Important Evaluation Factors of UML Tools for Health Informatics

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***Abstract*—Health Informatics (HI) is a multidisciplinary field that uses health information technology (HIT) to improve health care systems. A system which is given careful thought during the design phase in the Software Development Life Cycle (SDLC) covers the basic of the software design principles and caters for correctness and completeness of a system. Unified Modelling Language (UML) is a standard modeling language that is widely used in different industries; medical field included to support in SDLC. There are several UML modeling tools available out in the market, ranging from open-source tools to commercial tools. A common decision faced while applying UML in HI is the selection of an appropriate tool for modeling as it has a great impact on the overall success of an HI project. Appropriate tool selection can also be time-consuming. Because of these limitations, a framework for UML tool evaluation is introduced here for defining the suitability of UML tools for HI application. The objective of this research is to shortlist suitable UML tools specifically for HI related disciplinary regarding modeling effort required to complete a task correctly. Features and price list can easily be compared, but the productivity needs thorough empirical evaluation. This research presents a framework for an empirical study to evaluate the productivity of UML modeling tools suitable specifically for HI.**

***Index Terms*—Empirical evaluation; Health Informatics; Software Development Life Cycle, Unified Modelling Language.**

I. INTRODUCTION

The systems development life cycle (SDLC), also referred to as the application development life-cycle, is a term used in systems engineering, information systems and software engineering to describe a process for planning, creating, testing, and deploying an information system [1]. A system which is given a careful thought during the design phase of the SDLC covers the basic of the software design principles and caters for correctness and completeness of a system.

Health Informatics combines information technology (IT) and clinical medicine to improve healthcare delivery, education and research [2]. Sound and reliable information is the foundation of decision-making across all health system building blocks and is essential for health system policy development and implementation, governance and regulation, health research, human resources development, health education and training, service delivery and financing [3]. As such, selecting the right modeling tool in the design phase can influence how quickly the tool can be utilized to the HI project's benefit.

In the last decade, Unified Modeling Language (UML) [4] succeeded to become the *de facto* standard for modeling software systems [5]. UML modeling tools help software designers to model their ideas into visual designs. There are numerous commercial and open-source tools available to support UML modeling. These available modeling tools vary in terms of price tag and their features. Price and feature list can easily be compared but the impact on the productivity of using the tools need thorough empirical evaluation. A common decision faced while applying UML in practice is the selection of appropriate tool for modeling. Decision making becomes more crucial when applying UML in critical health systems and the time constraint of choosing amongst a list of 100 over tools during SDLC does not always allow software developers to choose suitable modeling tools in the analysis and design phase. This paper is intended to help comprehend informaticians/software developers on what to look for in a UML tool. This paper provides a list of criteria as a framework which helps narrow the list of potential tools down to the shortlist that should be relevant to HI situation.

Before looking into UML tools, a good understanding of what are the common requirement specifications for HI is a must. The process of identifying the required specifications is a crucial first step in the evaluation process, and it must be done irrespective of the evaluation method applied. The software requirements specification document enlists enough and necessary requirements that are required for the project development [1]. Requirements are the statements that describe the functionality needed for an information system to support the business process [6]. The process involved in HI projects varies from simple data recording, data transfer to more complex real-time critical system. The focus requirement specifications of this paper is on HI. The objective of this paper is on the evaluation framework for UML tools on the implementation of HI.

Section I is the overall introduction to the topic of this paper. In Section II, a systematic literature review relating to this study is constructed. Section III, discusses the research questions followed by section IV, which is where the objectives of this study are presented. The methodology used for this paper is presented in Section V and finally, the whole paper is concluded in Section VI.

II. COMMONLY USED UML TOOL IN HI

Research work for this paper focuses specifically on the evaluation of UML tool on HI projects. Only one paper which comes close to the objective of this paper [7], where the evaluation of UML tools was carried out for clinical pathways. The requirements for the tools stated in this paper were an open-source tool, web-based, formats support interoperability, model-driven approach, easy modeling, good ergonomics and clear navigation. Similar work but not involving UML tools in [8], aims to define, test, and validate

evaluation metrics for software tools designed to support the processes associated with the definition, management, and implementation of clinical information. The authors are determined that their defined Clinical Information Modeling Tool (CIMT) evaluation survey tool is generic enough to be applied to multiple electronic health record (EHC) standards and specifications. However, the UML tools were not part of this study and as such does not really contribute much to this paper apart from providing us with some functional requirements to be considered for the evaluation of UML tools for clinical involvement.

In [9], the authors discussed the different features of requirements and the reasoning behind their choices. The authors developed a metric model called Requirement Tree and worked on the desired characteristics that will help to evaluate different UML tools. The Requirement Tree consists of features, modeling support, OCL support, customization, installation and performance and finally tool support which is further subdivided. The authors expect to continue improving their current metric model and also start with the process of building the Aggregation Structure as well as commence to collect data for the different Performance Variables in view to subject some of the more popular UML tools to evaluation using the complete model. Another metric based model by the same authors in [10], took a hierarchical approach to the evaluation of UML tools. By applying the Logic Scoring of Preference (LSP) method, a list of desired characteristics was constructed, and based on the characteristics a few products were rated by criterion functions. LSP is a method for the realization of complex criterion functions and their application in the evaluation, optimization, comparison and selection of general complex systems. However, the evaluation carried out in [11] is on diagram level only and there were no precise results on the rating of the tools, adding to the drawback on relying on an earlier version of UML [10, 11].

In paper [12], thirteen commercial and open-source UML tools were evaluated to find the most suitable tool for quality-driven architecture model transformation. The evaluation was divided into two separate stages. First, the tools were studied from vendors' website to find the most promising tools and secondly, three of the most promising tools were selected for trial. An empirical study to evaluate modeling effort, learnability, time taken and memory required on three different UML tools was carried out in [13].

The above-mentioned papers provide a number of requirements to look out for in the evaluation process of UML tools. While the requirement for [7, 8] were specific to clinical pathways and based on UML 2.0, the other three papers [9, 10, 11] were very general in requirement specification and some [9 , 10] used older version of UML 1.x.

A 10-step framework modeling software requirements was drawn using UML diagram in [13]. In this paper, the authors presented a review of modern requirement analysis issues emphasizing motivation for more consistent application of UML for requirement modeling. A similar work is presented in [14] as an ongoing research. The work is towards a model execution framework based on fUML [15] that enables to test and validate UML models efficiently by providing debugging capabilities and model testing. This execution framework is for UML diagrams level and not for evaluation of UML tools.

The first research question posed in the paper was already investigated and partially answered in literature in the selection context of the evaluation of UML modeling tools for clinical pathways, [7]. Results show that all the chosen modeling tools can be used for the representation of clinical pathways. However only two tools full filled the requirement of the study. The authors, however, did not attempt to evaluate UML modeling tools for the critical Health system and there was no framework as a result.

After a thorough search, a few studies in the literature that compare and evaluates UML modeling tools were found. A common decision faced while applying UML in practice is the selection of an appropriate tool for modeling. Safdar [12] conducted a study to compare three of the well-known modeling tools. In this study, the authors measure the productivity in terms of modeling effort required to correctly complete a task, learnability, time and number of clicks required and memory load required for the software engineer to complete a task. However, there was no single tool outperformed others in all the modeling tasks with respect to time and number of clicks.

Rani and Garg [16] compared four UML modeling tools, i.e., ArgoUML, StarUML, Umbrello UML Modeller, and Rational Rose based on their features. Different UML tools were compared and Pros and Cons were presented with case study form.

III. Research Question

The research presented in the paper is organized according to several research questions. The main research question posed for the complete research in the paper is:

What are the appropriate UML modeling tools in terms of productivity and correctness in completing tasks for Health Informatics?

This research question is stimulated by literature reviews that currently there are not many specific UML modeling tools appropriate for Health or healthcare informatics. Though there was an evaluation study of UML modeling tools for clinical pathways [7], however, no evaluation for critical Health systems were found.

A large number of commercial and open-source tools are available to support UML modeling, including Rational Rose, MagicDraw, Dia, Papyrus, zOOml, UMLet and many more. In for this particular paper, the interest is in the issues related to the correctness and completeness of the UML modeling tool. In the next level, four UML modeling tools were shortlisted for HI based on the literature survey on tools for Health related systems; the following question is posed:

RQ1: What are the widely used UML modeling tools for health informatics or healthcare system development?

The choice of selecting a modeling tool has a great impact on the overall success of Health informatics project. Based on that it is important to establish a context of the framework for empirical evaluation of UML modeling tools for Health Informatics (critical health system included). The answer to this research question is important for the further course of research in the study.

Since the paper is based on a framework for empirical evaluation, the following research question is posed:

RQ2: What are the important factors in evaluating UML

modeling tools for Health Informatics?

This research question provided a basis for understanding what technical limitations of using open-source UML modeling tools that are readily available in the market for Health Informatics. It is hoped from this particular question, a framework for evaluating UML tools for HI can be derived.

Another research question posed in order to identify the important factors in UML modeling UML tools for Health informatics:

RQ3: How effective is the proposed framework to HI?

The focus is on applying the shortlisted UML modeling tools Health Informatics case study to identify factors important for the realization of HI. From the case studies, another research question aimed at finding how important HI perceives the evaluation framework is posed:

RQ4: How important are the evaluation framework elements to HI?

Research question RQ4 is posed to obtain prioritization of elements of the framework on HI environment. It is important to find which elements were required to be given more attention in the course of the research as a means of supporting future HI undertakings.

IV. RESEARCH OBJECTIVES

UML modeling tools help software designers to model their desired design according to requirement specifications. Most of these tools support: drawing, exporting UML diagrams, documents linking, report generation, code generation and reverse engineering.

The main objective of this research is produce a framework for empirical evaluation of UML tools for HI. In order to achieve the main objective, four subsequent objectives are full filled. Following are the subsequent objectives:

OB1: To identify suitable open-source UML modeling tools for HI

From the literature reviews [7, 12], four UML modeling tools namely, Dia, UMLet, MagicDraw and Rational Rose were selected. These tools were shortlisted based on the healthcare nature the authors were evaluated.

OB2: To design a framework for empirical evaluation of UML modeling tools

A framework is a basic structure underlying a system or a concept [21]. In order to carry out a systematic evaluation, an improvised framework of evaluation is designed. Important features for HI projects are analysed and drawn so that the framework for evaluation of UML modeling tools can leverage the productivity when working with these tools in terms of effectiveness and completeness.

OB3: To evaluate the proposed framework to two different Health informatics case studies

HI encompasses a wide range of scope, from a simple Health records system to critical life support system. For this research, the evaluation framework is applied to Health system case study. This is to evaluate the effectiveness of the framework in HI developments.

OB4: To investigate the impacts of using the shortlisted UML modeling tools in modeling HI

A framework will not be value-added if the impact is not established. From OB3, the magnitude of the framework is established, hence suitable UML modeling tools recommended to HI developers and e-health related projects. The research questions, objectives and results are summarized in Table 1.

Table 1
Summary of Research questions, Objectives and Results

Research Questions	Objectives	Results/Contributions
RQ1: What are the widely used UML modeling tools for Health or health informatics?	To identify suitable open-source UML modeling tools for HI	Four UML modeling tools selected through critical literature reviews
RQ2: What are the important factors in evaluating UML modeling tools for Health Informatics?	To design a framework for empirical evaluation of UML modeling tools	An improvised framework for selecting UML modeling tool for HI
RQ3: How effective is the proposed framework to HI	To evaluate the proposed framework to Health Informatics case study	Effective UML modeling tools selected for HI
RQ4: How important are the evaluation framework elements to HI?	To investigate the impacts of using the shortlisted UML modeling tools in modeling Health Informatics	Value for Health informatics developers and e-health related projects

IV. METHODOLOGY

The objective of this paper is to develop an evaluation framework based on desktop/web-based context, and the tools to be evaluated must focus on characteristics that fulfil the requirement of common HI specification, utilizing two empirical methods, they are, literature surveys and case studies. The approach for this paper is a two phase research model adapted from Friedman and Wyatt [17] shown in Figure 1. Requirement specification issues were identified through literature review. With the overall view of the HI requirement obtained, initial evaluation framework is constructed.

The literature on evaluations of UML tools in HI environment and well as other general fields to identify evaluation criteria that will be of beneficial to this study is reviewed. Various literature search approaches were engaged to cover some disciplinary such as healthcare requirement specification, UML tools, evaluation framework, clinical pathways and HI. The search included electronic databases (Researchgate, Pub-Med), other literature from both health care and other industries involving UML tools as well as searching multiple websites (Google/ Google Scholar). Some articles were filtered out as they were not in the scope of this study.

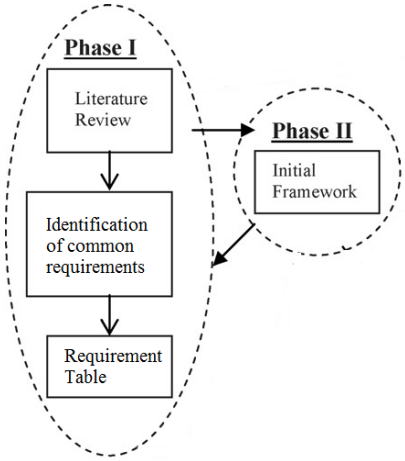

Figure 1: Interim Research Design

The first step to identify the factors in evaluating UML tools for HI is to clearly determine what the requirement specifications and the main features of the system are. Several requirement specifications for HI (especially real-time critical system) [14, 15] were shortlisted. These requirements were categorised as functional requirements and they are namely registration/recording, update, edit, delete and report generation. The non-functional requirements were shortlisted and mapped into Table 2 concerning three different health environments from the literature reviews in [18, 19, 20] for Healthcare Systems.

Table 2
Common Non-Functional Requirement Specification for Health Informatics

Health Care System \ Non-Functional Requirement	Connectivity	Security	Privacy	Performance	Usability	Reliability	Human Factors
Home Health Care Software System		*	*	*	*	*	*
Real-time Health System	*	*		*	*	*	*
Patient Recording for Primary Healthcare Clinic	*	*		*	*	*	

Based on the requirements above, it is clear that security, performance, usability and reliability are the most required non-functional elements for UML tools in HI. The evaluation framework for HI emphasises on what aspects of the tools will be considered when judging tools performance and the tool standards to reflect its success. This framework is a conceptual structure intended to serve as a guide for software developers and health informaticians to make a decision on using the appropriate UML tool for HI specific software development.

Studies on evaluation framework were characterised by their main features that suit HI. The basic structure of this framework consists of five main categories, which were derived using the HI requirement specifications. The framework presents an abstract approach to understanding evaluation as an interaction technique. It attempts to provide a structure that address the fundamental concepts and components of evaluating UML tools specifically for HI.

V. Conclusion

To apply UML in practice, the need to make a critical decision about the selection of appropriate tool for modeling especially when it involves HI is important. This paper discussed the research questions and objectives of a framework for empirical evaluation for HI. Four UML modeling tools: Dia, UMLet, MagicDraw and Rational Rose were selected based on literature reviews on their productivity on HI related areas. Features for HI projects were analysed and drawn so that the framework for evaluation of UML modeling tools can leverage the productivity when working with these tools in terms of effectiveness and completeness. Based on the requirements above, it is clear that security, performance, usability and reliability are the most required non-functional elements for UML tools in HI. The evaluation framework for HI emphasises on what aspects of the tools will be considered when judging tools performance and the tool standards to reflect its success. The above-mentioned UML tools are then applied in HI case study to evaluate the effectiveness of the framework. It is hoped the results of this research will also help health informaticians/developers in their e-health related projects.

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