

# Advancement of Mobile Computing Application with Context-Aware in Higher Institutions

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## Abstract

Mobile computing application with context-aware is widely used due to the potential of using context information to solve problem that are traditionally impossible. It utilizes pervasive and ubiquitous environment where devices, software agents and services interact through human needs. In this paper, advancement of mobile computing application with context-aware was carried out through literature review to investigate the contributions of previous studies and identified evaluation measures specifically in higher institutions. It also identifies contributions of research done so far with emphasis on education. Method of evaluation in the domain is equally identified to know area of future research. Search terms with relevant keywords were used to select primary studies that relate to the topic of discussion. Consequently, 23 context-aware studies were identified and analysed in education with respect to higher institutions. Ontology techniques was rarely utilized as only 3 are found in the studies. The application of the ontology to explicit representation of knowledge was still low. Information and service abundance is a major challenge in the society and world at large. Most research contributions presented still have shortcomings especially with the use of multi-agent concept as they were used by only 3 of the studies investigated for context-aware between 2017 and 2018 respectively. Based on this shortcoming, the identify gaps suggest further study.

**Keywords:** Context-aware Computing, Techniques, Mobile Computing Application, and Evaluation Measure.

## I. INTRODUCTION

The term context-aware is a property of mobile computing. Context-aware originates as a term from ubiquitous or pervasive computing [1], which is an act of linking changes in the environment with computer system that is static. The present target of

pervasive computing is to integrate intelligent agent that is capable of knowledge empowerment and reasoning to understand the local context and shared information to support intelligent application and interfaces [2]. It is very rare, to see disciplines and industries where context-aware related applications will not fit in, because of context and its relationships with environment and situational changes in our daily life. This statement supports previous research in the literature from [3], with explanations provided for context and the origin of ‘context-aware computing’ as proposed in [4] also cited in [5]. Several concepts have been proposed in the various disciplines such as education [1,6], building automation [7], health care [8], library management [9], movie industry [10], business [11], restaurant [12], banking institution [13] to mention just a few. The pervasive and mobile computing applications possess the potentials to take context-awareness to the next level considering that massive and dynamic data coming from diverse institutions for education source can be exploited, via available software interfaces, to build more dynamic and intelligent services [14]. Figure 1 and 2 shows the flow of a viable context-aware service with mobile applications in higher institution.

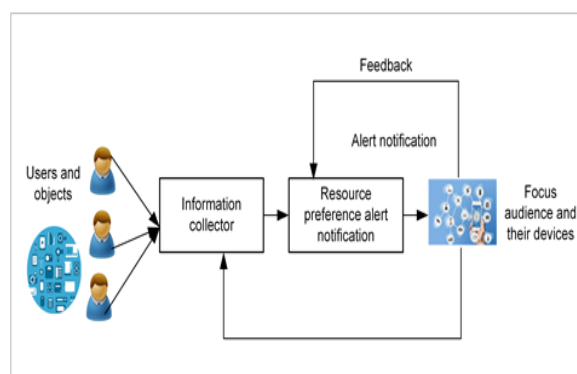


Fig. 1: Modified Context-aware with mobile computing application-based service in higher institution [14].

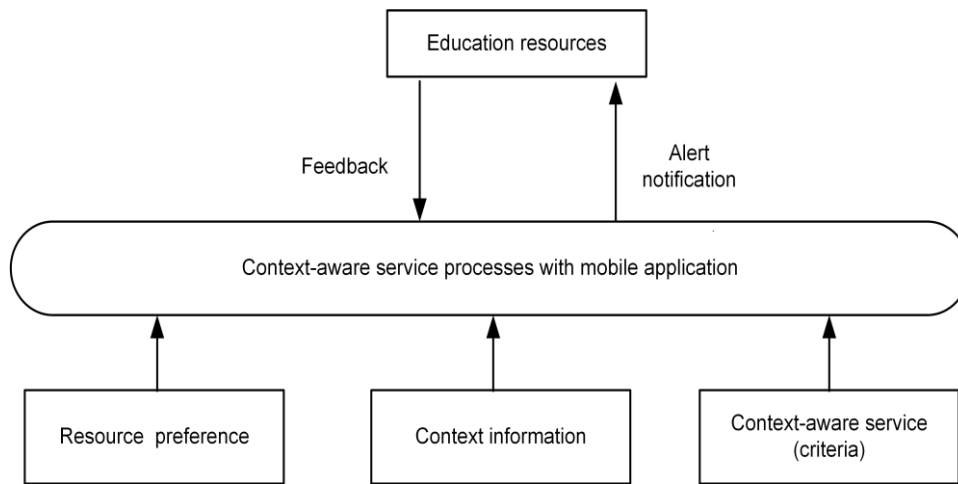


Fig 2: Modified architecture of mobile computing application with context-aware service in higher institution [14].

To achieve the aim of this study, two research questions (RQ) were formulated and presented as follows:

RQ1: Are there contributions in the previous research for mobile computing application with context-aware in higher institutions?

RQ2: How are the previous research contributions evaluated in this domain?

## II. METHODOLOGY

The methods used in [15] is adopted in undertaking this study. The phases of review protocol are therefore shown in Fig 3.

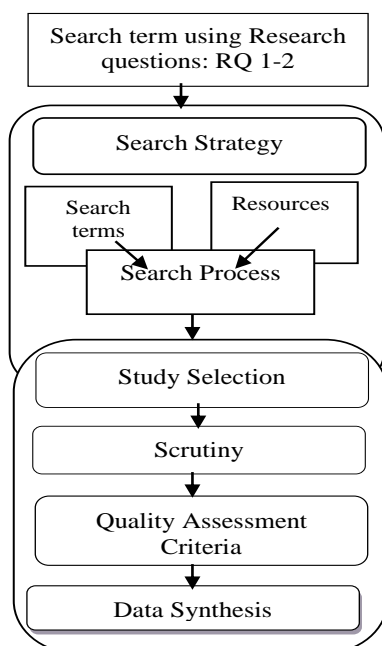


Fig. 3: Phases of the review

In Fig. 3, the review’s protocols comprise of six phases are itemized as follows: research questions, search strategy design, data extraction results, scrutiny, quality assessment criteria and data synthesis. From the first phase, some sets of research questions are presented based on the aim of this study. The second phase shows a search strategy that was designed in line with the formulated research questions which consisted of the identification of search terms and the choices of literature resources. The third phase depicts the collation of extracted data while the fourth phase dealt with the refinement of extracted data (studies) by scrutinizing the titles of collated studies to confirm their relevance. In the fifth phase, the scrutinized studies are subjected to evaluation by applying the quality assessment criteria presented in Table 2. While the sixth phase, show the final studies selected for analysis and further actions.

### A. Search strategy

The overall details of the search strategy employed for this research comprises of search terms, literature resources and search process as presented in this section:

#### 1. Search terms

The under listed search terms were used for obtaining relevant studies because of the topic of discussion; “Context-aware, techniques, strengths, limitations, mobile computing, contribution, datasets used and evaluation”. These search terms were further modified by:

- 1) Identifying the key terms from the formulated research questions.
- 2) Identifying different spellings and substitutes of key terms.
- 3) Accessing the index terms of relevant publications.

- 4) Embedding the Boolean OR in alternative spellings and synonyms.
- 5) Embedding the Boolean AND between links of key terms.

The resulting search terms are described as follows.

Context-aware AND (mobile computing/ OR technique/) AND (mobile computing application “category” OR “technique” OR “classification” OR techniques OR “limitations/” OR “shortcomings/” OR “issues/” OR “evaluation/” OR “datasets” OR “research-type/” OR “significance/”). However, with Google Scholar, data extraction was done using the titles of the subject of discussion.

### 2. Literature resources

Seven electronic database resources were used to primarily extract data for synchronizations in this research. These include: ScienceDirect, ACM digital library, IEEE Xplore, Scopus, Springer, CiteSeer and Google Scholar. Title, abstract and index terms were used to conduct search for published journals papers, conference proceedings, workshops, symposiums, book chapters, IEEE bulletins and theses.

### 3. Search process

The advance study based on literature review deals with a comprehensive search of all relevant sources about a subject of discussion. However, the search processes used in this research are classified into two main search stages as described above as presented in Fig 3.

Search stage 1: A thorough search is launched on the seven electronic database sources and the returned results (papers) are assembled as sets of prospective papers.

Search stage 2: The reference lists of all relevant papers were perused to detect additional relevant papers and then, if any, combine them with the ones in stage 1.

#### B. Study selection

From the first search stage, 6690 prospective studies were realized. Next, the titles of these studies were used to scrutinize and collate relevant studies. This task was necessary to eliminate duplicate and irrelevant studies. Consequently, 144 relevant studies were selected. Thereafter, the references on each selected study were perused to determine important studies that might have been missed out during the initial search process. This effort led to the identification of 44 additional studies that were missed out in the initial search process which took the tally of the selected studies to 188. Finally, the quality criteria stipulated in Table II were applied to these 188 studies. Details of quality score is within the scope of this paper. At the end of the exercise,

131 studies were finally selected and deemed capable for providing answers to the formulated sets of research questions. Table 2 represents the quality scores of selected studies.

#### 1. Scrutiny

From Fig. 3, 6690 prospective studies were obtained during the first search process. Therefore, scrutiny was necessary to streamline these studies to relevant ones. First, the title of each study was considered; then their contents were briefly studied. Hence, all the papers that do not reflect the topic of discussion or are incapable of addressing any of the formulated research questions were expunged from the relevant studies list. Also, only studies written and published in English language from peer-reviewed journals, refereed conference proceedings, workshops, symposiums, book chapters, IEEE bulletins and theses published were considered for inclusion in the list of relevant studies. However, when multiple copies of the same paper appeared, the most complete, recent and improved one is included in the search process while the others are excluded. A summary of the criteria used for scrutiny are shown in Table I.

**Table I**  
**Inclusion and exclusion criteria**

#	Inclusion criteria	Exclusion criteria
a.	Published papers written in English language	Published papers not written in English language
b.	Papers that focused on context-aware and mobile computing application	Papers that do not answer any of the research questions
c.	Relevant papers that are published previously until 2018	Papers without proper reference information
d.	Papers with publishing details	Paper not yet published but in press
e.	All published papers whose contents are related to the research problems and have contribution	Duplicate papers with unclear method and contribution

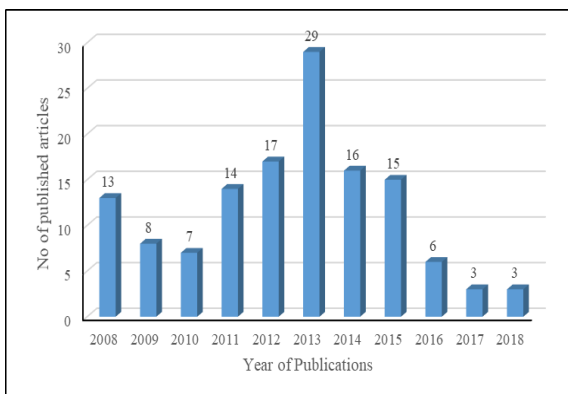
#### 2. Quality assessment criteria

The metrics score criteria adopted in [16] as shown in Table 2 were used to evaluate the qualities of selected studies or papers for data extraction purposes, the result of the quality score is not presented in this paper.

**Table II**  
Slightly modified quality assessment score criteria [16]

Assessment criteria	Response options for score (field in Endnote)
Does the purpose of the research adequately or convincingly explained?	Yes = 2; moderately = 1.5; no = 0
Does the proposed technique well explained?	Yes =2; moderately = 1.5; no = 0
What any contribution made from the study?	Yes =2; moderately = 1.5; no = 0
Does the contribution adequately validated?	Yes =2; moderately = 1.5; no = 0
For each paper, what is the acceptance quality rate based on research findings?	No finding = 0; over 85% = 2; under 15% = 1.5
Estimate in %	Enter % in quality assessment field in Endnote

About 89.9% of the studies included in the literature review have quality scores that are good to excellent. These metrics in [16] serves as guide for the interpretation of findings of the selected studies. Thus, determine the validity of the inferences drawn for each of the article which forms the primary study. It also helped in determining the credibility and coherent synthesis of the systematic literature review. To ensure quality and relevance of selected studies, all the selected studies were considered based on the specified evaluation metrics. Figure 4 presents the summary of primary study papers from 2008 to 2018.



**Fig. 4: Bar chart for Number of papers by year of publication (2008-2018)**

### III. RESEARCH TYPE

The research type presents the kinds of research done in the primary study. We employed the scheme proposed by Weiringa et al [17] and that of Abid and Dayang [18] for the classification of research type. Below are descriptions of research type identified in the primary study:

#### A. Evaluation

This type of papers tries to examine a solution that has been applied practically. Such paper normally explores the practical implementation of solution and comes up with results using case studies or field studies.

#### 1. Solution

A solution paper or research provides solution to any problem mention or described in the paper. It is achieved by contributing a novel solution or possible extension of existing method or technique. Also, it present or highlight benefit for doing such using an example through reasoning.

#### 2. Experience

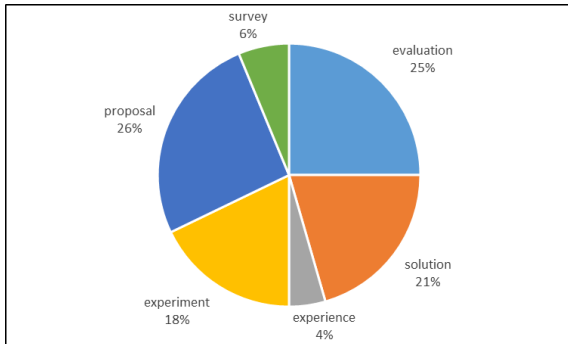
This kind of paper reports on personal knowledge reviling past ordeal in their real-life project. It usually presents details on how the project was accomplished, as well as how it was done for a publication.

#### 3. Experimental

This type of papers is like a solution paper that applied practical measure. Such paper normally explores the practical implementation of solution and comes up with experiment as a benchmark with other related research in specific domain to compare with expected result's outcome.

#### 4. Survey

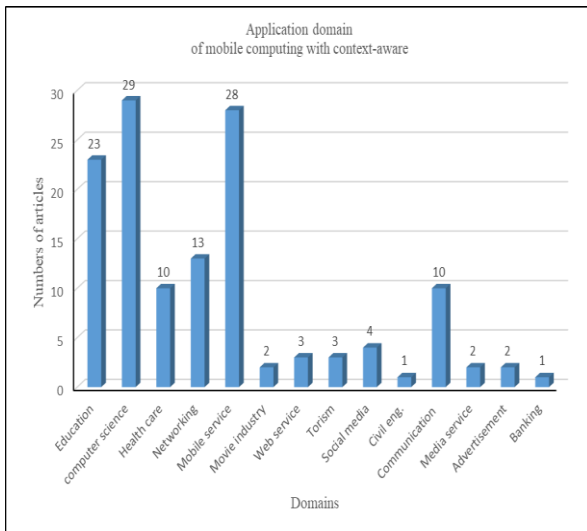
This paper deal with a general view of any research topic in an extensive form (in-depth). It is also regarded as investigation of what other researchers have done in a domain, identify problem and proffer solution. In this case, we focus on context-awareness mobile computing related studies. Below is the detail of the research type for the selected studies. Fig 5 shows the distribution of research typed focused on over the period under review.



**Fig. 5: Mobile computing application with context-aware research types**

#### IV. RESULTS AND DISCUSSION

Fig. 6 summarized the entire publications used in this paper based on mobile computing application with context-aware between 2008-2018.



**Fig. 6: Distributions of existing mobile computing application with context-aware (2008-2018)**

As one can see computer science has the highest with 29, followed by mobile service having 28, next to that is education, networking, health care, communication with 23, 13, 10, 10 respectively, while the least applied domain is Civil Eng. and Banking having 1 each. The reason for Computer Science being the highest is the fact that pervasive computing is hot topic and is a current research in computer science and human computer interaction namely: Knowledge driven [19]; Recommendation [20]; Context-aware recommender systems [14].

The contribution identified so far include the following; technique proposed for context-aware library management system in [21] fall in higher institution but the study has a shortcoming in the use of software agents that can promote information

provision by the system, which can offer better insights to the benefits of agent technologies for mobile augmented reality; Model proposed in [22] which does not cater for text transformation in automatic form, that is capable code generation for context management middleware platforms. However the study does not take cognisance of the practical related context-awareness which is a necessity for the future; [23] proposed a robust approach of social recommendation for context-aware mobile services, but failed to give consideration to other methods like identity personalization of recommendation such as application of latent semantic analysis on tag extraction for extracting concepts from folksonomies; [24] presents a framework that consist of architecture for user context-aware mobile assistant but their paper does not include the actual contextual information as well as the set of indexed service on the mobile phone for the users and did not support usability, talk less of making provision to offer the necessary flexibility expected of a framework for context-awareness interaction; several algorithm proposed in [25] for context-awareness based personalized recommendation where they presents fuzzy petri net model, and does not address the software engineering issue of scalability i.e. how the system will perform in a real life situation when many users are using it concurrently. In addition to that, [26] in their context-aware collaborative filtering using genetic algorithm raised an issue of data scarcity problem that lead to ‘sparsity problem’ which they could not addressed, and the system still depends on the user’s current need on specification’s request which is not ideal for a context-aware solution.

Above all [27] proposed an excellent architecture that is more context-aware, especially in the sense that it leverages on the relationships that exist between its constituent objects. Knowledge within the system was encoded using ontology. The architecture, though, caters only for structured data in a university environment by relying on the existing database in pervasive university scenario. Consequently, the authors overlooked the relevance of unstructured data in the university environment which can also help the system or platform to be more context-aware by increasing the structured data availability in the university. This system cannot handle emergency, likewise validation of their architecture with only two (2) students is in adequate for large audience. Of all the contribution identified in this study, in line with the aim of the study; lots of issues are yet to be addressed which call for ‘gap’ that need to be filling to further extend research with the use of context-aware approach and its application in higher institution. Figure 7 shows the previous context-aware researches and their focus in the previous years presented in Aliga et al [28].



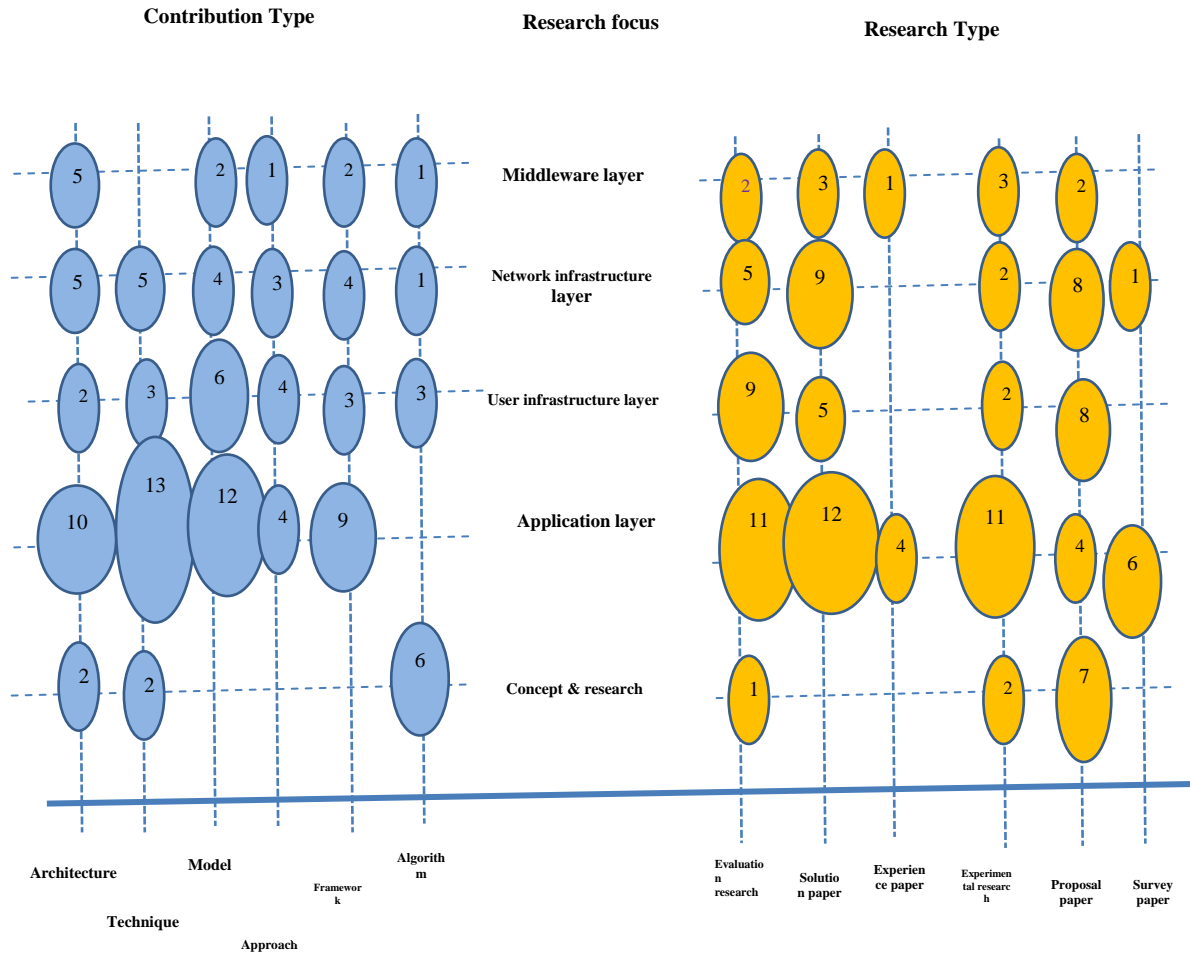


Fig. 7: Pie chart showing the Mapping of research; contributions, focus and types in mobile computing with regards to context-aware between (2000-2016) Aliga et al. [28].

Notably the methods used for evaluation of the framework with context-aware approach found in literature are categorized into three namely: (i) scenario based with hypothetical example using develop application, (ii) comparative analysis using side by side comparison of components in the said framework based on technique or model [29] and (iii) metric evaluation with accuracy, precision, recall and f-score with experiment on related activities [14]. An example for one of the method as demonstrated in [14] is shown in Figure 8. The figure explains that using contexts and trust related information in the recommendation filtering process can improve the recommendation quality. For example, average F-scores at N = 5 for the 3 models are 0.68, 0.25 and 0.74 respectively showing a progressive improvement in the recommendation accuracy shown in Figure 8.

In the proposed solution, F-Score is used to illustrates the accuracy of a trust-based recommendation over traditional context-based with average precision.

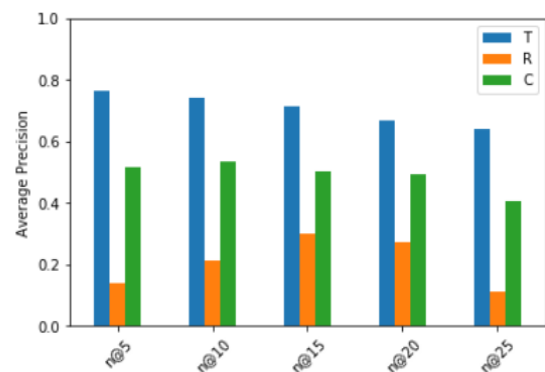


Fig. 8: Comparison of Average Precision for Traditional Recommendation (R), Context based Recommendations(C) and Trust based Recommendation (T) [14].

## V. RESEARCH FINDINGS

Mobile computing application with context-aware is an important aspect of software development and

human computer interaction since it has relationship with people, object, physical communication, time, location and other relevant things one can think of. Hence, the impact will continue as long as the world exists due to its ubiquitous nature. From this study the following findings were discovered:

1. Context-aware service has significant role to play for continuous sustenance of smooth collaboration in every organization in this modern world due to its integration of sensed data, context acquisition and proactive programming, most importantly higher institution as identifies in this study.

2. Ontology based platform is a guarantee for smooth context-aware interaction that will stand test of time for any approach be it a framework, model, or architecture and any other contribution that one can think of as of today. This is evident from the research findings which revealed that 23 out of 131 were applied in education related domain with few found in higher institution. Ontology technique is mostly used across many domains with only 3 found in higher institution regarding education. However, ontology as technique also has its shortcoming, but it has lots of advantages on the long run. Only few studies apply multi-agent concept as a solution in the entire studies considered in this study.

3. Of all contribution most paper used an existing database (structure data) for data extraction in their approach, few studies have used contextual information from (unstructured data) like TeetPulse as a case study [30], social media [31-32]. As a result of these, there is the need to explore the mentioned techniques and its benefit more particularly in higher institution due to huge data possibility in the system. This call for appraising the benefits attached to unstructured data in [33] where it was reported that in every organization there exist 80% of unstructured data for every 20% structured (data or textual). This statement advocates the need for knowledge extraction from unstructured data source.

4. Few papers mentioned security and privacy issues but not addressed at all. This is also a critical concern, if context-aware must contribute progressively? As long as human being differs so our solution to problem will take different dimension.

5. Despite all the context-aware and mobile computing application research related to education investigated only few one [27, 34-35] focuses on universities as a case study. But none of them explore contextual information synchronization within university context to trigger up a service or extract information from unstructured source. Thus, issue of emergency leading to data losses of failure was overlooked without paying attention to it.

6. Identified technique and the nature of performance evaluation presented in this study will help us to know the best one to adopt for our future research. Some study did not present any experiment

nor validate the presented approaches but provide answer to other research questions considered in our previous work [28].

#### **A. Summary of findings**

Table III presents the recent related work from the selected primary studies reviewed to show the gap identified literature. Mobile computing application with context-aware and its system development is an active research area that needs an extensive research for solution to modern days' problem worldwide from ubiquitous computing researchers. This fact is deducing from the report that context-aware computing market worldwide currently worth US\$ 120 billion as at June 2018 [36]. However, even though different techniques in context modeling were observed and noticed, there is still no consensus on the existing context models, hence the previous context models are either in complete or domain specific [37].

Ontology is most utilized; its application to explicit representation of knowledge is in adequate compared to the opinion of [37]. There is lack of standard in the few frameworks presented and cannot be suitably use as benchmark for context-aware with mobile application's developers.

Multi-agent using ontology context can assist the mobile applications developers in this direction. It is hoped that future research will facilitate effective information and service delivery in organizations and various higher institutions. Above all there is no guideline that inform researchers regarding the approach that will form basis of the immense benefit to any organization even in higher institution inclusive. It was obvious that there are more models and architectures contributed as noted in [28] from the selected studies reported. Future work aims to investigate the framework that can further extend the foundation laid by previous researchers for example [27] with context-aware and mobile application to enhance the outcome of the future products in higher institution within education domain.

**Table III**  
**Summary of most recent selected papers review**

Author (year)	Ontology	Multi-Agent Context	Issue Addressed	Contribution	Domain
(Neves et al. [27])	Not explicit	Agent	Information and service abundance challenge	Architecture	University
(Wang et al., 2014) [38]	X	X	Challenges faced by new students in location of academic class rooms and hall of residence	Architecture	University
(Gallego et al., 2013) [39]	X	X	Problem of teachers in finding a suitable resource considering their needs e.g. topic or pedagogical items	Model	E-learning
(Ku and Chia-Chi [40])	X	X	Helping non-native to overcome learning of Chinese language barrier	Model	university
(Shatte et al., 2014) [21]	X	✓	In capability of context aware sensitivity of mobile augmented reality	Framework	Education library system
Kayes et al. [29]	X	X	Context recognition for access control	Framework	X
Otebolaku and Gyu [14]	X	X	Context-recognition and reasoning	Framework	X

## VI. CONCLUSION

The paper investigated the current state of the art research concerning mobile computing application with context-aware research in higher institutions. To achieve this, the study conducted literature review to advance research in the domain of education specifically on the applied pervasive computing technology regarding context-aware in higher institutions. It was discovered that, although a lot of contributions have been made in both application and system development despite that, further advancement is still required in the existing research. Some of those improvements requires are on interoperability, ambiguity, ease of use, reliability of results, data extraction from unstructured sources (unstructured data), evaluation method in real life settings and need to access relevant datasets from different higher institutions to help realize the research goal. Therefore, further studies on framework as an approach and appropriate methodology adoption using relevant context information can help to address the knowledge gaps observed as limitations as identified in this paper.

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