Research Trends and Open Issues in Mobile Application Software Engineering

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Abstract—*Mobile development is becoming an increasingly critical area of software engineering as more users are integrating mobile devices into the fabric of their daily lives. As an evolving field, it is important to identify the research trends and challenges in order to assess if the open issues are receiving the requisite research and if any gaps exist. Some of the challenges involve improving user interfaces, software development processes, tools, and education programs. This paper presents the results of a literature review analysis that identified research work in mobile application software engineering and subsequently classified papers by topic to identify trends in relation to open issues. Results include an analysis into the distribution of 103 classified publications, to include identifying common research questions. It was discovered that progress is being made on some of the open challenges to mobile application software engineering.*

Keywords—mobile application, software engineering, literature review

1 Introduction

Mobile application software engineering is an emerging field and presents fresh software engineering challenges (e.g., location-sensitivity or context-awareness, usability, power consumption, etc.) [1, 2]. The development of meaningful and functional mobile applications is important to multiple stakeholders to include end users, businesses, and organizations as they all try to interface with one another in an increasingly mobile and networked environment.

It is difficult to precisely describe how mobile application software engineering is different than traditional software engineering. One earlier perspective by Roman, Pico, and Murphy stated that "mobility represents a total meltdown of all the stability assumptions" made in software engineering [3]. A more moderate view by Wasserman, points out that mobile applications offer some unique requirements that are less commonly found in traditional software engineering [1], including: interaction with other applications; sensor handling; native versus hybrid applications; families of hardware and software platforms; user interfaces; and complexity of testing. Wasserman also offers a research agenda for software engineering research in the development of mobile applications in the following areas: user experience, non-functional requirements, portability, and processes, tools, and architecture [1]. While mobile application software engineering has been active,

the research community needs a better research agenda to enable the design and development of more meaningful, usable and robust mobile applications. To catalyze a research agenda in mobile application software engineering, this work presents a literature review analysis that was conducted with the goal of identifying current trends and exploring the relationship between published research and some previously observed challenges in mobile application software engineering. This paper helps to improve understanding of the current trends and challenges with mobile application software engineering as well as the research currently being conducted. In this analysis, mobile application software engineering trends were identified by reviewing 103 full-text, peer-reviewed publications published between 2008 and 2012 that were acquired from the IEEE and ACM digital libraries [4–106]. Specifically, this paper provides the following contributions:

- An analysis of current mobile application software engineering research trends.

- A discussion of the open issues or least reported topics related to mobile application software engineering research.

The culmination of these contributions will enable mobile application software engineering researchers to focus their efforts in solving open research challenges in this area. This work is part of a larger effort to better understand the current trends and the open issues in mobile application software engineering. The results will inform mobile application developers with an overview of trends in software engineering techniques and tools to design and develop high-quality mobile applications as well as existing open issues.

2 Research Methodology

The research goal of this work is to improve the understanding of the current trends in mobile application software engineering research and exploring the gap between published research and some open issues in mobile application software engineering. Specifically, the research questions addressed in this study are:

- *What are the common topics and nature of the publications reporting on mobile application software engineering?*

- *What are the open issues or least reported topics within related to mobile application software engineering?*

Answering these questions may inform mobile application developers with an overview of trends in software engineering techniques and tools to design and develop high-quality mobile applications as well as existing open issues that warrant further research. Prior to article collection, explicit inclusion and exclusion criteria were established as parameters for the literature review performed in this work. The inclusion criteria were as follows:

1. The publication was in English.
2. Mobile applications as a part of a software engineering context.
3. The literature was current, which we defined as being published between January 2008 and December 2012.
4. The literature was peer-reviewed and presented in a scholarly ACM or IEEE conference/journal.

Similarly, the established exclusion criteria were as follows:

1. Publications prior to January 2008 since we were solely focused on identifying current trends.
2. Literature that was considered non-scholarly reviewed: unpublished working papers, conference tutorials, workshops or abstracts, news reports and editorials.
3. Topics unrelated to mobile applications in a software engineering context.
4. Summaries or other situations in which the full-text publication could not be acquired.

The papers in this literature review were collected in February 2013 from the ACM and IEEE digital libraries, and most were drawn from conferences. Table 1 illustrates the ten conferences that were found to have published the most articles related to mobile application software engineering. An advanced keyword search was completed for *software engineering* in the ACM digital library using the keywords *mobile* AND *application*, and published as a journal, proceeding OR transaction for full-text publications since 2008. This resulted in an initial capture of 73 possible articles that was subsequently reduced to 64 possible articles based on a closer review of titles and abstracts utilizing our selection criteria.

Similarly, in the IEEE digital library for Conference Proceedings, an advanced keyword search was conducted for *software engineering* in Conference Name using the exact phrase *mobile application* in full-text publications since 2008. This resulted in an initial acquisition of 44 possible articles that was subsequently reduced to 39 possible articles based on closer review of titles and abstracts.

Table 1. Popular Conferences

Conference Title	Count	%
Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing	5	4.9%
International Conference on Software Engineering	5	4.9%
Software Engineering and Advanced Applications	5	4.9%
Symposium on Applied Computing	4	3.9%
Computer Science and Software Engineering	4	3.9%
Advances in Mobile Computing and Multimedia	4	3.9%
Mobile and Ubiquitous Multimedia	4	3.9%
MobileHCI	3	2.9%
Australian Software Engineering Conference	3	2.9%
Brazilian Symposium on Software Engineering	3	2.9%

After eliminating papers out of context, the remaining 103 papers were classified and the following data was recorded: primary author, title, venue published, year and the 1998 ACM Computing Classification System (CCS) tags and a brief summary of the research. The papers were classified with the relevant ACM CCS tags by the reviewer; if the publication did not already have classifications. If there was any uncertainty, the entire full-text publication was reviewed. There were 55 different ACM CCS tags used to describe the publications overall. Many publications had more than one ACM CCS classification. Table 2 shows a breakdown of 194 classifications within the ACM CCS Level 2 for the set of 103 papers.

Table 2. ACM Second Level Classification Breakdown

ACM CCS Level 2	Count	%
C2 Computer Communications Networks	16	8.2%
C3 Special Purpose and Application-Based Systems	1	0.5%
C4 Performance of Systems	6	3.1%
C5 Computer System Implementation	2	1.0%
D1 Programming Techniques	3	1.5%
D2 Software Engineering	79	40.7%
D3 Programming Languages	8	4.1%
D4 Operating Systems	2	1.0%
F2 Analysis of Algorithms and Problem Complexity	1	0.5%
F3 Logics and Meanings of Programs	3	1.5%
H1 Models and Principles	3	1.5%
H2 Database Management	2	1.0%
H3 Information Storage and Retrieval	11	5.7%
H4 Information Systems Applications	6	3.1%
H5 Information Interfaces and Presentation	26	13.4%
I2 Computing Methodologies	2	1.0%
I6 Simulation and Modeling	1	0.5%
J1 Administrative Data Processing	1	0.5%
J3 Life and Medical Sciences	3	1.5%
K3 Computers and Education	8	4.1%
K4 Computers and Society	7	3.6%
K6 Management of Computing and Information Systems	3	1.5%
	194	100.0%

Table 3. Temporal Distribution

Year	Count	%
2008	25	24.2%
2009	20	19.4%
2010	20	19.4%
2011	15	14.6%
2012	23	22.4%

Data analysis of the 103 publications found the temporal distribution as follows: 2008 (25), 2009 (20), 2010 (20), 2011 (15), and 2012 (23), as seen in Table 3.

Initially a bottom-up classification system was considered, so the papers could create their own classification system. After trial and error it was determined that a top-down classification methodology using an already established hierarchical classification system would be a better approach to identify trends and to prevent any gaps in information.

3 DISCUSSION

Table 4 illustrates that one of the most frequently discussed mobile application software engineering categories involved Design Tools and Techniques (D.2.2). Reoccurring topics involved software libraries, modules, interfaces and computer aided software engineering. Examples can be found in [13, 20, 33, 36, 44, 47, 49, 69, 74, 77, 89, 93, 98, 101, 103].

As Wasserman suggests, the challenge of making the best possible use of limited screen space, user interface design takes on greater importance than ever for software engineering [1]. The findings reflected mobile-related software engineering based on User Interfaces (H.5.2), human computer interaction, user-centered design, screen design, creating user interfaces for differently-abled people and improving usability were prevailing themes. Examples can be found in [4, 7, 13, 40, 41, 43, 47, 67, 69, 75, 77, 86].

Table 4. Popular ACM Classifications

ACM CCS Level 3	Count	% of Total
D.2.2 Design Tools and Techniques	17	8.8%
H.5.2 User Interfaces	17	8.8%
D.2.5 Testing and Debugging	13	6.7%
D.2.11 Software Architectures	11	5.7%
C.2.1 Network Architecture and Design	8	4.1%
D.2.8 Metrics	8	4.1%
C.2.4 Distributed Systems	7	3.6%
C.4 Performance of Systems	6	3.1%
D.2.4 Software/Program Verification	6	3.1%
H.3.5 Online Information Services	6	3.1%
K.3.2 Computer/Information Science Education	6	3.1%

Publications related to Testing and Debugging (D.2.5) covered tracing, code inspections, walk-throughs, debugging aides, distributed debugging and error handling and recovery. Examples can be found in [12, 24, 38, 70, 87, 94, 96].

Software Architecture (D.2.11) related publications discussed interoperability, domain-specific architectures, patterns, distributed objects and service-oriented architecture. Examples can be found in [11, 27, 42, 57, 66, 73, 78, 99].

This paper is an initial attempt at identifying trends and open issues with software engineering related to mobile applications. The overwhelming majority of articles in the final data set represented qualitative research. There was a lack of publications discovered during this literature analysis that dealt with the following ACM CCS areas: Processor Architectures (C.1), Coding Tools and Techniques (D.2.3), Distribution, Maintenance, and Enhancement (D.2.7). There is a need for more quantifiable data, empirical studies and industry experience on the trends in mobile application software engineering. These gaps may be reflective of the early stage of technology adoption or the fragmented nature of mobile computing technologies. The following limitations were also noted for this study:

- Different keyword searches may lead to different findings. So the keywords were chosen to provide a focused overview of current trends within the mobile application software engineering community.

- The same keyword search in the same libraries at a different date could lead to different findings (e.g., due to search engine or library updates). We were satisfied with selecting 2008, because it signified the beginning of broader acceptance of smartphones and mobile applications in the general population, which were influenced by the iPhone AppStore and Android Market (now called Google Play).

These noted limitations were addressed and mitigated as best as possible.

4 CONCLUSION

This paper briefly describes the findings of a limited literature review and analysis conducted using research articles published in the IEEE and ACM digital libraries. The ACM CCS was used to classify 103 publications with a top-down approach. Although this review was not exhaustive, it indicates that progress is being made to address some of the identified research challenges with mobile application software engineering.

Future work is geared towards further investigating the open issues and lack of publications involving the following categories: privacy related issues, coding tools and techniques, software distribution, maintenance, and enhancement. More extensive investigation can be accomplished with a manual citation review of identified publications as well as expanding into journals and other digital libraries. There is a need for more quantifiable data, empirical studies and industry experience in mobile application software engineering.

5   ACKNOWLEDGEMENTS

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