

Model-Driven Development Based Cross-Platform Development: A Review

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Model-driven development of cross platform applications has proved to be the efficient and less prone to discrepancies. In today's age, portability is the basic need of application developers to run the code written in one language on multiple platforms. This can only be achieved using the cross platform application development frameworks available in the current market. Due to the emerging use of these cross platform frameworks, we have conducted a systematic mapping study in order to synthesize the elements of cross platform application development and model driven development. Analysis of the study reveals the most used tools and techniques in cross platform application development and also shows the newly designed domain specific languages used in the model transformation. This study finds implications for: (i) industry practitioners in terms of exploring the current status of tools and techniques prevalent in the industry, and (ii) for the researchers to deepen their understanding on the topic and to further the development on the existing limitations.

Keywords: model-driven, cross-platform, software engineering, systematic mapping, review

1. INTRODUCTION

Today, the need to quickly develop application with limited human resources is the main concern of every business. The problem to this solution lies in the model driven development in combination with the usage of cross platform application development frameworks. The cross platform frameworks enable the developers to use one base code language and port it to other platforms [1]. Mobile applications on the other hand use different versions of operating systems and exhibit variety of screen resolutions which is a big challenge for mobile application developers. Thus, the need of the hour is to develop portable applications using one base code yet compatible with all possible sorts of operating systems.

Android and IOS being the most popular mobile operating systems to date are the major reasons researchers need to focus on cross platform application development frameworks. Since Android is based on Java and IOS is based on C language so both of the operating systems exhibit entirely different architecture. Therefore the frameworks are still not able to provide reliable working native APIs for camera, gyroscope, accelerometer, and other OS specific elements.

Model-driven engineering (MDE), on the other hand, shows promising increase in efficiency and productivity in design and functionality of the applications. MDE suggests modeling the requirements, behavior, and operations of the application using formal do-

main specific modeling languages (DSML). The models are taken as primary artefacts created with the help of a domain specific modeling language, then model transformation methods are employed to generate the application code automatically based on the models [2]. Transformations are of two types. 1. Model-to-Model transformation, and 2. Model to Artefact transformation. In model-to-model transformation, the source models are transformed into target models. As for model-to-artefact transformation, the source model is transformed into code or document using a code generator or document generator respectively. Model-to-code transformation usually refers to transforming model into artefacts such as scripts, configurations or code in various languages depending on the target platform. Whereas, in model-to-document transformation, models are transformed into document artefacts such as textual or graphical representations. Fig. 1 shows the visual representation of model to code and model-to-document transformations.

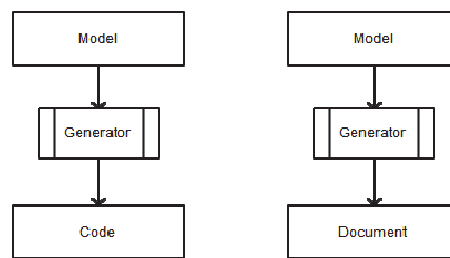


Fig. 1 Model to artefact transformation.

These transformations in MDE can be automated using tools/frameworks known as transformation engines. The number of model-to-model transformations depends totally on the abstraction level of the transformation engine of the framework being employed. Cross Platform development (CPD) goes hand in hand with the model driven engineering (MDE) as models are an efficient source of understanding the behavior and requirements of an application.

Fig. 2 shows the actual process flow of model driven engineering and cross platform application development in function.

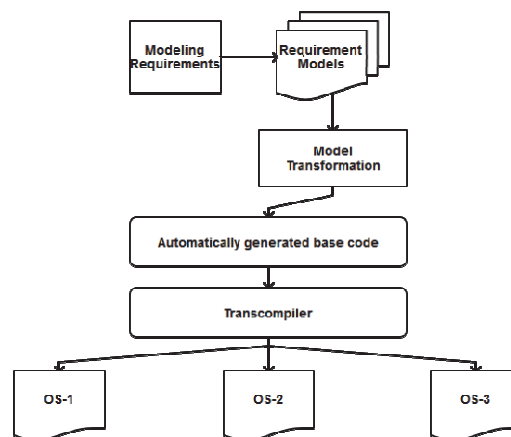


Fig. 2. MDE and CPD process flow.

In this paper, we have conducted a systematic mapping study to highlight the tools and techniques in MDE available in the literature and emphasized on the domain specific languages (DSL/DSML) employed in the model transformation process. Furthermore, we have identified the nature of articles that are highly relevant to the scope and classified them based on their research and contribution facets.

The paper is organized as follows: Related work is discussed in Section 2. Research methodology is explained in Section 3. Research protocol is defined in Section 4. Results and discussion is described in Section 5. Section 6 shows the threats to validity and conclusion is described in Section 7.

2. RELATED WORK

A survey has been conducted on the tools of cross platform application development. The study has compared the tools and provided a detailed analysis on the compatibility of these tools based on their support to camera, gyroscope, accelerometer, and GPS functionalities. The study revealed the strengths and weaknesses of the available tools. The findings also stated that only a limited number of tools use MDE (Model Driven Engineering) approach [3].

Another survey study presented an overview of the cross platform application development approaches. The study revealed that most of the companies still use the native application development frameworks. However, only a small percentage is using cross platform techniques to enhance compatibility and portability of the applications for wide usage and adoption [4, 5].

In another recent study taxonomy of cross platform application development approaches is presented. The study also discussed advantages and disadvantages of various approaches used for cross platform development. The study provided solution to existing approaches and stated future directions in terms of open areas of research as implications for future researchers [6].

Model driven engineering has been in the forefront for the developers going towards cross platform development. It is considered as a vital part in understanding the elements of the application visually in the form of a model and then transform it into artefacts using a specific transforming engine. A work on state of the art of model driven game development showed the wide area of game development frameworks based on the abstraction level of the transforming engines. The study shows the number of software/tools being employed by the developers based on their popularity and sophistication of features [7].

Summarizing above, it can be seen that cross platform application development is needed to capture larger audience and to target massive usage. However, there are a handful of studies surveying the latest trends and technologies prevalent in industry. In addition, minimal work has been done on analyzing cross platform development with respect to MDE. Therefore, we aim to close this gap by conducting a systematic mapping study to explore on the MDE approaches, tool, and technologies used for cross platform development in mobile application development.

3. RESEARCH METHODOLOGY

3.1 Search String

Keywords = ((model driven) AND ((cross OR multi) platform application development))

3.2 Exclusion Criteria (EC)

EC-1: Articles that do not belong to conferences, journals or magazines are excluded

EC-2: Articles that are not peer reviewed are excluded

EC-3: Articles that are not written in English are excluded

3.3 Inclusion Criteria (IC)

IC-1: Articles relevant to the scope of the research are included

IC-2: Articles that shows empirical evidence of research are included

IC-3: Primary and secondary studies are included.

Table 1. No. of articles.

Repositories	Total number of articles identified after applying query	Articles identifies after searching Titles and Abstract	Final Pool of articles identified
IEEE	28	18	18
ACM DL	3	3	3
Science Direct	7	3	3
Springer	160	1	1
Google Scholar	3	1	1
Total	201	26	26

4. RESEARCH PROTOCOL

In order to guide the research, we have followed a research protocol based on the guidelines of [8]. The protocol helps us to direct our research and establishes a systematic process of identification, analysis and evaluation of articles. Fig. 3 shows the research protocol we have followed throughout the research.

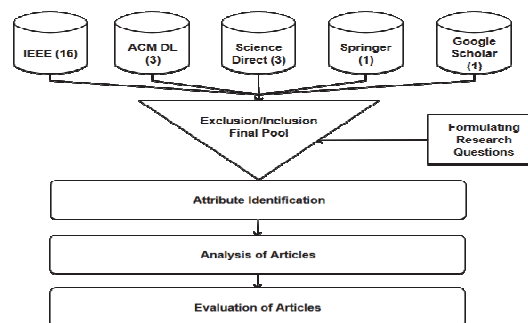


Fig. 3. Research protocol.

4.1 Research Goals/Questions

The process of formulating goals, research questions and highlighting the attributes/metrics in them has been taken from [9]. The goal of the study is to identify the nature and characteristics of articles in the area of MDE and Cross platform application development. Furthermore, to learn about the quality of articles based on the evaluation used in those articles and identify the demographics and bibliographic of the area. Following are the research questions formulated from the goals of this mapping study.

RQ-1: What is the nature of articles published in the domain of cross platform application development?

RQ-1.1: Which model driven development approaches are used in cross platform application development?

RQ-1.3: What are the tools employed in cross platform application development?

RQ-1.4: Which domain specific languages are employed in cross platform application development?

RQ-1.5: What are the cross platform application development frameworks used specifically for games development?

Rationale

RQ-1 focuses on the nature of articles in terms of the research and contribution facet. The model driven approaches employed in cross platform application development and the tools that are employed in cross platform application development. The domain specific languages used in model transformation process while developing cross platform applications.

RQ-2: What is the approach categorization in the articles?

RQ-2.1: What types of models are employed in the articles?

RQ-2.2: What types of transformations are mentioned in the articles?

RQ-2.3: Which target platforms are focused in the articles?

Rationale

RQ-2 concerns with how the articles are categorized in terms of their focus on the types models used in Model driven development, transformation forms and target platforms listed in the articles.

RQ-3: How are the articles evaluated in the area?

RQ-3.1: Are the articles empirically evaluated?

RQ-3.2: Which empirical methods are employed in the articles for empirical evaluation?

Rationale

RQ-3 concerns with the evaluation of articles that includes the number of articles evaluated empirically and what empirical methods are used in those articles.

RQ-4: What are the demographics and bibliographic details of the authors?

RQ-4.1: Which are the articles with highest citation count?

RQ-4.2: Which authors are with highest number of articles?

RQ-4.3: What are the venues of the articles?

Rationale

RQ-4 focuses on highlighting the demographics and bibliographic of the area of model driven engineering and cross platform application development.

4.2 Map Construction

Table 2. Research map.

Research Questions	Attributes	Description
RQ-1.*	Nature of articles	Classify the articles based on their research/Contribution facet, identify the tools and techniques, DSLs proposed in the articles
RQ-2.*	Categories of approaches, Types of Models and transformations	How the articles has categorized their approach and types of model transformations
RQ-3.*	Evaluation of articles	Identify the articles have been evaluated empirical and what empirical methods have been employed
RQ-4.*	Bibliographic and Demographic details	Identify the bibliographic and demographics in the area

5. RESULTS AND DISCUSSION

RQ-1.1: What is the nature of articles in the domain of cross platform application development?

39% (9/23) of the articles proposed technique followed by 22% (5/23) of the articles that proposed framework for cross platform development. The rest of the articles proposed methods, models, techniques, and tools. Fig. 3 shows the details of classification of the articles based on research and contribution facet.

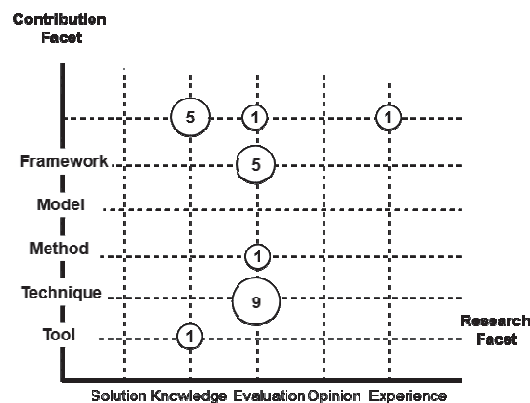


Fig. 3. Classification of articles based on research/contribution facet.

RQ-1.2: Which model driven approaches are used in cross platform application development?

Table 3 shows the model driven approaches used in cross platform application development.

RQ-1.3: What are the tools employed in cross platform application development?

A total of 30% (8/23) studies mentioned tools used in the articles for cross platform development. Table 3 shows the tools listed in the articles for cross platform application development.

RQ-1.4: What domain specific languages are employed in cross platform application development?

In order to perform model transformation process, the requirements are modeled in some formal domain specific language *i.e.* UML. A total of 56% (13/23) articles proposed domain specific languages for model driven development. Table 3 shows the domain specific languages employed in cross platform application development in the identified articles. The results show that UML has been used in article [21, 23].

Table 3. Model Driven Development techniques/tools/Dsl.

Articles		Names
[10]	Techniques	AXIOM
[11]		MD ²
[12]		ICPMD
[13]		PIMAR
[14]		ModAgile
[15]		Applause
[1]	Tools	WebRatio
[16]		PhoneGap
[17]		Cordova
[18]		Appcelerator Titanium
[19]		Rhodes
[20]		DragonRad
[21]		Pharo
[22]		UIG
[1]	Domain Specific Languages	IFML
[21]		SmallTalk
[21, 23]		UML
[24]		MVC based DSL
[22]		MD-UID
[25]		MDD
[26]		MobDSL
[27, 28]		Mobl
[29, 30]		Canappi mdsI
[31]		SLGML
[32]		GameDSL

RQ-1.5: What are the cross platform application development frameworks used specifically for games development?

There are cross platform development frameworks specially designed to develop 2D and 3D games. Keeping in view the portability and time to market demands, the developers are keen to use these frameworks that provide stable and reliable coding experience. Some of the highly used Game development frameworks are listed in Table 4.

Table 4. Game development frameworks.

URL	Framework	License
http://www.unrealtechnology.com/	Unreal Engine	Commercial
https://unity3d.com/	Unity Engine	Commercial
http://www.crytek.com/	Cry Engine	Commercial
http://www.cocos2d-x.org/	Cocos2d	Open source
http://www.jmonkeyengine.com/	JMonkey	Open source

RQ-2.1: What is the approach categorization in the articles?

A total of 56% (13/23) articles focused on categorizing their approaches for the following categories of applications: Web, Mobile, Hybrid, Interpreted, Cross-Compiled, Native and business applications.

RQ-2.2: What types of models are employed in the articles?

A total of 65% (15/23) articles used models in model drive engineering. These models include IFML, UML, BPML diagrams, abstract model tree (AMT), MVC, XML, Meta models, EMF, ECore and State diagrams. Fig. 4 represents the percentage of models employed in the articles.

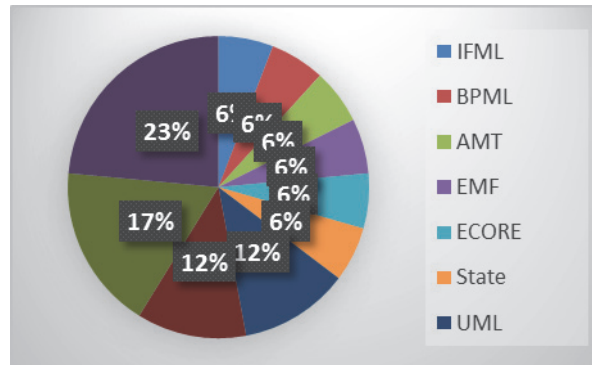


Fig. 4. Percentage of models employed in articles.

RQ-2.3: What types of transformations are mentioned in the articles?

A total of 60% (14/23) articles focused on types of transformation in which (13/23) focused on model-to-artefact transformation while (1/23) focused on both model to model and model-to-artefact transformation. Fig. 5 shows the distribution of articles based on model transformations.

RQ-2.4: Which target platforms are focused in the articles?

A total of 60% (14/23) articles mentioned target platforms for their approaches. The platforms include Windows, Web, IOS, Android, Websphere, SAP Netweaver, Superwaba, J2ME MIDP 1.0, J2ME MIDP 2.0. Fig. 6 shows the number of articles with their target platforms.

RQ-3.1: Are the articles empirically evaluated?

A total of 39% (9/23) articles have evaluated the proposed approach and tool empirically. Fig. 7 shows the number of articles empirically evaluated.

RQ-3.2: What empirical methods are employed in the articles?

A total of 39% (9/23) articles used empirical methods to evaluate their approaches. These empirical methods include Prototype and Case study. Fig. 8 shows the number of articles with their empirical methods.

RQ-4.1: Which articles are with highest citation count?

Articles with highest citation count are shown in Table 5.

RQ-4.2: Which authors are with highest number of articles?

Authors with highest number of articles are shown in Table 6.

RQ-4.3: What are the venues of the articles?

The venues of the articles are shown in Table 7.

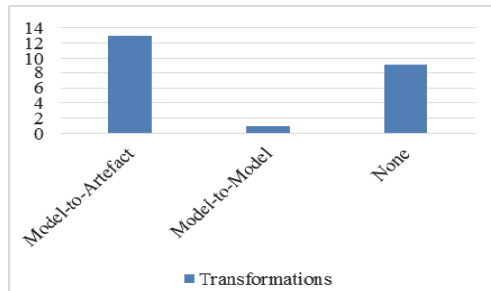


Fig. 5. Model transformations.

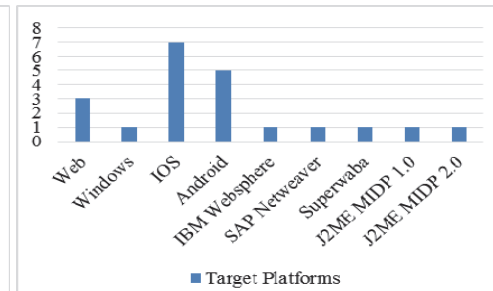


Fig. 6. Target platforms.

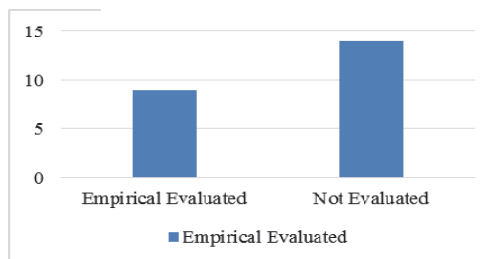


Fig. 7. Number of articles empirically evaluated.

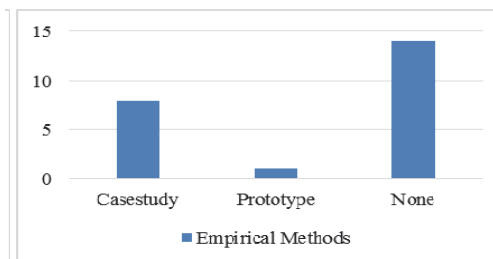


Fig. 8. Number of articles with empirical methods.

6. THREATS TO VALIDITY

The study is prone to generalizability threat as the search string used in the study might have missed some of the relevant articles. To overcome this threat we have performed forward snowballing to include the rest of the relevant articles. Moreover, there are some tools that do not exist in the literature but are used commonly in the industry which also affects the external validity of the study. To overcome this threat, we have manually searched for the popular tools used in the industry to be reported in this study.

Table 5. Articles with citation count.

Articles	Citation Count
Cross-Platform Model-Driven Development of Mobile Applications with MD 2	65
A study on approaches to build cross-platform mobile applications and criteria to select appropriate approach	48
Using domain-specific modeling towards computer games development industrialization	44
Survey on Cross-Platforms and Languages for Mobile Apps	43
XMobile: A MB-UID environment for semi-automatic generation of adaptive applications for mobile devices	39
MobDSL: A Domain Specific Language for multiple mobile platform deployment	33

Table 6. Authors with highest number of articles.

Authors	Number of Articles
Abdullah Bassem A	2
Grønli, Tor-morten	2
Heitkötter, Henning	2
Kuchen, Herbert	2
Latif, Mounaim	2
Majchrzak, Tim A	2
Nfaoui, El Habib	2
Yousef, Ahmed H	2

Table 7. Venues of the articles.

Venues	Number of articles
6th OOPSLA Workshop on Domain Specific Modeling DSM'06	1
AIN SHAMS ENGINEERING JOURNAL	1
Economy Informatics Journal	1
Journal of Interactive Learning Research	1
Proceedings of 2nd International Conference on Computer Science and Network Technology, ICCSNT 2012	1
Science of Computer Programming Journal	1
Software & Systems Modeling Journal	1

7. CONCLUSION

The study helped in synthesizing the most emphasized development area nowadays. The companies are striving hard to lessen the time to market by adopting agile and quick development methodologies. Cross platform application development plays its part in increasing productivity and efficiency of the product with less resources. Furthermore, the amalgamation of model driven development and cross platform development has increased the software productivity in past few years. This review enables the researchers and practitioners to gain a bird-eye view of the field. In particular, this study helps the practitioners both from research and industry to gain insights of the currently used tools and techniques in cross platform application development. Also, the study helps in understanding the domain specific languages used to conduct model transformation process.

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