Analysis of Formal Methods for Specification of E-Commerce Applications

SADIQ ALI KHAN*, AND HUMA JAMSHED**

ABSTRACT

E-commerce based application characteristics portray elevated dynamics while incorporating decentralized nature. Extreme emphasis influencing structural design plus implementation, positions such applications highly appreciated. Significant research articles reveal that, applying formal methods addressing challenges incumbent with E-commerce based applications, contribute towards reliability and robustness obliging the system. Anticipating and designing sturdy e-process and concurrent implementation, allows application behavior extra strength against errors, frauds and hacking, minimizing program faults during application operations. Programmers find extreme difficulty guaranteeing correct processing under all circumstances, however, not impossible. Concealed flaws and errors, triggered only under unexpected and unanticipated scenarios, pilot subtle mistakes and appalling failures. Code authors utilize various formal methods for reducing these flaws. Mentioning prominent methods would include, ASM (Abstract State Machines), B-Method, z-Language, UML (Unified Modelling Language) etc. This paper primarily focuses different formal methods applied while deliberating specification and verification techniques for cost effective.

Key Words: Formal Methods, E-Commerce Applications, Specification Language, Formal Methods, z-Language, Unified Modelling Language.

1. INTRODUCTION

With the rise in Internet popularity, trend for investing in business operations has changed drastically. Now days rather opening physical outlets, entrepreneur prefer online stores, seeking reduction in overheads. Be it product sales or service offering, transacting over these virtual stores is now becoming a very acceptable phenomenon, and, Electronic commerce is rapidly replacing conventional methods of doing business, while catering to all segments of market i.e. from B2B, B2C, C2B and C2C. Collectively speaking Electronic commerce represents the exchange of data, where the facility provides means for the financing and payment aspects of business transactions. Investors are now considering electronic commerce as an effective and efficient way of processing transactions within an organization, while conducting trade in one of the most effective, cost efficient and useful way. It simplifies and eases the burdens of market entry strategy for entrepreneurs of all scales. Organizations converge to Electronic commerce, expecting to utilize network recourses and informational technology, comprehensively called E-

* Assistant Professor, Department of Computer Science, University of Karachi, Karachi.
** Lecturer, Department of Computer Science, Shaheed Zulfiqar Ali Bhutto Institute of Science & Technology, Karachi.

commerce applications, designed for alleviated execution of central processes that these entities perform.

The method of implementing E-Commerce or internet commerce is a tediously complicated and extremely precarious work, which tends to become extremely expensive. Identifying each requirement and constraint, beforehand, and anticipating remedy for the unforeseen circumstances by the system designer are always a prerequisite. Due to its definitive on the types of product information requirements makes E-commerce application characteristic diverse and requires a standardize method which accommodate all the heterogeneity in the system implementation. Even at the smallest of scale, such systems are complex and their correct designing is extremely complicated. Approaches used in implementing and designing such systems are random and temporary, which in turn lead towards unreliable and irregular system operations.

Throughout the life cycle of E-commerce application services, various forms of subtle and intolerable errors emerge, reducing the capacity to guarantee precision of E-commerce system. These errors are marked as unexpected behavior, which materialize during execution of computer program and deployment of complete system. Variance pertinent to the task of validating these errors becomes quite rigid and laborious if only tests, simulations and common techniques of system validation are used.

Researchers and analysts persist that traditional methodologies like compositional development and prototyping are inadequate for any online business application development. As stated by Taylor Etal [1] in a survey based study, online business applications such as E-commerce based websites implementations strategies lacks formal and specialized practices that are present in conventional information systems application development. Currently researchers are trying to use various techniques to analyze the system specification. One of the most common methods is to use formal methods to analyze system behavior, risk factors and other issues related to its implementation.

Defining briefly, formal methods are mathematically based approach used for any hardware or software based system specification, development and verification. Further extending the perception of concept, in computer science, a set of strings of symbols that may be constrained to rules that are specific to it are known as formal language, where in turn the formal language itself is utilized, in computational sciences to realize the complexities of a particular system and its applications. Employing formal methods on an E-commerce project may assume diverse forms, varying from mathematical notation represented in English language statements, to formal specifications with specific semantics. Recent researches are signifying the clear advantages of using formal methods to capture software system and design requirements. These methods show provision for added reliability to modeling requirements by ways of logical reasoning, because of their tendency of implementation in rigorous and repeatable manner, while giving a fair amount of preview of the underdeveloped system saving time and expenses. In addition, the accurate deployment of requirements and design for software systems can be crucially prone to errors, which in turn resulting in expensive and time consuming repairs, leaving drastic effects, study of various software systems show the necessity of building more reliable foundations for high quality systems during the early phase of system development. Consequent documentation resulted amid analysis retaining research work on E-commerce requirement specification using z-language and Unified Modeling Language. Both methods have their importance, and either of the two may come into adaptation for system specification in order to capture complete detail and understanding of the system. However implementing either of these approaches does not guarantee a perfectly secured system by any means.

2. BACKGROUND AND RELATED WORK

Numerous design and documentation methods utilize informal approach, for example, system developers frequently use natural language and diagrams for illustrating hardware and software based system, which

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

20

results in simple design and proper documented application. A very prominent and notable advantage of a formal notation is its precision and clarity, therefore, the formal notation always provides an accurately defining description reducing the chances of misconception. Several case studies, analysis and comparison work were placed under consideration in preparing this cumulated study. Yusufu and Yusufu [2] studied and evaluated different formal specification methods properties (z-language, UML, LOTOS, SDL, B method) by designing a part of the ABM system for each method. They concluded by highlighting some likeness among these different approaches and mentioned their differences based on a particular part of the ABM system, and further evaluated these methods by considering their strengths and weaknesses. An interesting work on online E-commerce applications specification by Conallen [3], Wang [4], and Saleh [5], they used Unified Modeling Language to identify and document E-commerce websites. However, their approach gave little attention to business logic and market aspects of application development as they mainly focused on computer based objects. Kefalas [6], presented a developing tool which identified steps to follow and defined a specification language. The proposed tool was used for verification and testing.

Similarly, Dupuy, et. al. [7] presented a tool for system speciation using z-language for formal specification. The automated tool was called RoZ. RoZ increased quality of system specification by combining formal language and UML together for complete system specification. Jeannette [8] significantly demonstrating the association between security and formal methods in general, proposes a future work to improve and adopt the formal method in critical secure systems. Anthony and Roderick [9] implemented a secure system using unsecure and unreliable commercial off the shelf components using correctness by construction methodology. Jim, et. al. [10] dedicated their work for an E-commerce based application for to Mondex electronic system. In Halimah, et. al. [11]

demonstrated formal specification for inventory management system using z-language. The work reflects Formal method as the optimum technique helping in reduction of errors, particularly at earlier stages of system development. Therefore, the system design and development process propels, improving quality and efficiently influencing time span for development, which in turn proves cost effective.

In another study, Latif, et. al. [12] presented system specification of safety critical system using z-language. The study introduced some extensions in z-specification language in order to support multimedia contents. Z-language specification is most appreciated language for system specification as it provides a simpler syntax and semantics for developers and it is being a widely used formal language providing familiar platform for developers. Research also emphasized that for structured application development such as multimedia application z-language is more suitable than object oriented approach. An implementation by Jun, et. al. [13] in the year 2008 used z-specification as formal method for implementation of mathematical model of a class scheduling system. The formal language was used for system's data modeling, system states and operations. The Search claims that specification efficiently improved system reliability, design time and directness. Therefore, it significantly enhanced quality of system design and development. Studies also reveal variant of z-language called object-Z [14-15]. It is an object-oriented representation of the z-formal specification language which increases the accuracy of large system specification via improved structuring. In Object z-specification classes are template for the object. Classes define states, methods and associated attributes of object. Object states are called instances of class and state transition represents individual object operations. Kim and David [16] research work presents UML class constructs for syntactic structure and semantics which translates UML diagrams to Object Z representation.

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

21

3. ECOMMERCE BUSINESS PROCESS MODEL

This section briefly defines a business process for an E-commerce application. A business process have clearly defined actors with initial and closing stage and associated tasks per stage. The process usually defines set of activities to be performed, and the control flow between them. The process includes state that contains the current activity (active or suspended), the formerly executed activities. For example in an E-commerce application checkout process includes set of activities which user execute in sequence; user logs in, chooses the product or service offered, confirms the order, enter shipping details, decide on delivery options, select payment methods etc. By following the mentioned steps the checkout process is completed successfully. Therefore, a business model of an E-commerce application defines actors involved, the services they offer to each other and activities they perform.

4. PROBLEM STATEMENT

Considering the scenario where worldwide electronic cash system faces issues pertinent to key security requirements while providing services in harmony. Any online transaction processing system should be able to tackle predicaments related to privacy, security, fair trade [17]. Online traders as well as consumers seek systems that are secure from any hacking activity, information leakage, illegal behavior and technical malfunction of any type. Formal methods are in contemplation to improve the security by providing reliability and solutions to security threats by monitoring user's behavior and highlighting suspicious activities. Here we will attempt to analyze two different formal methods used as specifications, over a single scenario of an E-commerce secure system. Primarily this paper will circumference on employing analysis concentrated to en route the E-commerce design specification, while attempting to achieve security in E-commerce system. Choice of two platforms z-language and UML is justified due to their syntax and semantics.

System developers and designers prefer working with these two notations for specification methods as their implementation is more convenient during the analysis of systems and results are more accurate and comprehensive. UML represents system components in form of diagram with interaction of stakeholders with system components, where as the z-language is based on propositional and predicate calculus. It maps problems or a system as relations and functions with pre and post condition of data set.

5. PROBLEM SCENARIO

Hypothetically consider a situation where E-commerce website needs protection from potential security threats like [8]:

(i)   Attempted purchase with insufficient balance.

(ii)   Execute balance recharge via illegal method.

(iii)   Purchase product without logging (money theft).

(iv)   Hackers login for credential theft (eavesdropping).

Consider the system variables as:

(i)   Customer accounts containing user-names and passwords.

(ii)   User accounts with bank details.

(iii)   User status and user state (showing offline or online status and state).

(iv)   Product data containing product description and complete product information.

Consider System Design Requirements as:

(i)   Allow customers to login into the system.

(ii)   Allow customers to purchase while logged in.

(iii)   Check user balance to make a purchase.

(iv)   Maintain product status (available, not available).

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

22

(v) Maintain user status (Login or Logout).

(vi) Allow payments through credit card.

(vii) Product descriptions must be easily maintained and updated by store employees.

(viii) Security-Alert data type contains alerts indicating malicious activities and behavior of user's for example user try to manipulate payable amount.

6. SYSTEM DESIGNS

E-commerce based application schema is represented by inputs and outputs variables needed by the system to operate. These constraints will be used to determine completion for behavior and actions. Description of variables is as follows:

■ Email Id: secure user logging ID.

■ Password: used for authenticating the user.

■ Balance: credits used to online buying and charging transaction.

■ Status: user status during system usability (Safe, Suspicious, Blocked)

■ State: current system logging state (User is Offline, User is Online)

■ Alert Points: to find out user status.

Each product has a quantity and a price, which will be applied to determine the completion of buy operation.

■ Quantity: Product quantity.

■ Price: Product price.

7. Z-LANGUAGE SYSTEM SPECIFICATION

Using mathematics only to determine big specifications very rapidly become uncontrollable and incomprehensible due to the complexity of the specifics. Advantage with z-language is that it incorporates schema notation with the basic mathematical notation additionally, to help and support the structuring of specifications.

Essential computational languages are specifications, but these focus on how to achieve the results, whereas, functional computational languages are considered as specification languages, describing what result will be acquired. Therefore, the idea of implementing abstract z-specifications is to describe what a system does rather than how to achieve the goals.

Although it is possible to write z-specifications in functional style, as mentioned previously, however a more convenient approach would be to use a state or model based approach in most circumstances, and consideration of modeling a system as an abstract state and a sequence of operations on this state would be a better choice.

It is essential to specify an initial state or the start of the program and it can be represented by abstract state with some extra predicates defining the preliminary situation of the system. State changes are caused by system processes and operations. There will be a starting state called as initial state and after state which is the state of system after operation. For every system process, a number of predicates will identify precisely what it is required to do. Inputs and outputs may also be included. Fig. 1 1illustrating variable initialization scenario. Temporary state components can be added for clarity of the specification.

Once a system structure has been outlined, it can be used to state and derive theorems about the system. This is helpful in initial system design verification and to identify mistakes at early stage for example modification in any data leaves the system state unchanged. This procedure can be tedious, particularly if done completely by hand, but it is very valuable to lessen errors and gain understanding about the process of the system before implementation.

8. IMPLEMENTATION USING Z-SCHEMA

Fig. 2 illustrates the first schema, called LOGIN. It checks the availability of usernames and passwords in system user's record. If unavailable, the user is blocked. If the user exists and login information is correct, then the user

state changes to online, meaning the user is authentic and is signed-in to the system.

Illustration in Fig. 3 shows second schema i.e. BUY. This make sure if the user has sufficient credit to buy the product. If funds are available then the product cost will be deducted from user balance, otherwise the user is blocked, and the product will be made available.

Fig. 4 shows the third schema is ALERT, which changes user status if the user executes suspicious activities.

Fig. 5 presents the fourth schema called LOGOUT. Its function is to sign off user from the system.
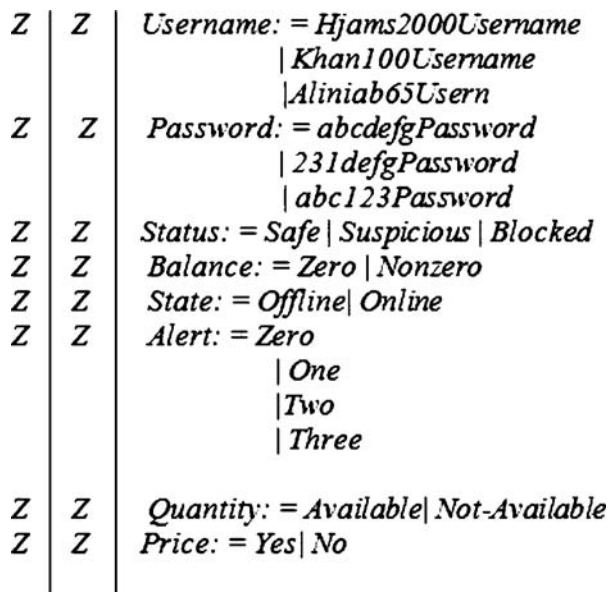
9. SYSTEM SPECIFICATION USING UML

Second choice selected as modelling language for visualizing the design of the system analysis is UML. UML is a widely used language used in computer science for modelling system behaviour and structure. It provides a standard way to display system more diagrammatically to formalize user system requirements. Visual models help by logically grasping altering user requirements and effectively communicating them to the development team [19]. Successful development of an E-commerce
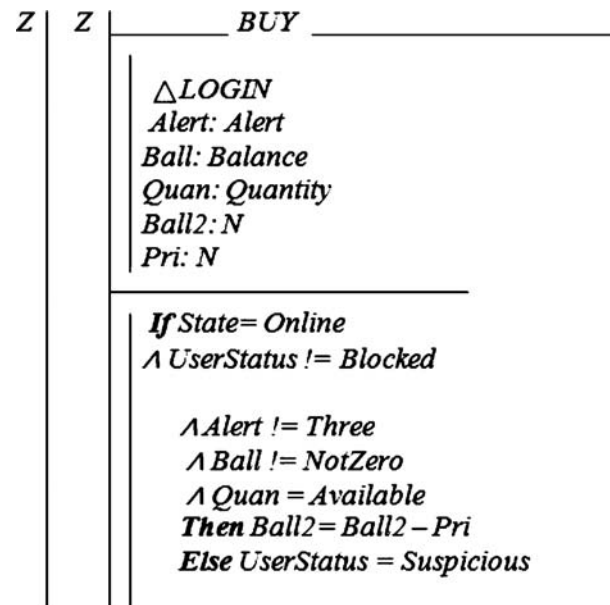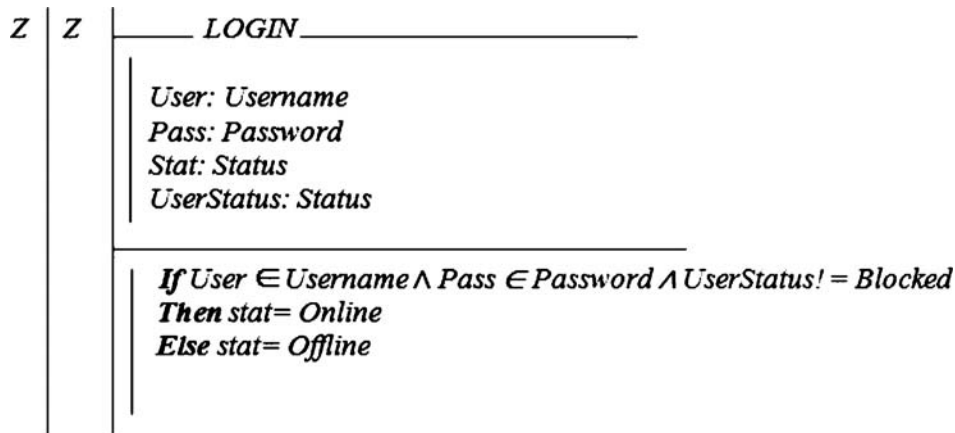

FIG. 1. VARIABLE INITIALIZATION

FIG. 3. BUYING SCHEMA

FIG. 2. USER LOGIN SCHEMAS

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

24

application may be accomplished by visually modelling the system's architecture. Requirements analysis and abstraction (i.e. filtering redundant details) is a significant factor in web application development. Realizing a formal specification method into a system makes development and execution more expedient and cost effective.

Visual modelling offers a way to visualize problem using a standardized graphical notation organized around real-world ideas [20]. UML models are employed for capturing interactions among the system entities, system behaviour, external interfaces, system operation and other software components of the system being analyzed. Ultimately UML defines the system specification through comprehensive illustration, achieving detailed system requirements and filtering out dispensable elements, granting developer ability to launch the most suitable architectural basis for design. Hence, UML provides strong notations which help in system design, leading to better implementation of the system, and additionally, the diagrammatic representation of the system also formulate its findings easier to comprehend.
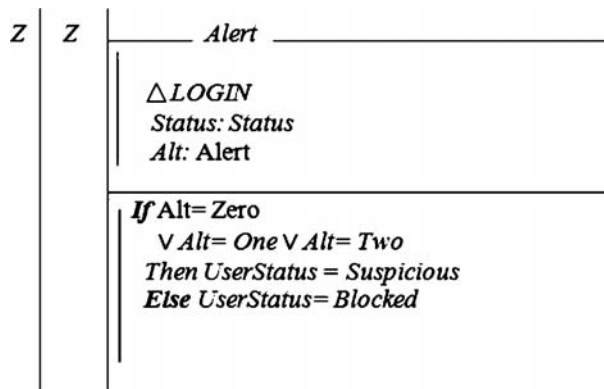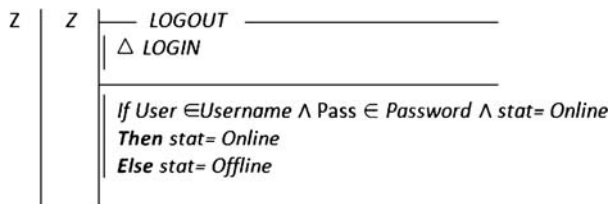

FIG. 4. ALERT SCHEMA

FIG. 5. LOGOUT SCHEMA

UML is popular for development of management information systems based on business logics and objects [21], business process modelling [22-23], and design service components of management systems [24].

10. IMPLEMENTATION USING UML

The same scenario when placed under specification using UML. Fig. 6 illustrates a comprehensive diagram showing user activities associated with the system. User is able to login to the system, buy product and checkout. The login system further includes user verification process. Checkout process verifies user details, user status, and alerts associated with the user.

Clearly the reason for popularity of using UML for system specifics is its visual elaboration. The developers as well as the clients can more conveniently view the working of the system.

11. SUITABILITY OF FORMAL METHODS IN E-COMMERCE APPLICATIONS

Development of Internet based business applications is exposed high security risks and attacks. Efficient development strategies are required for cost effective implementation. The z-language notation as system specification for design of e-commerce based system provides policy and mechanism for implementation of a secure system. It may high lights constraints on system at early stage before its implementation. Thus it reduces over all development and maintenance cost of system. It also helps in bridging the gap between end user specification and practical issues in implementing the system.

For the proposed specification verification, numbers of online E-commerce stores such as (Amazon, E-Bay) were considered as case study. The case study considered online buyers who had enough credit to buy product. The system accepted the transaction if buyer had enough credit. For suspicious behaviour user buying step prompts invalid messages. Our proposed specification method use alert points for monitoring user activity until transaction

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

25

is complete. For malicious activity are proposed model increments alert points, once the alert point increment reaches a threshold value the system blocks the users and will be prohibited from using the website.

As far as UML is concerned, it is an ISO standard language for visualizing the structural and behavioural activity of a system (Table 1). UML provides system architects, engineers and developers an overall view of system behaviours and interaction with system stakeholders. Prior knowledge of how system will interact with end users enables reduction in development and deployment cost of software product. UML is cost effective as it is used to depict various aspects of software system which are dynamic in nature. The system specification of E-commerce application using use case diagram identify actors associated with system usage and relevant function they perform with the system. The abstract modelling of system behaviour enables the system developer to clearly map user requirement into line of codes which reduces requirement change cost and demands minimal maintenance.

12. CONCLUSIONS

Formal specification is precise, hence, the task of judging errors in a specification becomes easier, whereas, an informal specification is often vague, making it more complicated to distinguish errors and sub-sequential corrections. Better understanding of operations within the system is available at premature stage of design, aiding developers and designers in selecting the correct course. Additionally, possibility to formally reason about a system by stating and proving theorems provides a check that the system will behave as expected.

Formal methods can help explore design choices, giving added advantage to the designing team while considering

TABLE 1. SPECIFICATION BASED COMPARISON OF Z-LANGUAGE AND UML

	z-Language	UML
Behavioral Specification	Strong	Week
Function Representation	Strong	Week
Graphical Representation	Week	Strong
Objects Relations	Strong	Week

FIG. 6. USE CASE REPRESENTATIONS

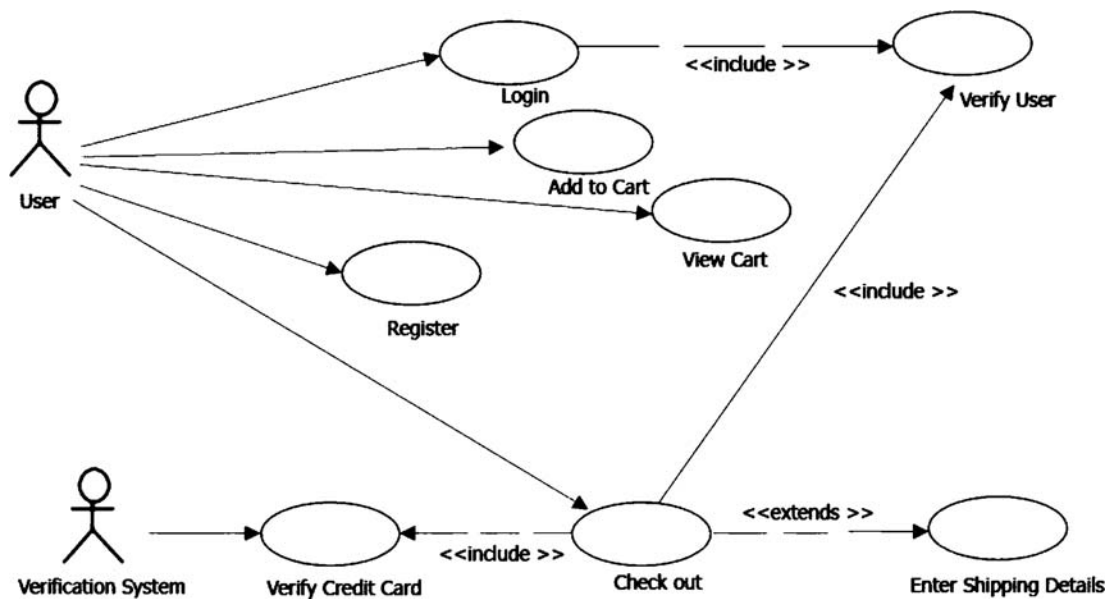**Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]**

26

the process of the system prior to its implementation. Missing modules of a partial specification become clear, therefore, easy recognition of remaining parts of a design can be identified and alternative possibilities considered. In particular, error situation can be tracked by calculating the precondition of an operation, and then dealing with the errors to make sure that the prerequisite of the complete operation is true. With informal methods, it is easy to over look such details until the implementation stage. The ability to recognize design flaws at early stage helps reduce the overall cost. Errors corrected at design stage will decrease cost by two folds rather than tackled with at later stage. The biggest barrier in using formal methods is the notation, which contains unfamiliar symbols, and necessitates designer's expertise in execution. However, in general the notation is no worse than learning a new style of programming language. The Formal Methods such as UML or z-Language deals with software specification and documentation, it does not focus on quality of software being developed. It focuses on software attributes such as correctness and reliability where as other characteristics such as user friendliness and efficiency are addressed to minor extent.

ACKNOWLEDGEMENT

REFERENCES

[1]   Taylor, M., William, J., Forsyth, H., and Wade, S., "Methodologies and Website Development: A Survey of Practice", Information and Software Technology, Volume 43, pp. 381-391, 2002.

[2]   Yusufu, M., and Yusufu, G., "Comparative Study of Formal Specifications through a Case Study", IEEE Conference on Information Science and Technology, Volume 10, pp. 23-25, 2012.

[3]   Conallen, J., "Modeling Web Application Architectures with UML", Communications of the ACM, Volume 42, pp. 63-70, 1999.

[4]   Wang, S., "Toward a General Model for Web-Based Information Systems", International Journal of Information Management, Volume 21, pp. 385-396, 2001.

[5]   Saleh, K., "Documenting Electronic Commerce Systems and Software using the Uniûed Modeling Language", Information and Software Technology, Volume 44, pp. 303-311, 2002.

[6]   Kefalas, P., Eleftherakis, G., and Sotiriadou, A., "Developing Tools for Formal Methods", 9th Panhellenic Conference on Informatics, pp 626-638, Thessaloniki, 2003.

[7]   Dupuy, S., Ledru, Y., and Peccoud, M., "An Overview of RoZ: A Tool for Integrating UML and Z Specifications", International Conference on Advanced Information Systems Engineering, pp 417-430, Sweden, 2000

[8]   Jeannette, W., "A Symbiotic Relationship between Formal Methods and Security. Computer Security, Dependability and Assurance: From Needs to Solutions", IEEE, Volume 10, pp. 26-38, 1999.

[9]   Anthony, H., and Roderick, C., "Correctness by Construction: Developing a Commercial Secure System", IEEE, Volume 19, pp. 18-25, 2002.

[10]   Jim, W., Susan, S., David, C., John, C., and Jereour, J., "The Certification of the Mondex Electronic Purse to ITSEC Level E6", Formal Aspects of Computing, Volume 20, pp. 5-19, 2008.

[11]   Halimah, S., Bakri, A., Harun, H., Alzoubi, A., and Ibrahim, R., "The Formal Specification for the Inventory System Using z-Language", International Conference on Computing and Informatics, pp. 419-425, 2013.

[12]   Latif, M., Noshairwan, W., and Tariq, M.Z., "The Use of z-Language for Multimedia Systems", IEEE, pp. 1-4, Pakistan, 2007.

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

27

[13]   Jun, Y., and Zhi-Yi, H., "Using Formal Methods to Design a Class Scheduling System", IEEE, pp. 56-59, China, 2008.

[14]   Duke, R., and Rose, G., "Formal Object Oriented Specification Using Object-Z", Palgrave Macmillan, Chapter-2, 2000.

[15]   Smith, G., "The Object-Z Specification Language", Kluwer Academic Publishers, ACM Digital Library, 2000.

[16]   Kim, S., and David, C., "Formalizing the UML Class Diagram Using Object-Z", The Unified Modeling Language, Springer Verlag, pp. 83-98, Colorado, USA, 1999.

[17]   Papazoglou, P., and Tsalgatidou, A., "Business to Business Electronic Commerce Issues and Solutions", Decision Support Systems, Volume 29, No. 4, pp. 301-304, 2000.

[18]   Noman, M., Alsmdi, M., and Jaradat, S., "The Specifications of E-Commerce Secure System using z-Language", The Research Bulletin of Jordan ACM, Volume 2 ,pp. 127-131, 2013.

[19]   Bergner, K., and Rausch, A., "A Critical Look upon UML 1.0, The Unified Modeling Language -Technical Aspects and Applications", Physica Verlag, pp. 79-92, 1998.

[20]   Quatrani, T., "Visual Modeling with Rational Rose and UML", 3rd Edition, Boston: Addison Wesley Longman Inc. 240, [ISBN: 9780201699616], 1998.

[21]   Korthaus, A., "Using UML for Business Object Based Systems Modeling, The Unified Modeling Language Technical Aspects and Applications", Physica Verlag, pp. 220-237, 1998.

[22]   Wolf, M., Burkhardt, R., and Philippow, I., "Software Engineering Process with the UML", UML Workshop, pp. 271-280, Mannheim, Germany, 1997.

[23]   Korthaus, A., and Kuhlins, S., "A Software Development Process Model Integrating Business Object Technology and UML", The Unified Modeling Language, pp. 215-239, France: Springer Verlag, 1999.

[24]   Kande, M., "Applying UML to Design an Inter-Domain Service Management Application", The Unified Modeling Language, pp. 200-214, France: Springer Verlag, 1998.

Mehran University Research Journal of Engineering & Technology, Volume 35, No. 1, January, 2016 [p-ISSN: 0254-7821, e-ISSN: 2413-7219]

28