applications: The oracle forms case study	2017
[17]	Understanding cloud-native applications after 10 years of cloud computing - A systematic mapping study	2017
[18]	A framework to support selection of cloud providers based on security and privacy requirements	2013

TABLE II
Tools to Support the Migration Phases

Phase	Studies
1	CloudAdoption Toolkit [12]
2	CloudGenius [13], CDOSim [19], CloudSim [20], NetworkCloudSim [21], GreenCloud, iCanCloud, TeachCloud, GroudSim, CloudAnalyst, MDCSim, GDCSim, SPECI, Seagull, OPERA, Microsoft Migration Accelerator, SmartCloud, iCanCloud, CloudAnalyst, ContainerCloudSim, JCloudScale Midleware [22], CDOXplorer [23], CloudNetSim++ [24]
3	CloudMIG Xpress [25], [19], [26], Cloudify [27]

CloudSim [21] is a simulation framework to support modeling, simulation, and experimentation in the Cloud computing infrastructure and application services. It enables evaluating the performance of a given application service in a controlled and heterogeneous Cloud environments (for example, combining the use of two or more different providers).

CDOSim [19] is a tool that can simulate cloud deployments of software systems that were reverse-engineered to Knowledge Discovery Meta-Model (KDM) models [28]. It can compare cost and performance of competing cloud deployment options (CDOs). It is compatible with application models based on the KDM of the OMG. This enables the simulation to be to some extent independent of programming languages for the cases that a corresponding KDM extractors is available for the target programming language. The tool incentives the use automated reverse-engineering techniques to create application models.

NetworkCloudSim [21] is a tool that extends CloudSim with modeling features of the application behavior as well as internal network of a data center.

GreenCloud [29] is an extension of the network simulator Ns2 [4]. One of its relevant feature is the possibility to extract, aggregate, and provide information related to energy consumption of both computing and communication elements of the data center.

MDCSim [29] is a Multi-tier Data Center Simulation Platform is announced as a flexible and scalable simulation platform for in-depth analysis of multi-tier data centers. It was designed as a pluggable architecture aiming to capture the important design specifics of the underlying communication paradigm, kernel level scheduling artifacts and the application level interactions among the tiers of a three-tier data center. The flexibility of the simulator is explained by its ability to experiment with different design alternatives in the three layers and in analyzing both performance and power consumption with realistic workloads.

The **iCanCloud** [30] tool is a simulation platform aimed at modeling and simulating cloud computing systems. iCanCloud was built to meet several requirements: (1) to be able conduct large experiments; (2) to provide a flexible and fully customizable global hypervisor, enabling users to implement any brokering policies; (3) to reproduce the instance types provided by a given cloud infrastructure; (4) to provide a user-friendly

[4] http://www.isi.edu/nsnam/ns/

GUI for configuring and launching simulations, ranging from a single VM to large cloud computing systems comprising thousands of machines.

TeachCloud [31] is a modeling and simulation environment for cloud computing. It was developed an extension of CloudSim to experiment with different cloud components, namely processing elements, data centers, storage, networking, Service Level Agreement (SLA) constraints, web-based applications, Service Oriented Architecture, virtualization, management and automation, and Business Process Management. TeachCloud uses the Map-reduce processing model to handle "embarrassingly parallel" data processing tasks.

GroudSim [32] is a Grid and Cloud simulation toolkit for scientific applications based on a scalable simulation-independent discrete-event core. GroudSim aims to provide comprehensive support for complex simulation scenarios from simple job executions on leased computing resources. It enables calculation of costs and background load on resources. Simulations can be parameterised and are extendable on the basis of probability distribution packages to deal with failures that can occur in complex environments. To work, GroudSim requires one simulation thread only, instead of one separate thread per entity.

CloudAnalyst [33] is a tool built on top of CloudSim that aims to simulate large-scale cloud applications with the purpose of studying the behavior of such applications under various deployment configurations. CloudAnalyst aims to provide developers with insights on how to distribute applications among cloud infrastructures. It also provides services such as optimization of application performance. It supports visual modeling and simulation of large scale applications deployed on Cloud Infrastructures. CloudAnalyst also allows the description of application workloads, namely information of geographic location of users generating traffic, location of data centers and the number of resources in each data center.

GDCSim [34] is a simulation tool that unifies existing techniques to green data center management and aims to enable a holistic design and analysis prior to deployment. It is used to iteratively design green data centers. It analyses data center energy efficiency by studying and testing several factors such as: (1) different data center geometries, (2) workload characteristics, (3) platform power management schemes; (4) scheduling algorithms and (v) data center configurations.

SPECI (Simulation Program for Elastic Cloud Infrastructures) [35] is a simulation tool for the exploration of aspects of scaling as well as performance properties of future data centres.

OPERA (Optimization, Performance Evaluation and Resource Allocator) [36] is a layered queueing model used to evaluate the performance of web applications deployed on arbitrary infrastructures. OPERA serves to model an applications architecture and performance characteristics, perform operations on control points, estimate response time, throughput, and utilization of resources (i.e., CPU and disk)[5].

Microsoft Migration Accelerator (MA[6]) assists in the migration to the cloud [37]. MA is designed to seamlessly migrate physical, VMware, Amazon Web Services and Microsoft Hyper-V workloads into Azure. It automates all aspects of migration including discovery of source workloads, remote agent installation, network adaptation and endpoint configuration. It aims to reduce cost and risk of the migration project. It claims to change the cloud migration paradigm, by offering: *Heterogeneity*: MA enables migrate workloads running on a broad range of platforms such as VMware, Microsoft Hyper-V, Amazon Web Services and/or Physical servers within the environment. *Simple, Automated Migration*: the MA portal allows users to automatically discover their enterprise workloads, remotely from the cloud. It enables end-to-end configuration of migration scenarios. *Migrate Multi-tier Applications*: MA claims to have the unique ability to migrate multi-tier production system with application level consistency orchestrated across tiers. *Continuous Replication, Least Cutover Time:* MA for Azure provides full-system replication including the OS and application data.

SmartCloud iNotes [38] is a branded collection of Cloud products and solutions from IBM. It includes IaaS, SaaS, and Platform as a Service (PaaS) offered through public, private and hybrid cloud delivery models [7].

ContainerCloudSim [39] was proposed for the study of resource management techniques in CaaS environments and was developed as an extension of CloudSim [21]. Its supports the modeling and simulation of "containerized" cloud computing environments. ContainerCloudSim provides an environment for evaluation of resource management techniques such as container scheduling, placement, and consolidation of containers.

JCloudScale Midleware [22] is a Java-based middleware supporting building elastic applications on top of a public or private IaaS cloud. It allows the migration of applications to the cloud, with minimal changes to the application code. It also takes over virtual machine management, application monitoring, load balancing, and code distribution. It aims to run on top of any IaaS cloud, making it a viable solution to implement applications for private or hybrid cloud settings.

CloudMIG Xpress [40] is a approach for supporting practitioners and researchers to semi-automatically migrate existing software systems to cloud-based applications. It incorporates usage patterns and varying resource demands in creating a target architecture candidate and concentrates on enterprise software systems offered by SaaS providers. The approach is composed of six major activities as follows. Extraction, Selection, Generation, Adaptation and Evaluation. It addresses challenges such as systematically comparing cloud environment candidates, checking the conformance with particular cloud environments, or simulating monitored workload for envisioned cloud-based target architectures to evaluate future costs and provides tool support for the comparison and plan-

[5]http://www.ceraslabs.com/technologies/opera

[6]https://azure.microsoft.com/pt-br/blog/introducing-microsoft-migration-accelerator/

[7]http://www.ibm.com/cloud-computing/us/en/

ning phases to migrate software systems to PaaS or IaaS-based clouds [40].

Cloudify[8] and **Kubernetes**[9] are Open Source software projects that support the orchestration of Docker containers [41]. They can be used to automate the deployment and to scale applications in the cloud. Cloudify allows developers to model the application topology through YAML.

CloudNetSim++ [24] is a toolkit for modeling and simulation purposes to support the simulation of distributed data center architectures using the cloud. CloudNetSim++ was designed to enable the analysis of data center architectures regarding network traffic patterns through the use of custom protocols and applications. CloudNetSim++ claims to be the first cloud computing simulator that uses real network physical characteristics to model distributed data centers. The tool support users to define, among other features, a SLA policy, scheduling algorithms and modules for different components of data centers throughout the use of a generic framework.

Answers to RQ2: *What are the main challenges and opportunities reported in the literature related to the migration of legacy systems to the cloud?*

Studies from the literature reveal that the transition to the cloud is not limited to evolving existing legacy systems. It also results in modifying the way these systems operate, provide services, and are maintained [4]. For example, despite the ongoing advancements in the cloud computing, there is no common standard for the development of cloud services [42]. This leads to the challenge of integrating legacy systems to cloud services, since different providers offer cloud services with different underlying technologies and non-standard proprietary APIs [4]. Moreover, evidence from the literature shows that many of the difficulties in the migration process are related to: (i) inappropriate understanding regarding cloud computing requirements, (ii) inadequate or no planning [4]. In this context, many companies have concerns on how to avoid failure in cloud environment.

V. Conclusions and Future Research

In this paper, we presented an updated list of tools that support the migration of legacy systems to the cloud as follows: one tool to support the planning of the migration phase, twenty-two tools that support the design of the migration phase and finally two tools related to the enable phase. We briefly discussed the features of these tools and contextualized them in the migration process. To the best of our knowledge and based on the findings from this study, we did not identify in the literature reports from the use in the industry of tools that support the whole migration process to the cloud. Most of the tools focus on specific phases of the migration process.

As future work, we plan to evaluate the usage of the tools Cloudify as an open source cloud orchestration framework and the Open Tosca Container that is the TOSCA Runtime Environment to deploy and manage Cloud applications. It enables the automated provisioning of applications that are modeled using TOSCA and packaged as CSARs.

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[8](http://getcloudify.org)

[9](kubernetes.io)

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