Information and Software Technology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof

Agile development in the cloud computing environment: A systematic review

Muhammad Younas[*,a,b], Dayang N.A. Jawawi[a], Imran Ghani[c], Terrence Fries[c], Rafaqut Kazmi[a]

[a] Universiti Teknologi Malaysia (UTM), Malaysia
[b] Government College University Faisalabad (GCUF), Pakistan
[c] Indiana University of Pennsylvania, Indiana, Pennsylvania, United States

ARTICLE INFO

Keywords:
Agile
Agile software development
Agile methodology
Cloud computing
Systematic review

ABSTRACT

Background: Agile software development is based on a set of values and principles. The twelve principles are inferred from agile values. Agile principles are composition of evolutionary requirement, simple design, continuous delivery, self-organizing team and face-to-face communication. Due to changing market demand, agile methodology faces problems such as scalability, more effort and cost required in setting up hardware and software infrastructure, availability of skilled resource and ability to build application from multiple locations. Twelve (12) principles may be practiced more appropriately with the support of cloud computing. This merger of agile and cloud computing may provide infrastructure optimization and automation benefits to agile practitioners.

Objective: This Systematic Literature Review (SLR) identifies the techniques employed in cloud computing environment that are useful for agile development. In addition, SLR discusses the significance of cloud and its challenges.

Method: By applying the SLR procedure, the authors select thirty-seven (37) studies out of six-hundred-forty-seven (647) from 2010 to 2017.

Result: The result of SLR shows that the techniques using existing tools were reported in 35%, simulations in 20% and application developed in 15% of the studies. Evaluation of techniques was reported in 32% of the studies. The impact of cloud computing was measured by the classification of four major categories such as transparency 32%, collaboration 50%, development infrastructure 29% and cloud quality attributes in 39%. Furthermore, a large number of tools were reported in primary studies. The challenges posed by cloud adoption in agile was reported as interoperability 13%, security & privacy 18% and rest of the primary studies did not report any other research gaps.

Conclusions: The study concludes that agile development in cloud computing environment is an important area in software engineering. There are many open challenges and gaps. In particular, more quality tools, evaluation research and empirical studies are required in this area.

1. Introduction

The aim of agile methodology is to help software teams, think differently, work efficiently, deliver on time, keep learning and re-learning from previous iterations. In order to achieve this aim, agile manifesto was proposed with four core agile values leading to twelve principles. The composition of agile values are as follows [37].

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

It can be seen and is already widely acknowledged that more importance should be given to the value on the left side (in bold), whereas, previously (before the introduction of this manifesto), more importance was given to the right side value. It does not mean that the right hand side values are not important. They are, however, no more important than the left side values.

- First value or feature refers to individuals or team members, customers and business people. The interaction among these individuals should occur through the face-to-face communication, self-organizing team and by tuning teams' behaviour.

* Corresponding author.
E-mail address: younas.76@gmail.com (M. Younas).

https://doi.org/10.1016/j.infsof.2018.06.014
Received 17 December 2017; Received in revised form 25 June 2018; Accepted 25 June 2018

- Second value refers to focus on working software. This implicitly suggests technical excellence, simplicity and good design.
- Third value refers to customer collaboration in the form of working closely with business people and developers together. Furthermore, customer satisfaction is achieved through early, frequent and continuous delivery of software. This continuous delivery shows the pace of development progress.
- Fourth value refers to customer satisfaction that becomes firm with accommodating the change in requirements at any stage of development and reducing the time to commit change.

According to this manifesto, twelve (12) agile principles were also proposed. Agile principles further explain and enhance the importance of agility in software development. However, these agile guidelines are not fully implemented due to rapid change in market demand and while terms are working in distributed environment. Several hindrances exist such as scalability, transparency [58], face-to-face communication [51], availability of experts [43], smooth control of development, ability to build applications from distributed locations [61] and resource management [14,58]. The changing demands require an environment to test new ideas. The provision of resources for testing news ideas increases the development cost.

In order to deal with these hindrances, cloud computing provides an environment to quickly test new ideas in the marketplace [48,53]. Cloud Computing has the potential to reduce the cost of agile development through data sharing, distributed application, prioritizing tasks and by providing infrastructure (hardware and software) [61]. Cloud computing enhances the development process by eliminating the need for installations procedures, software patches, and re-installation [50]. Cloud services provide storage and computing resource based on pay per use [17,39]. Cloud computing extends the existing agile process through fast delivery, lowering cost and increasing software quality [6,58].

As we discussed earlier, agile software development is based on frequent delivery, strong working relationship between user-developer, technical excellence and accommodating change in any stage of development. The question is how can these features of agile be implemented in a cloud computing environment. In order to answer this question, the review study will analyse agile management and development methods in conjunction with cloud computing. This analysis will explore the re-usability of various tools and interoperability of cloud services, as there are some existing studies in this area. Therefore, the SLR study first shows the growth of research in this area. The study identifies different techniques, their evaluation, comparison and use of tools in agile and cloud computing environment. The SLR study explores the effect of cloud over agile software development, issues, challenges reported in primary studies and future trends in this area.

This paper is organized into six sections. The following section introduces background and motivation of study. Section 2 describes research method to conduct SLR. Section 3 presents the concise results of the SLR and discussion. Section 4 describes the threats regarding the validity of primary studies. Finally, the Sections 5 and 6 describe future work and conclusion, respectively.

1.1. Background of agile development in cloud computing

The conjunction of agile and cloud is beneficial to distributed application development, data sharing, prioritising task, transparency and infrastructure building [58,61,66] in the sense that cloud computing affects the ecosystem of agile software development with increasing prominence [23,43,62]. Ecosystem means a system or group of interconnected elements in agile perspectives such as development environment, teams interconnectivity and the whole system. Other benefits are that cloud computing reduces cost, enables scalability and performance in agile software development [12,17]. In addition, agile's practice of communication is implemented with the help of cloud-based social technologies [23]. However, in terms of academic research, there is not much research that discusses such findings, share research gaps and related issues in both these domains, together. Separately, agile and cloud computing have enough peer-reviewed material but not on both. Therefore, this review paper focuses on the literature containing the studies on both agile methodology and cloud computing.

Table 1
List of related review studies.

Study reference	Review focus	Studies reviewed	Time covered
[24]	Overview of AGSD and cloud	8	2008–12
[2]	SLR on SE and cloud	17	2008–10

To explore more, the authors have searched online research sources to find relevant studies using agile development in cloud computing environment. In the literature, there are only two review studies on agile software development and cloud computing. The list of previously reviewed studies is given in Table 1.

The first review study [24] reported the challenges and benefits in Agile Global Software Development (AGSD) and cloud computing. This study examined eight (8) studies from 2008 to 2012. Furthermore, they included white papers, which are considered as grey material in research community, in their review [2]. They identified the challenging factors such as synchronous communication, collaboration difficulties, communication bandwidth, tool support, large team, office space, multiple sites and coordination among distributed team members. The study concluded that socio-cultural (difference of custom, lifestyle and culture on distant team members) issues exist, and that more effective cloud services are needed. They also suggested that there is a need for an artificial intelligence based service that can detect communication weaknesses and abnormalities among team members.

The second review study [2] mainly focused on the big umbrella of software engineering and cloud computing environment, not specifically agile software development. The review study discussed the problem faced by the developer and also explained the benefits of cloud computing for developing software using agile methodologies. The review study examined seventeen (17) studies from 2008 to 2010. They identified issues such as multi-tenancy, need for standardization and interoperability, issues due to concurrence execution of test cases.

First motivation point for our study is that the previous review studies have considered eight and seventeen studies from 2008 to 2010 and 2008 to 2012. We enhance the review with an increased number of articles (37) and classify the type of solutions for practicing agile development in cloud computing environment, their evaluation and comparison. Re-usability of tools in agile management and agile process implementation in conjunction with cloud is discussed. We identify the studies that addressed agile based and cloud-based features, the classification of impact due to cloud computing on agile software development, the challenges in conjunction with cloud computing and identify the research gaps in these areas.

1.2. Agile software development methodology

For the beginners, this section presents a concise introduction to agile software development and the important terms used in this area. Agile methods are based on small development cycles, continuous integration of software versions, adaptive planning, team collaboration, customer involvement, and feedback. Agile software development has various methods [60].

1.2.1. Scrum

Scrum is defined as a flexible, holistic product development strategy where developers work as a unit to reach a common goal" [44]. In Scrum, iteration is called **Sprint**, with a usual duration from one week to one month. At the beginning of project, **Sprint Planning** is started to specify and prioritize the features. The list of prioritized features is