A Systematic Mapping Study of Innovative Cloud Applications

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Abstract. Cloud computing is a business paradigm wherein computers and computing related services are provided by Cloud Service Providers to consumers either as software, development platform, or infrastructure. Innovative applications are growing in a productive manner on the cloud landscape. Innovative applications are being developed for use in the area of e-learning, automotive processes, cloud containers and machine learning. The objective of this paper is to conduct a systematic mapping study of innovative cloud applications and experiences. The systematic map provided a structured overview of research work carried out and the frequency of publications, presenting them pictorially in form of a map. The obtained results showed that 7.34% of the publications were on development of innovative cloud applications in terms of model. Architecture and modelling, and simulation in relation to model were both at 13.76%, 11.93% of the papers respectively, while 8.26% of the articles were on deployment in terms of process. Architecture had most publication in the area of solution research, with 15.2%. For articles published on deployment and development, most were on solution research with 8.80% and 14.40% respectively. The outcome of this study will be beneficial to practitioners in the industry and academic researchers alike.

1. Introduction

The Cloud is a parallel and distributed computing system consisting of a collection of interconnected and often virtualized computers, which are dynamically provisioned and presented to customers as a single computing resource based on pre-agreed service levels between the Cloud Service Providers (CSPs) and the Cloud customers [1]. Although the CSPs are striving to provide very efficient and reliable services on the cloud, there are also issue of service level agreements [2]. Traditionally, there are three Cloud service models, namely: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). These services are offered to clients in one of four deployment models - private, public, community and hybrid [3]. Cloud computing now offers some unique experiences and affect lives in completely new ways. In addition, cloud computing is very broad and there is a plethora of subjects such as virtualization and Cloud identity management requiring significant discussion. Such issues are directly or indirectly related to the focus of this study [4, 5].

There are numerous research works on going in the area of innovative Cloud applications and experiences targeted at both private individuals and corporate organizations alike. The Cloud-based
Accounting solution is a mobile SaaS that allows the use of mobile phones to access accounting data. Containerization presented in [6] for instance allows for application abstraction which results in application portability and rapid deployment. Cloud as a heating source in [7] uses heat generated from super computers to warm homes. Cloud-based car parking in [8], uses the Cloud to manage parking lots. In [9], the Cloud is used for remote cars diagnosis and to proffer solutions in event of a breakdown. With the development of private educational cloud, web based lecturing and collaboration are now a possibility [10]. In [11], a location-based augmented reality application is presented which uses mobile phones and geographic location information to provide transform the users’ environs and provide a life-like digital experience.

With the increasing use of cloud computing, there has also been an increase in the need for applications which would provide cloud-based services. Some examples of innovations currently in the cloud includes intelligent databases, internet of things, advanced identity-based security, container operations, etc. There are various benefits of using cloud applications, this has also been acknowledged by cloud computing users. With a lot of innovations evolving in cloud computing in terms of cloud applications, there is the need to properly study and conduct research on the technology driving these applications in other to avoid challenges like data insecurity and enhance service quality and performance. In addition, it is important to study cloud innovations because individuals, corporations and government agencies benefit from these innovations. Researchers will therefore be motivated to improve on existing innovations or develop new innovations. The systematic mapping process is usually done in facets to allow for consideration of all aspects. Three facets were employed in this study namely; the topic, contribution and research facets. The topic facet was used to extract core aspects of innovative cloud applications. The research facet focused on the types of research carried out, while the contribution facets focused on the method and model applied.

The motivation for this work is that more researches are still required in the areas of innovative cloud applications. Hence, the problem this study seeks to address is identifying areas where there are dearth of papers and pointing it out to upcoming researchers. The purpose of this paper therefore, is to conduct a systematic mapping study of innovative cloud applications and experiences. The major contribution of this review is that a visual map was created with percentages indicating the extent of work that has been done in various research types and research contributions such as framework and model in this field of study. The remaining part of the paper is organized as follows: section 2 examines related work, section 3 discussed the materials and methods, while the results and discussion are presented in section 4. Finally, the paper is concluded in section 5 with recommendations for future studies.

2. Related Work
[12] examines how researchers should conduct the process of systematic mapping and identify how the guidelines should be updated based on lessons learned from existing systematic maps and systematic literature review guidelines. In the affirmative, the authors conducted a systematic mapping study of systematic maps, considering some practices of systematic review guidelines. They discovered that in the large number of the studies conducted, multiple guidelines were used and combined which lead to different ways in conducting systematic mapping studies. [13] assesses the impact of systematic literature review which are the recommended evidence-based software engineering methods for aggregating evidence. The authors used a manual search of Journals and conference proceedings. In total, of the 20 relevant studies, eight addressed research trends rather than technique evaluation. Seven systematic literature reviews addressed cost estimation. The quality of systematic literature reviews was fair with only three scoring less than 2 out of 4.

[14] is a systematic mapping study of cloud policy languages and programming models which based their work on the concepts of [12]. This study provided six classes of study in the areas of survey, framework, privacy, paradigms, accountability and reliability, and security in relation to the focus of study. The selected studies were applied on the contribution facet in relation to tool, method, and model. In addition, the selected studies were used on the research facet which dealt with evaluation, validation, solution, experience and opinion research. [15] is Cloud Design and Deployment Models: A Systematic Mapping Study. The classification scheme in relation to design and deployment models discussed six topics which are design, service deployment, implementation, configuration, privacy and security. The
selected studies were applied on the contribution facet based on metric, tool, method, and model. In addition, the selected studies were applied to the types of research in terms of evaluation, experience, opinion validation and solution research.

[16] is A Systematic Mapping Study On Cloud-Based Mobile Application Testing. The classification scheme in relation to cloud-based testing discussed four topics which are security testing, compatibility testing, functional testing and GUI testing. The selected studies were applied on the contribution facet based on framework, metric, tool, method, and model. In addition, the selected studies were applied to the types of research in terms of evaluation, validation and solution research. The study also examined Testing-as-a-Service using some contribution category consideration. From literature examined, there has been no work focused specifically on systematic mapping study of Cloud native applications.

3. Materials and Methods

3.1. The systematic mapping process
A systematic mapping study employs a visual representation process to grant insight into materials published in a field of study. This systematic mapping study was carried out using the formal guidelines for a systematic mapping study as described in [12]. It is defined in [17] as a repeatable process for extracting and interpreting available materials related to a research objective. The first step is the definition of research questions in which the scope of the study is outlined. A search is conducted for primary studies in the proposed area of study. The publications found are then screened to determine their relevance to the study. The next step is the key wording, which involves using the abstracts of the paper for designing a classification scheme. The last step is the process of data extraction, which results in the creation of the systematic map. These steps were rigorously followed in this paper. With respect to the title of this paper and in order to meet the objectives as well as answer the research questions, a total of 125 papers were deemed relevant out of an initial search comprising of 1,449 papers. This study covered the period 2013 – 2018.

3.2. Conduct Search for Primary Studies
An appropriate research question is essential for a comprehensive study, because the essence of a systematic map is to have an insight into the quality and type of research activities that have been done in a given field of study. These issues determine how the research questions are crafted in order to accurately capture the essence of the study. In this particular study, the research questions are as follows:
--RQ1: What areas in Innovative Cloud Applications and Experiences are addressed and how many articles cover the different areas?
--RQ2: What types of papers are published in the area and what particular evaluation and novelty did they introduce?
--RQ3: What research approaches do these studies apply and what contributions were enunciated?

Typically, searching for papers usually involves exploring major digital libraries. However, this can also be accomplished by manually searching through books, printed materials, conference proceedings and journals. For this study, only papers available on online databases were considered, thus excluding book and printed resources. The primary search focused on searching relevant literature from online database resources using the search string below. Thereafter, a backward snowballing was carried out to enhance the search process [18]. The search utilized five digital libraries which are ACM, IEEE, Science Direct, Springer and Scopus. The search string for this study was designed in terms of outcome, population, comparison and intervention. The keywords used in the search string were taken from every aspect of the structure of the title of the study. For this study on innovative cloud applications and experiences, the search string used on the selected databases is:

(TITLE-ABS-KEY (Cloud) AND (TITLE (Innovative) AND (TITLE-ABS-KEY (Applications) OR TITLE-ABS-KEY (Experience)))).

The searches were performed using the customized search string above on document metadata to ensure that relevant studies were not omitted. For this study on innovative cloud applications and
experiences all the result from the relevant databases relating to cloud and computer science were examined. The goal of the selection criteria was to find and include all papers relevant to the field of study. It is usual to use the inclusion and exclusion criteria to eliminate papers that are not relevant to a study. The inclusion and exclusion criteria were also used to remove papers that were not relevant to the research questions. Abstracts can usually be considered here as they provide concise yet sufficiently detailed information about the main focus of a paper. However, abstracts are not usually included in papers on editorials, summaries, tutorials, presentation slides, panel discussions and prefaces; hence these types of publications were excluded from the study. In building the classification scheme, a thematic analysis approach, which aimed at identifying, analyzing and reporting themes within the studies under consideration was adopted [19].

4. Results and Discussion

4.1. Topic Category and Contribution Facet

The contribution facet focus on discussion in the areas of framework, model, tool, evaluation, metric and method [20]. The topics category was central to this study. The topics that were expected during the classification scheme of innovative cloud applications and experiences are: deployment, advantages and disadvantages, development, architectures, modelling and simulation and orthogonal. The list of primary studies used for checking the topics against the types of contributions is at table 1. The systematic map of innovative cloud applications and experience is depicted in figure 1. On the X-axis of the left half are the results of the contribution facet. This category depicted the contributions to a study. The result showed that 41.28% of the publications discussed model in relation to innovative cloud applications and experience. While those on metric were 1.83%; tool was 19.27%; method was 23.85% and process were 13.76%.

From the figure 1, model discussion contributed 41.28% of the paper reviewed in this facet. The breakdown showed that 2.75% of model discussion were on deployment, 3.67% on advantages and disadvantages, 7.34% is on development, while architectures and modelling and simulation facets each has 13.76%. Other results on the contribution facets as it relates to topics are shown on figure 1.
4.2. Topic Facet and Research Category

The categories and description of research works as listed in [21] was utilized for the third facet. They are validation research, evaluation research, solution proposals, philosophical papers, opinion paper and experience paper. The list of primary studies used for examining the topics against the types of research is at table 2. Depicted on the X-axis of the right half of figure 1 are the results of the type of researches

| Contribution Facet | Metric | Tool | Model | Method | Process |
|--------------------|--------|------|-------|--------|---------|
| Deployment         | 48, 56, 76, 77, 104, 106, 122, 19, 21, 60, 12, 13, 17, 34, 54, 107, 110, 1, 4, 8, 20, 22, 27, 36, 44, 123 |
| Design             | 78, 81, 121, 93, 96, 113, 38, 73, 79, 91, 3, 40, 51, 52, 61, 71, 74, 80, 82, 94, 120, 124, 125 |
| Development        | 14, 16, 18, 30, 33, 39, 59, 28, 29, 35, 37, 41, 45, 46, 47, 50, 57, 86, 87, 89, 90 |
| Architecture       | 58, 62, 66, 67, 83, 84, 85, 102, 2, 5, 6, 9, 10, 11, 15, 23, 97, 111, 25, 31, 114, 115 |
| Modelling and Simulation | 42, 43, 49, 65, 68, 69, 72, 100, 117, 118, 119, 116, 99, 108, 109 |
| Percentage         | 0.00% | 22.22% | 41.67% | 22.22% | 13.89% |

Figure 1. A Systematic Map on Innovative Cloud Applications and Experiences.
conducted within the focus area. The results showed that 48% of the surveyed papers proposed solution, while 15.20%, were evaluation-based publications. 17.60% were validation-based, 4.80% were philosophical, 12.0% were experience and 2.40% were opinion papers. On the figure, Solution proposal contributed 48% of the paper reviewed in terms of type of research. Out of this 48%, 8.8% discussed deployment, 1.6% were on advantages and disadvantages, 14.4% were on development, 15.2% were on architectures and 8.0% were on modelling and simulation.

### Table 2. Primary studies for topic and research facets.

| Research Facet | Evaluation | Validation | Solution | Philosophical | Experience | Opinion |
|----------------|------------|------------|----------|---------------|------------|---------|
| **Deployment** | 76, 77, 76, 104, 106, 54, 55, 53, 56, 122, 123 | 1, 4, 8, 12, 13, 17, 19, 21, 26, 36, 44 | 20, 22, 27, 34, 48, 60, 107, 110, | | |
| **Design** | 73, 91, 93, 96, 113, 71, 79, 80, 82 | 3, 38, 52, 74, 94, 124, 125 | 40, 51, 61, 75, 101, 103, 98 | | |
| **Development** | 30, 33, 39 | 14, 16, 18, 28, 29, 35, 37, 41, 45, 46, 47, 50, 57, 59, 86, 87, 89, 90 | 7 | 95, 70, | | |
| **Architecture** | 63, 64, 58, 62, 66, 67, 83, 84, 85, 102, 105 | 2, 5, 6, 9, 10, 11, 15, 23, 24, 25, 31, 32, 88, 92, 97, 111, 112, 114, 115, | | | | |
| **Modelling and Simulation** | 116, 99, 108, 109 | 42, 43, 49, 65, 68, 69, 72, 117, 118, 119, 100 | | | | |

#### 4.3. Major Findings

The result of the analysis carried out and presented on figure 1, made it easy to identify which areas had more emphasis based on the frequencies of publications. From figure 1:
a. It can be seen that 7.34% of the publications were on development of innovative cloud applications in terms of mode. Architecture and simulation in relation to model were both at 13.76%, 11.93% of the papers respectively. Finally, 8.26% of the articles were on deployment in terms of process.

b. Similarly on the right half there were more publications on advantages and disadvantages in terms of evaluation research which was 4.0%, more articles on advantage and disadvantage in terms of evaluation and philosophical at 4.0% and 3.2% respectively. Architecture had the most publications in the area of solution research, with 15.2%. For articles published on deployment and development, most were solution research with 8.80% and 14.40% respectively.

c. To the best of the researchers’ knowledge, there were no articles identified by this study on modelling and simulation except under model which had 13.76%. There were also no articles on modelling and simulation in terms of validation and philosophical researches. Few articles were seen on orthogonal with the most being evaluation research at 3.20%. Similarly, no facets made contributions to Metric except Orthogonal. With respect to architecture, research work was only focused on evaluation, validation and solutions.

d. Generally, it was identified from the map that there were more publications on evaluation, validation and solution areas of research; and very few on philosophical and opinion.

The unique thing about a systematic map is that there are several interesting aspects of the results generated. The visual appeal of the map helps to summarize and provide information to potential researchers on what areas to focus on. There is no doubt that the bubble plot results will be quite useful. Suffice to mention, a systematic map without a systematic literate review has a unique value in itself, as it clearly helps to identify research gaps for further studies.

The relevance of this is that researchers at all levels and industries practitioners can use this as a starting point to conduct further studies. This study provided six classes of topics namely: deployment, advantages and disadvantages, development, architectures, modelling and simulation, and orthogonal in relation to innovative cloud applications and experience. In addition, the six classes of study can be discussed either in terms of tool, model, method, metric and process or in terms of evaluation, validation, solution, philosophical and opinion research. These areas amongst others are therefore recommended for future research. The list of primary studies would also assist intending researchers. The important lessons learnt in this study is that research work is a continuum and it is inexhaustible.

5. Conclusion

This systematic mapping study has been able to identify some areas where there was less emphasis in terms of innovative cloud applications and experience based on the categories used in the scheme. This paper has therefore contributed to knowledge by indicating different aspects of the study where there were gaps. The gaps that have been identified are recommended for further studies. It is expected that it would serve as a broad guide into topics that can be researched on in the area of innovative cloud applications and experience. Further research could also be carried out to validate this study or resolve contradictory issues. In summary, this study created a systematic map of innovative cloud applications and experience that can be beneficial to the cloud community. This study will help the researchers to uncover the critical gaps of innovative cloud applications and experience that many researchers were not able to explore. Thus, expanding the frontiers of knowledge in cloud computing.

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