Efficient Regression Test Selection and Recommendation for Component Based Software

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering
in
Software Engineering

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Certificate

I hereby certify that the work which is being presented in the thesis entitled, ***"Efficient Regression Test Selection and Recommendation for Component Based Software"***, in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Software Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of ***Ms. Ashima Singh*** and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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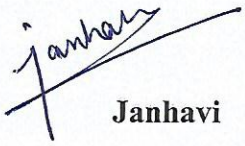

Janhavi

Abstract

Component-Based Development is an approach of developing software systems by using components. Component-based software system may contain external components as well as in-house built components. During the maintenance phase the components get altered or modified very often .When a component is altered, it is not only that component which is affected but it is the whole system which is affected. The type of testing which not only ensures that the modified component is working fine but also ensures that the changes have no adverse or severe effects on the rest of the system is called as regression testing. But due to unavailability of the knowledge about third party components it is difficult for the component users or testers to perform the testing in an efficient manner. As the Component users don't have the information regarding the modifications done in the component, it creates a problem for them to do an appropriate selection of the test cases from the original test suite for testing the altered system. Thus there is a need of an efficient regression test selection approach which results in a reduced regression test suite.

An efficient regression test selection and recommendation for component based software approach is proposed. The approach – "Regression Test Selection and Recommendation" (RTSR) uses UML diagrams (state chart diagrams and sequence diagrams) to investigate the changes, which are further used to select a subset of test cases from the initial test suite and also used to recommend new test cases for regression testing of component based software. The approach RTSR identifies the change, selects test cases from the original test suite, also recommends new test cases if needed and gives regression test suite as final output. An application is designed to validate the approach using case study of automated teller machine. The experimental results demonstrate that RTSR selects lower number of test cases than original test suite and a percentage reduction of 61.9 % is achieved in the regression test suite and also all the changes are tested successfully proving that the approach is efficient.

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Abbreviations	Description
CBSE	Component Based Software Engineering
CBD	Component Based Development
RTS	Regression Test Selection
UML	Unified Modeling Language
RTSR	Regression Test Selection and Recommendation
ATM	Automated Teller Machine

Chapter 1

Introduction

1.1Component Based Software Engineering

Component-Based Software Engineering (CBSE) means the development of systems by using already developed software components. Component-based software system may contain external components as well as in-house built components. The components are stored in the repository which is accessible to programmers. Component-based development approach builds the software systems by choosing appropriate components and then integrating them by using a well-defined architecture.

Need of Component Based Software Engineering

Software systems have become more complicated which causes higher cost of building the systems, lesser productiveness, and lowering in the system-quality. Thus need of finding a good economical development strategy arises. CBSE helps in decreasing the cost of building the systems, the time it takes to deliver to the customer, enhances the maintenance of the software and dependability on the system.

Component-Based Software Engineering Process

The Component-Based Software Engineering Process involves recognizing candidate components, qualifying the interface of each component, adjusting components to eradicate architectural conflicts, assembling the components into a defined architecture and also updating components when there is need of changing the system. Fig. 1 shows the process model for CBSE, focusing that domain engineering goes on simultaneously with component based development (CBD). Domain engineering constructs a domain model of application which is used during CBD for analysis of user requirements, a structural model which is used as an input to architectural design, and provides reusable components to developers for component based development.

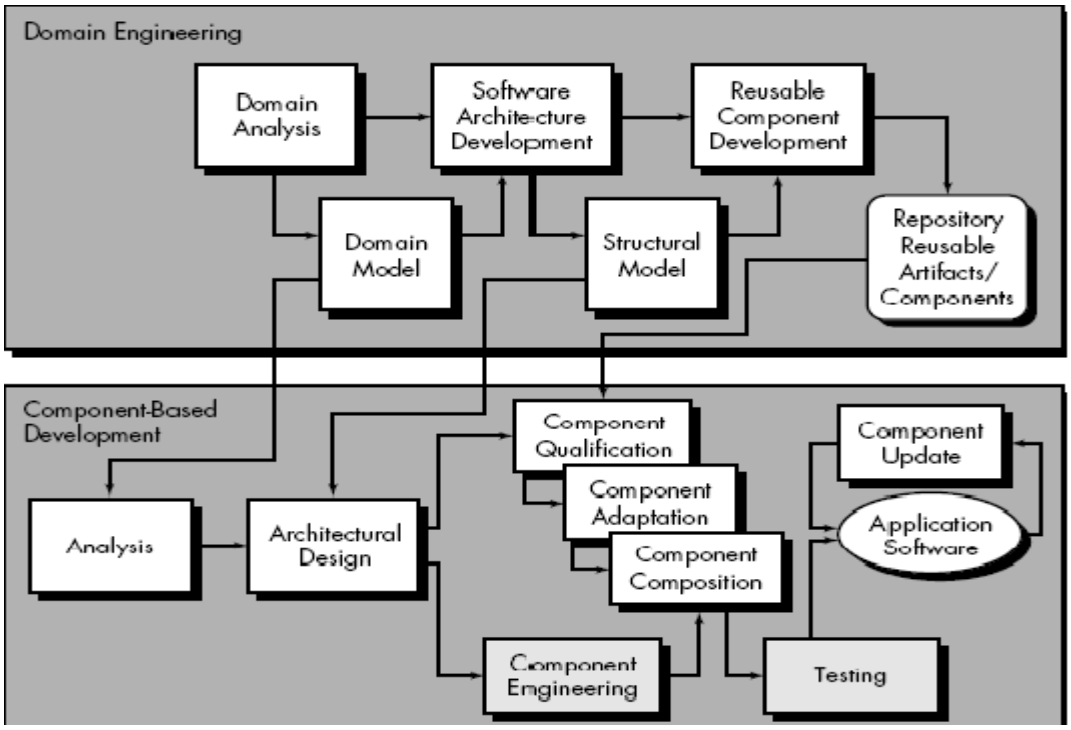


Fig.1: Component Based Software Engineering Process Model [1]

Domain Engineering

Domain engineering focuses on recognizing, constructing and publicize those components which can be used with the current and future software system in a specific domain. It involves analysis of the application domain during which the domain analyst finds out duplicate patterns in application inside a domain to design an application domain model, development of architecture for constructing structural model containing few number of structural elements showing unambiguous patterns of interaction and development of components which can be reused and stored in a repository which can be used by developers during component based development.

Component-Based Development

Component-Based Development (CBD) is an approach of developing software systems by using components. The programmer uses already existing components to fulfill the desired function which is required in the application. Let's say, if a component is created by some developer which allows a user to "log in" then other programmer can use it in their applications for that functionality.

As in conventional concept software systems are developed from the beginning, CBD varies from this concept. Fig. 2 describes that components are picked up and then integrated into the destined system.

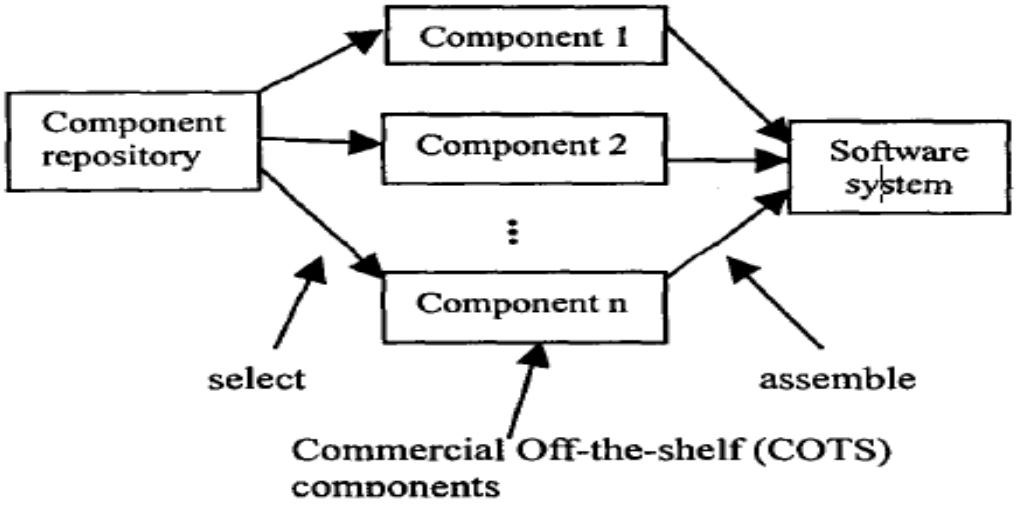


Fig.2: Component Based Development [2]

Component based development involves analysis of customer requirements and enhancement of architecture which is suitable in accordance with analysis model being designed for the application. Then architecture is supplied with components which are either already existing or newly developed. If the component is available to be reused then the component qualification (i.e. ensuring that the selected component executes all the desired functions, appropriately adjusts into the specific architecture and reveals the quality attributes such as availability, security, portability which are essential for the application),component adaptation (i.e. ensuring that constant ways for managing resources are used for every component, for every component a same set of activities are there and interfaces are realized in a constant way) takes place, however if not then component is engineered and then finally all the components are integrated and tested.

1.2 Software Component's Properties

Component

Component is a portion of the system which is not dependent and can be replaced and does its functioning with respect to a clearly- determined architecture.

Properties of a Software Component in CBSE [3]

i. **Identity**: Every component should be exceptionally recognizable in the environment in which it is to be developed and also in the environment in which it is to be deployed.

ii. **Modularity and encapsulation**: Software systems are divided into modules called software components thus they possess modularity. Every component encapsulates related data elements and implements a logic to provide a functionality.

iii. **Independent delivery**: Components should be provided as independent parts to component users so that they can use them to develop a component-based system.

iv. **Reusability:** Every software component must have the property to be reused. The assets which are reusable are analysis of specification, design, source code, and executables etc.

v. **Customizability and packaging**: This feature means that software components can be customized and packaged to meet the desired functionality. Such components are called customizable components.

vi. **Deployable:** A software component is said to be deployable if it is developed using a clearly stated strategy. It results in making an executable instance in the environment in which it is to be deployed.

vii. **Interoperability**: A component is said to have this property if it permits interactions and transfer of data with other components. It can be classified as local and remote interoperability. Local interoperability means a host centered environment for components and remote interoperability means components are on network.

viii. **Composition**: It allows components to have composition relationship which helps a component to produce and demolish other components. It is transitive, means if C is a part of A, and A is a part of E then C is a part of E.

ix. **Model conformity:** Components should be built on a clearly stated model of architecture, interface styles etc.

1.3 Software Component Testing

So far many definitions of software component testing have been proposed, we will describe few of them such as

Component testing means testing the component individually or a group of interrelated components [4]. Software component testing also refer to group of activities to find out errors and ensure the quality of individual components [3].

Software component testing has certain characteristics which are same as that of software testing. Major four of them are described as follows [5].

Software Component Testing Characteristics

i. **Dynamic:** Testing can be either dynamic or static, in dynamic testing actual execution of system under test takes place with certain inputs to check whether the output is as expected or not , by executing the test cases. While static testing takes place during early stages of software development life cycle i.e. usually before the coding phase and this testing is done without actually running the system under test. It is preferred that testing should be dynamic to meet the user's needs as it involves actual running of the system and hence gives more clear results as compared to static testing.

ii. **Finite:** The number of test cases can be infinite sometimes because of number of combinations of the conditions to be tested, which makes testing infeasible in terms of time and cost. Therefore the total test space should be finite i.e. the number of test cases to be actually executed must be finite so that it takes less time and resources for testing.

iii. **Selected:** Test cases should be properly selected from a huge existing test suite according to specific testing criteria for test selection and coverage to achieve cost-efficient and adequate fault revealing testing.

iv. **Expected:** Testing should result in a decision that a test had passed or failed in order to assess expected reliability and quality of the software. For this purpose test oracle is used which generated desired testing results for certain input and also compares the actual testing results with the desired results.

1.4 Software Component Testability

Testability in general means ability to be tested or in other words we can say testability means the extent to which software allows setting up of criteria for testing and efficiency of tests to check that if the established criteria is met or not; or it refers to the extent to which the requirements are described in such a way that they allow setting up of a criteria for testing and efficiency of tests to check if the established criteria is met or not [4].

Software Component Testability Characteristics

Software testability is considered as one of the major factors to compute software reliability [6]. In order to make component reliability measurable or quantifiable, the following characteristics can be used for measuring software component testability effectively. Fig. 3 shows characteristics which can be used to solve the problem of measuring of testability [7].

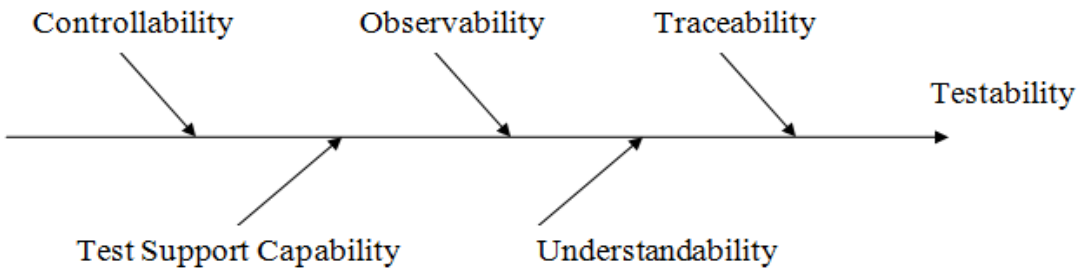


Fig.3: Software Component Testability Characteristics [7]

Freedman [8] considers two factors observability and controllability to illustrate testability of domain. Binder [9] also uses these as features of testability and traceability for representing testability and testing environment. Gao et al. [3] [10] expresses component testability by using following properties.

i. **Component Traceability:** Component traceability means the degree to which a component is able to track its functions, features and the way it behaves internally or externally.

A component which is traceable allows all its essential details for testing i.e. which are required to describe the way it executes, to be recorded. The major traces which can add value to testing of component are:

a. Operation Traces – keeps a track of communications within a component and between different components.

b. Performance Traces – keeps a track of the data related with efficiency and also of the standards for every method in a component for a specific work environment. These traces are also used to recognize problems related to performance testing.

c. State Traces – keeps a track of all the states in a component.

d. Event Traces – keeps a track of an event and sequence which has taken place in a component.

e. Error Traces – keeps a track of information regarding errors, any exception and corresponding details being produced by component.

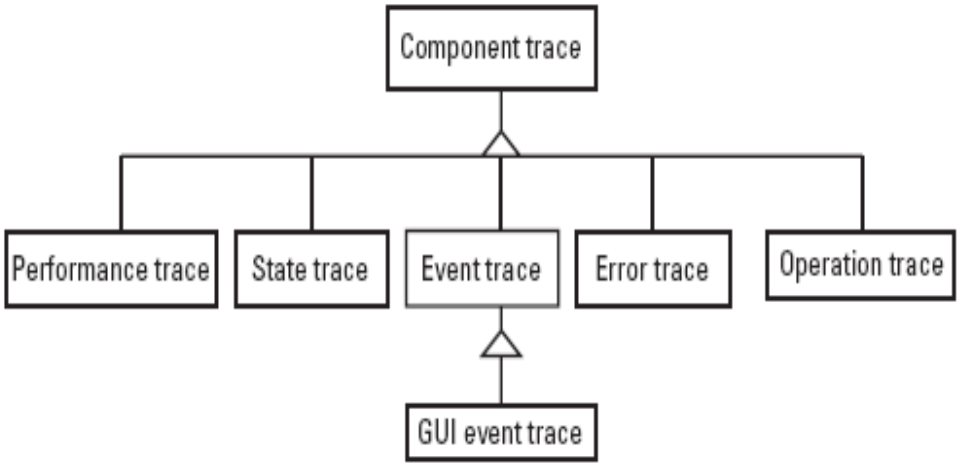


Fig.4: Software Component Traces [3]

ii. Component Observability: Component Observability means the extent to which it is simple to monitor the testing details on the basis of how a component behave, the given input, resultant output when executed for a test case. Clearly designed interface can improve the capability of a component to be observed, which allows

us to identify a relation between input given and subsequent output for a test case during testing.

iii. **Component Controllability:** Component Controllability means extent to which it is simple to control input given, resulting output, functions and behavior of component implementation while it is being tested. It is used for measuring the easiness of executing tests and generating a particular output by giving a particular input, in order to control the predictability of some desired output being generated from corresponding input.

iv. **Component Understandability:** Component Understandability means extent to which it is simple to understand the details of a component, allowing the testers to simply use the useful details such as requirement and specification to perform testing and also create efficient tests for software component testing. The key factors associated with this property are firstly availability i.e. whether all the documents like SRS, readme, design, code are available or not and secondly understandability i.e. whether the details are represented in a presentable way such that it is easy to read and understand it or not.

v. **Component Test Support Capability:** Component Test Support Capability means ability of a component to support its automatic testing and is concerned with ability of component to generate tests, ability to organize tests, ability to evaluate and analyze test coverage and ability to execute tests and support testing.

1.5 Regression Testing of Component Based Software

Regression testing means testing a system or a part of the system again to check that any change which has been done is implemented correctly and also the rest of the system is working fine as desired. It involves selecting some of test cases from existing ones and executing them again to test the changes and their impact on rest of the system. Regression testing is needed when some change has occurred in the original system as the new feature can be dependent on some other existing feature thus it is a quality check to ensure that the existing features are as same as they were earlier. A change can occur in a system as there may be change in the requirements of the client which is very common in real scenario, or there can be a need to add some new functionality into the existing

system, another major reason can be whenever a bug or a defect is fixed, as sometimes when we try to fix a bug this may lead to some new defects being introduced into the system. **Regression testing is applicable at all the levels**:

i. **Unit Level**: Regression testing can be done at unit level in order to test the change by testing the individual unit being modified.

ii. **Integration Level**: Let say there is some change in two components or units of the system, by doing regression testing on individual units we can just test that individually the components are working fine but we must ensure that when integrated together then also they must well as expected, hence once those parts are tested alone then they are integrated and tested again to ensure that the changes are implemented properly and don't have any bad impact on each other.

iii. **System Level**: It is very necessary to do regression testing at system level as the system is delivered to the client as a whole and not its individual parts are delivered. Hence if a change has occurred then once change is being tested then it is very important to ensure that it doesn't have any bad effects on rest of the system which can be assured by doing regression testing of the whole system.

Regression Testing Techniques: Regression testing can be done by different techniques, which is shown in Fig. 5 as follows:

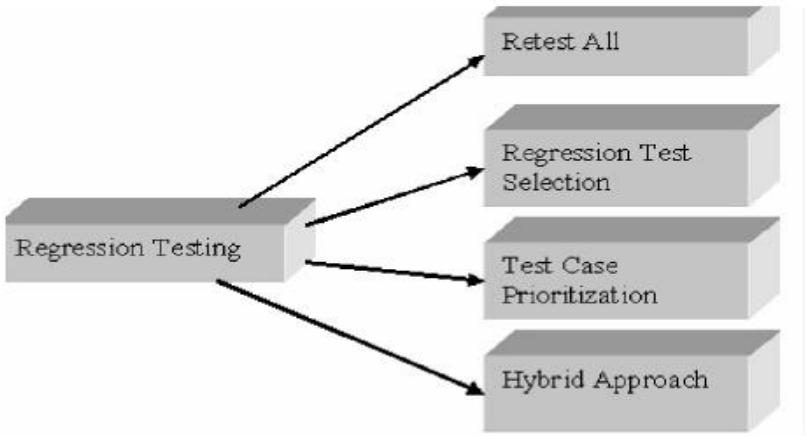


Fig.5: Regression Testing Techniques [11]

i. **Retest All:** In retest all technique, the whole test suite is made to execute again to test the changes and their impacts. It is a very time consuming task and leads to increase in cost of testing.

ii. **Regression Test Selection:** As retest all is a time consuming and costly method, therefore rather than we run the whole set of test cases again and again, we select some of the test cases which correspond well with the change and execute them to test the change and the system and this technique is called regression test selection. It can be further categorized as coverage techniques which uncover those elements in which there is some change and then choose the corresponding test cases, minimization technique which picks out least amount of test cases and safe technique which choose the ones that generate some other outputs for the changed system in comparison with existing system.

iii. **Test Case Prioritization:** In this technique the test cases are selected on the basis of priority, the test cases are prioritized by using some techniques which are categorized into three categories, Fig. 6 shows the classification of test case prioritization techniques:

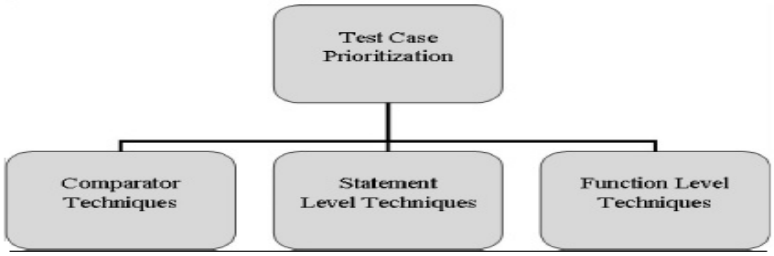


Fig.6: Test Case Prioritization Techniques [11]

a. **Comparator Techniques** - The selection of the test cases is done through two methods- random ordering in which prioritization of test cases is done in an arbitrary manner and optimal ordering in which prioritization of test cases is done according to rate of error detection.

b. **Statement Level Techniques** - The test cases can be selected using different methods- total statement coverage prioritization which prioritizes a test case according to count of statements , more the statements are covered higher the priority is given, another criteria is additional statement coverage prioritization which is alike the previous method but it also ensures that each line of code is checked by minimum 1 test case, another way is total fault exposing potential prioritization – the test cases are prioritized on basis of chances a test case can uncover a fault and last way is additional fault exposing potential prioritization just extension of previous way discussed.

c. **Function Level Technique**- The test cases are selected as similar to statement level techniques with a difference that these consider functions instead of statement.

iv. **Hybrid approach:** Hybrid technique is a combination of test selection technique and prioritization techniques so as to attain the benefits of both the approaches.

1.6 Organization of Thesis

i. Chapter 1 discusses the basic concepts related to CBSE and regression testing so as to have a basic knowledge about these concepts.

ii. Chapter 2 gives the overview and analysis of various approaches being proposed for regression testing of component based software.

iii. Chapter 3 states the research gap analysis, formulates the problem and objectives.

iv. Chapter 4 describes the proposed approach-"Regression Test Selection and Recommendation for Component Based Software".

v. Chapter 5 validates the proposed technique using case study.

vi. Chapter 6 concludes the work done and stated the future scope of the work.

Chapter 2

Literature Review

This section describes an overview of various approaches being proposed for regression testing or regression test selection of component based software. The aim is to investigate the techniques used, to know the contribution and to analyze the benefits and shortcomings of various approaches.

In the year 2001, Harrold et al. [12] presented a paper on regression testing, which is applied on the changed software to ensure that the modified parts are working as expected and the existing parts are not affected by the changes done on the original software. The paper stated first safe regression test selection technique for software developed in Java which efficiently handled the features of the language such as polymorphism, dynamic binding, exception handling. Also a regression test selection system named RETEST [12] that used this technique was developed. The technique was efficiently able to reduce the size of test suite but the amount of reduction was different for different versions.

In the year 2001, Orso et al. [13] proposed two approaches for solving the problem of selecting test cases for performing regression testing of component based software using the meta-content of the components. Code-based test selection techniques ([14, 15, 16, 17]) develop the graphical representation (like control flow graph) of the original program and then execute the test suite to find out the percent coverage with respect to some entity (like edges) in the graphical representation . Then the modified program is also represented in the same way and the two representations are compared to find out the differences between the two on the basis of entity being measured for coverage and then those test cases are selected which covered those entities being modified. The meta-contents required for selecting test cases for code based regression testing are test suite coverage percentage in context of edges, version of the component and information about the modified edges. Specification-based technique constructs test cases basis on

functional specifications of the system and finds out the coverage of the test suite percentage in context with entity in the functional representation. The meta-contents required for selecting test cases for specification based regression testing are test suite coverage percentage in context with test frames [18], version of the component and a way to find out information about the modified test frames. The approach is able to reduce twenty-six percent of the effort required for testing but certain factors like the cost of making meta-contents available and selecting the test cases are needed to be worked upon.

In the year 2005, Mao and Lu [19] proposed a technique for regression testing of component based systems by using improved information about the changes implemented in the original components. A new technique emerged involving both the developer of the component and the user of the component. The component developer provides the enhanced change information along with the component in form of a xml file which helps the user to select a subset of the existing test suite for performing regression testing. The technique is practical and also reduces the cost of testing for medium scale component based systems but is yet to be validated for large and real time systems. The Fig. 7, below shows the complete process of constructing a regression test suite using enhanced change information.

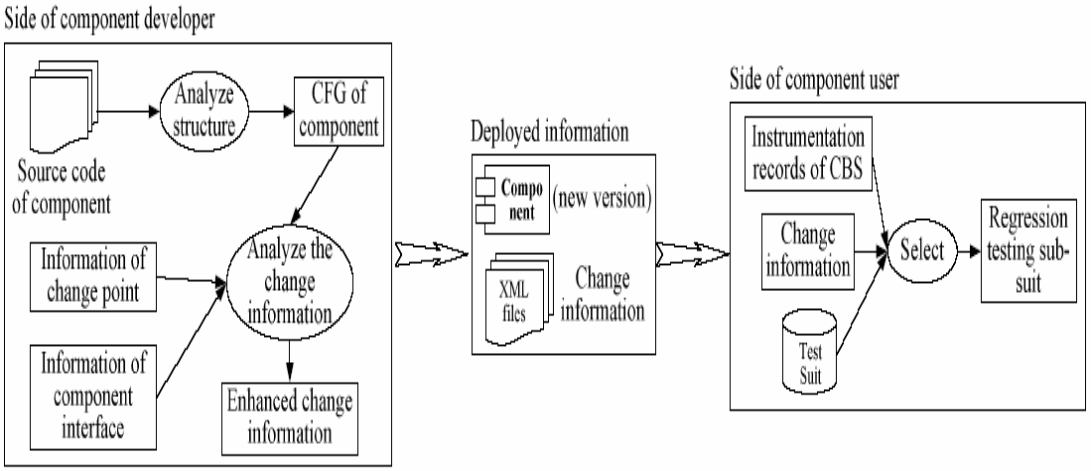


Fig. 7: Regression Testing Using Enhanced Change Information [19]

In the year 2005, Muccini, Dias and Richardson [20] presented a paper enlightening the concept of doing regression testing at an architectural level. There are certain existing testing methods to verify that whether the actual behavior conforms to

desired behavior [21] and to conduct integration testing [22, 23]. The aim was to provide a framework and a method for regression testing when changes have been introduced to both the software architecture and also to the implementation. The paper focuses on two goals, firstly how to reuse the test cases at code level to ensure that changed code corresponds to specifications at software architectural level and secondly how existing test cases defined at the architectural level can be reused to test the modified architecture.

In the year 2006, Gao et al. [24] presented a paper to address certain issues regarding regression testing like ways to make out the changes in a component, effects of those changes on that component, identifying the test cases which can be reused from the existing ones. Whenever a component undergoes some kind of change it is necessary to ensure that the component is working as per the desired requirements and then only it should be combined with must be tested and then it should be incorporated in the whole system. The paper proposed a retesting technique which deals with API based changes and effects on the component .A tool named COMPTest[24] based on this technique is developed which finds out API based changes in a component, impacts of those changes and the test cases which can be reused from the test suite of the component in an automatic manner.

In the year 2007, Mariani, Papagiannakis and Pezz'e [25] presented a paper which focused on two issues: firstly to rapidly recognize those components which conforms to the interface specifications but do not integrate well in the application environment and secondly to automatically produce the test cases for regression testing. A technique was proposed for solving such problems with the help of compatibility testing and prioritized regression testing. Compatibility testing is intended to construct a test suite which is able to rapidly find out and remove the components which are not compatible and prioritized regression testing is intended to construct a prioritized test suite which is small in size and which is able to detect as many faults as possible leading to reduction in testing cost and thus saves the time and effort needed for testing. Both the test suites are generated in an automatic manner from the behavioral models being produced by Behaviour Test and Capture technique [26].

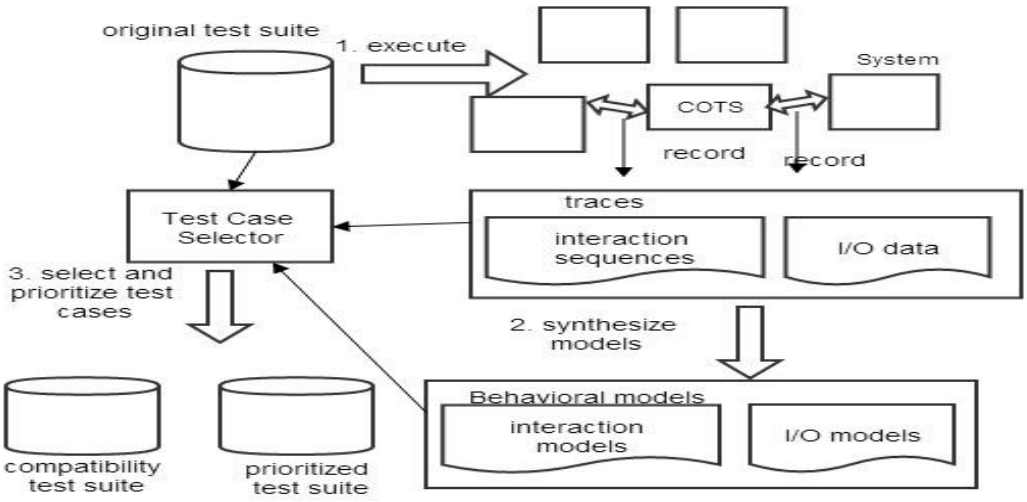


Fig. 8: Generation of Compatibility and Prioritized Regression Test Suites [25]

Fig. 8 shows the generation of compatibility and prioritized regression test suites. System integrators firstly execute the compatibility test suite related with the modified components to find out and remove the components which are not compatible. Then after selecting another component from the remaining compatible ones, runs the prioritized regression test suite to detect the integration faults. The technique was successful to solve the problems for the cases being considered and discovered few areas that are needed to be worked upon like finding out the dependency between efficiency of a prioritized test suite and its nature.

In the year 2007, Mao [27] proposed a built-in regression testing method for component based software in order to improve the ability of a component to be tested. The change information is provided to the users of the component by the developer of the component by incorporating the test scripts in the modified component. These test scripts usually either consists of the test cases or have the functionality to generate test cases. The component developer develops an interface for testing of the modified component and its details can be provided to the user in form of a xml file. The user must document the precondition of every function call made in the preceding testing processes and after that can perform the selection of the test cases correlated with changes in the modified component by executing the functions of the interface. The technique has proved to be much more practical, improves the ability of a component to be tested, decreased the

exchange of information and reduced the cost of testing and cost of storing the information about the version of the component effectively.

In the year 2007, Farooq et al. [28] presented a paper in which a model - based approach for selecting a set of appropriate test cases for regression testing was proposed which uses UML Behavioral state machines and class diagrams for recognizing the changes. The changes are categorized into two categories, class-driven changes means the changes which are identified from class diagrams and state-driven changes means the changes which are identified from state machines. State-driven changes are then used for classifying test cases into obsolete test cases, reusable test cases and retestable test cases, according to the classification scheme by Leung and White [29]. The test cases corresponding to the parts of system which are now obsolete are obsolete test cases. The test cases corresponding to the changed parts are retestable test cases and are required to be executed again so as to ensure that the changes have been implemented properly. The test cases corresponding to parts which have not been modified are Reusable test cases and are not needed to be executed again for regression testing. The Fig. 9 shows the step by step process followed in the proposed approach.

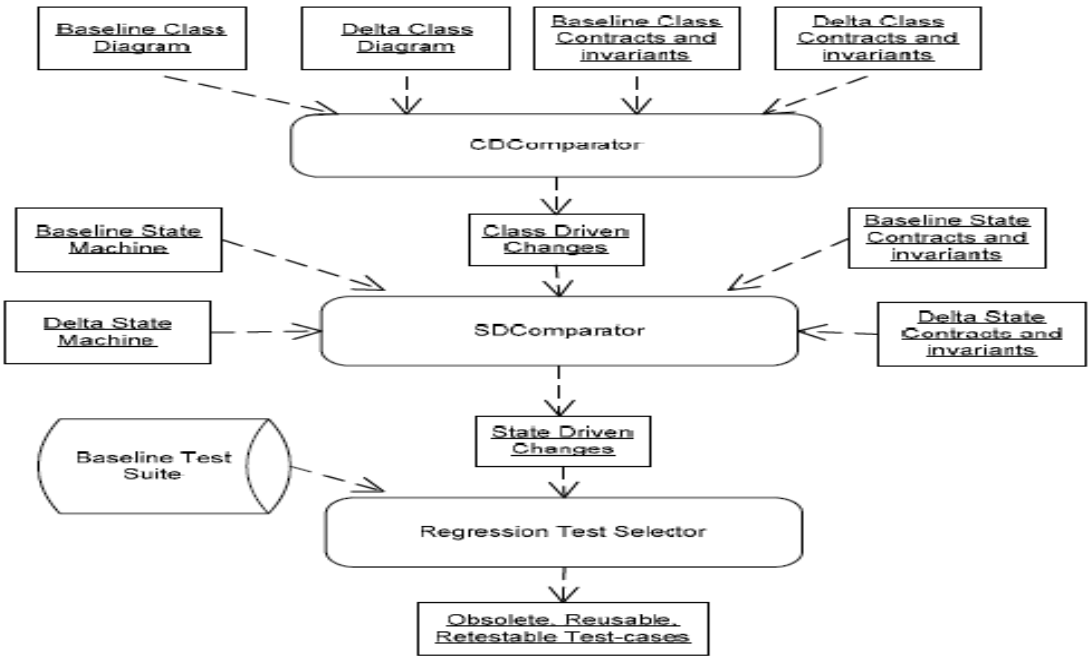


Fig. 9: State based Regression Testing [28]

In the year 2007, Naslavsky and Richardson proposed an RTS approach [30] based on control flow analysis of UML sequence diagrams for a model driven development environment. The technique involves a model-based transformation from a sequence diagram to a CFG. The traceability between test cases and the sequence diagrams is used to determine which CFG elements are executed by each test case. The two CFGs original and modified are then analyzed to find out the affected model elements, and the traceability information is used to select relevant regression test cases.

In the year 2007, Ali et al. [31] proposed an RTS technique based on analysis of UML class and sequence diagrams. The technique analyzes class and sequence diagrams at the level of class attributes and operations. The sequence and the corresponding class diagrams are analyzed and an extended concurrent control flow graph is constructed to model the program. The extended concurrent control flow graph models for the original and the modified version of the application are then analyzed to find out the changes between program versions and to select regression test cases.

In the year 2007, Gorthi et al. [32] proposed an RTS technique based on UML use case diagrams. The approach uses the concept of behavioral slicing which decomposes use cases into user actions followed by some computations and the output and also helps in identifying changes made to the activity diagrams. Whenever there is change in requirements that will be reflected in the activity diagrams also. The models for the original and the modified specifications are analyzed to find the changes and select test cases for regression testing.

In the year 2011, Hagai Cibulski & Amiram Yehudai [34] proposed regression test selection techniques for a test driven development. As in test driven development approach the test suite is re-executed even after a small change, and re-executing the whole test suite will lead to increase in cost, time and effort required for regression testing. Thus an efficient regression test selection technique is required which reduces the size of the test suite in such a way that it is still able to detect a bug in the piece of code modified and provides a fault detection rate approximately equal to the rate of the executing the whole test suite. A tool named Test Rank implementing test case prioritization techniques which were change sensitive was developed. The techniques use dynamic program analysis and natural language analysis. The approach proved to be

useful for medium scale systems but is yet to be proved for large real-time test driven development systems.

In the year 2011, Tao, Li and Gao [35] presented a paper which focuses on the problem that whenever a component is modified, it is not only that component which is affected but it can be the whole system which is affected. Thus a technique which just not tests the modified component but also the whole system was proposed. The technique involves analyzing the modifications, judging the effects of those modifications and updating the already existing test suite. Also a case study presented on a practical component based system proved the technique is workable and efficient.

In the year 2012, Tamil Sen and Rajib Mall [36] presented an article regarding regression test selection technique S-RTS by analyzing a component's state and dependence model. The approach aims to reduce the size of the test suite for regression testing. Whenever a component is modified a dependence graph is constructed for the modified component. Then the provider of the component figures out the information regarding the modification by analyzing the state and dependence models of the modified component. Then while the new version is to be released, the information regarding the affected transition [36] is provided to the user of the component. The selection of test cases is done by the user based on the information provided by the component provider and the transition coverage of the original test suite which is calculated by the component user in the application environment.

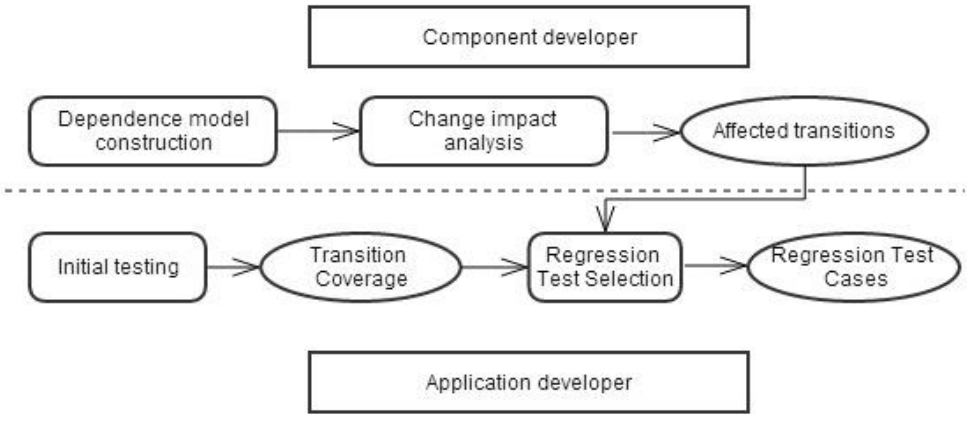


Fig. 10: A Schematic of S-RTS Methodology [36]

Fig. 10 shows the overview of S-RTS methodology .The technique assumes that the state model and the code of the component correspond well with each other and thus it is very easy to use the technique when the code can be produced automatically from the state model.

In the year 2013, Ural and Yenigun [37] proposed an approach for regression test suite selection using dependence analysis. Dependence analysis on an Extended Finite State Machine representation of the requirements of a system under test is used for identifying various types of control and data dependencies between transitions caused due to set of modifications on the requirements. The dependencies are used for RTS selection, by considering the coverage of dependencies related to the effects of the modifications and the dependencies identified as uncovered provide a basis for adding regression test suite with test cases covering uncovered dependencies.

TABLE I. SUMMARY OF SURVEY

Reference	**Analysis and Comparison of Regression Testing Techniques**		
	Thrust area	***Contribution***	***Results***
[12]	Regression test selection for Java software	First safe regression test selection technique for Java software. RETEST -regression test selection system was developed	The amount of reduction in size of test – suite was different for different versions
[13]	Using component meta-content to support the regression testing of component-based software	Proposed 2 approaches- Code-based & Specification-based test selection techniques	26% reduction in testing effort. The cost of making meta-contents available and selecting the test cases should be controlled
[19]	Regression testing for component-based software systems by enhancing change information	Developer provides the enhanced change information along with the component in form of a xml file allowing user to select a subset of the existing test suite	Technique is practical & reduces testing but is to be validated for large and real time systems

Reference	Analysis and Comparison of Regression Testing Techniques		
	Thrust area	***Contribution***	***Results***
[20]	Towards software architecture-based regression testing	The aim was to provide a framework and a method for regression testing when changes have been introduced to both the software architecture and also to the implementation	Does not specify how to recreate the original SA if the code no more corresponds to original SA for doing regression testing
[24]	A Systematic regression testing method & tool for software components	Retesting technique dealing with API based changes & tool – COMPTest was developed	The out-of-date and the reusable test cases can be easily detected
[25]	Compatibility and regression testing of COTS components based s/w	Proposed a technique using compatibility testing and prioritized regression testing	Solved problems considered
[27]	Built-in Regression testing for tomponent-based software systems	Proposed built-in approach, developer provides change information to the users by incorporating the test scripts in the modified component.	Enhances testability of component, reduced the cost of testing and cost of storing the information about the version of the component
[28]	An approach for selective state machine based regression testing	UML based selective regression testing strategy using state machines and class diagrams for change identification.	Validated for case study Student Enrolment System
[30]	Using traceability to support model-based regression testing.	Proposed RTS approach based on control flow analysis of UML sequence diagrams	Workable and yet to be proved for real time systems
[31]	Regression testing based on UML design models.	RTS technique based on analysis of UML class and sequence diagrams	Workable but yet to be proved for large scale systems

[32]	Specification-based approach to select regression test suite to validate changed software	Proposed RTS technique using UML use case & activity diagrams	Validated for medium scale systems
[34]	Regression Test selection techniques for test-driven development	Tool - Test Rank implementing test case prioritization techniques which were change sensitive was developed	Successful for medium scale systems but is yet to be proved for large real-time test driven development systems
[35]	Regression Testing of Component-Based Software: A Systematic Practise Based on State Testing	Proposed a technique involving analysis of the modifications, the effects of those modifications and updating the already existing test suite	Workable and efficient
[36]	State-Model-Based Regression Test reduction for component-based software	Proposed a technique S-RTS which analyze component's state and dependence model	Easy when the code can be produced automatically from the state model.
[37]	Regression test suite selection using dependence analysis	Proposed approach for regression test selection using dependencies in extended finite state machines	Does not address the problem of generating tests automatically

The research discovers that future work is required in the fields like finding out the use of additional dynamic models for example, temporal properties [38] for constructing test suites, verifying the approaches for large scale projects and real time applications, enhancing the ability of a component to be tested, using the concept of slicing to further improve the change information , finding out ways to improve the efficiency of a test suite constructed by using test case prioritization technique and the traits of the test suite like granularity and grouping [39], to develop an automatic testing tool and to develop a common platform for component developer and user.

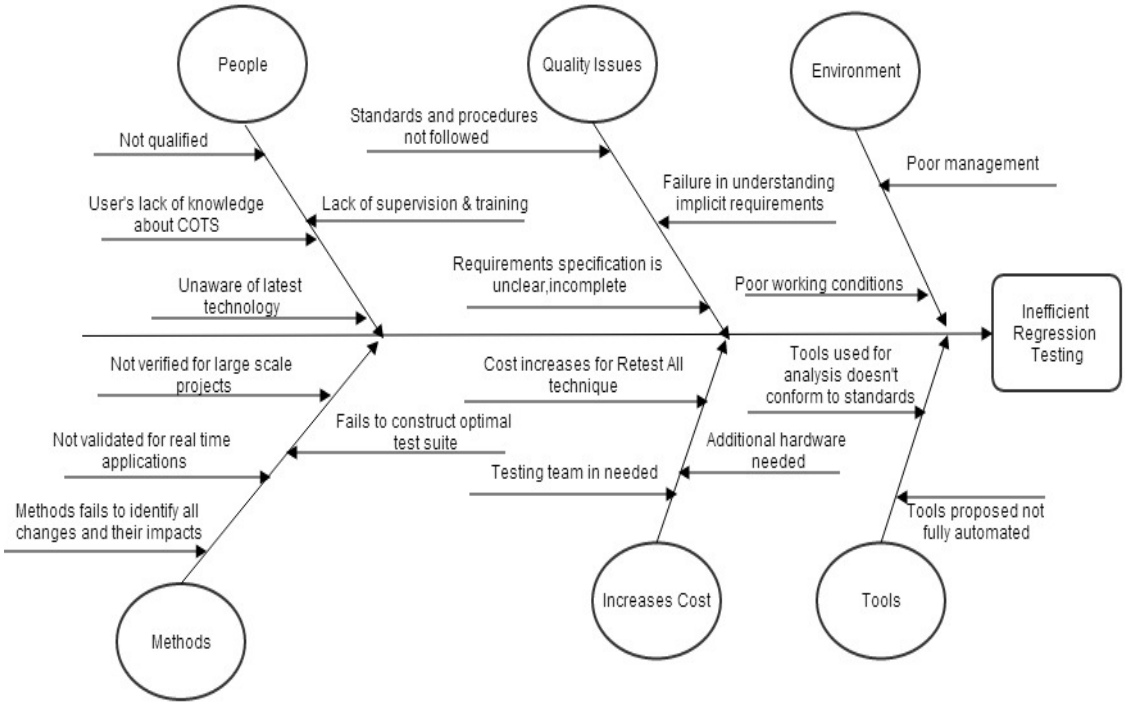


Fig. 11: Cause – effect diagram for Inefficient Regression testing

Fig. 11 shows the cause- effect diagram to solve the problem of inefficient regression testing. For finding out an effective approach towards regression testing it is very important first to identify the various reasons which results in inefficient regression testing. Here we are using cause-effect diagram to find out major causes which leads to an improper and ineffective regression testing of the component based software. Cause effect diagram is used so as to recognize the causes and the reasons behind those causes. The cause-effect diagram being proposed states that various causes can be people, methods, tools, environment, quality issues, and increase in cost.

i. People are a major cause, when we say people they can be testers, users of the components or the developers of the components. They are a major cause as sometimes they are not well qualified, not trained properly, not aware about the latest trends and technologies and the users of the components don't have complete knowledge about the third party components.

ii. Another major cause is the methods or the approaches which have been proposed, as these methods have not been validated for large-scale real time

applications, doesn't identify the changes and their impacts on rest of the system accurately.

iii. Quality issues are not handled carefully such as the poor documentation, improper requirement specification, proper standards and procedures are not followed while implementing a method or an approach and the implicit requirements are not well understood. Quality issues should be looked after carefully so that the final product or the final approach is a quality product or a quality approach.

iv. Another factor of ineffective regression testing is use of inefficient tools or the equipments which are used for analyzing the method proposed as if the tool which is used for analyzing itself is not accurate the test results will definitely be incorrect. Also various tools being proposed by the researchers are not fully automated.

v. Some other causes are improper working conditions and poor management. If the working conditions are not good and proper facilities are not provided to the employees, the efficiency of working decreases.

vi. Increased cost is one of the major causes as a testing team is required for doing effective testing, additional hardware is also needed and also retest all approach consists of re-executing all the existing test cases thus is an expensive technique and if used will lead to increase in cost of testing.

Chapter 3

Problem Statement

3.1 Research Gap Analysis

Various approaches for regression testing have been proposed based on different strategies each having merits and demerits. There are certain design model based approaches which uses UML models, where each approach uses different UML diagram or combination of diagrams. An approach proposed in [22] ,[28] is used for selecting a set of appropriate test cases for regression testing was proposed which uses UML Behavioral state machines and class diagrams for recognizing the changes and results in classification of test suite. The approach in [31] recognizes the change and selects the test cases by using UML class diagrams and sequence diagrams. The approach in [30] uses sequence diagrams for regression test selection in a model driven environment. The approach in [32] uses use case diagrams and activity diagrams to select the test cases. The approaches being reviewed selects or classifies the test suite but does not efficiently reduce the size of the regression test suite, also does not allow inserting new test cases into regression test suite corresponding to the new features being added in the system.

3.2 Problem Formulation

Component-Based Development is an approach of developing software systems by using components. The components are stored in a repository, which are usable by other programmers. Component-based software system may contain external components as well as in-house built components. During the maintenance phase the components get altered or modified very often .When a component is altered, it is not only that component which is affected but it is the whole system which is affected. The type of testing which not only ensures that the modified component is working fine but also ensures that the changes have no adverse or severe effects on the rest of the system is called as regression testing. But due to unavailability of the knowledge about third party components it is difficult for the component users or testers to perform the testing in an efficient manner. As the Component users don’t have the information regarding the

modifications done in the component, it creates a problem for them to do an appropriate selection of the test cases from the original test suite for testing the altered system. Thus there is a need of an efficient regression test selection approach which results in a reduced and effective regression test suite which test all the changes of the system.

3.3 Objectives

i. To study existing approaches being proposed for identifying and analyzing change and also understanding existing techniques for regression testing of component based software.

ii. To propose an approach which creates a reduced and efficient regression test suite by selecting the test cases from the existing test suite and also recommends new test cases to test new added features in the system.

iii. To validate the approach using the case study of automated teller machine and analyze the results.

Chapter 4

Proposed Approach: Regression Test Selection and Recommendation (RTSR)

4.1 Overview

A component changes very often in maintenance phase and those changes should be tested, also it is very essential to ensure that those changes do not have any side effects rest of the system. This type of testing is called regression testing. But re-exercising all the test cases will be a very time consuming and tedious task; therefore we need an approach which can select a subset of test cases from the initial test suite which can be used to perform regression testing. As when a system is evolving it has to undergo many changes and whenever some change will occur in the system the corresponding changes will be reflected at the design level also. We propose an approach "**Regression Test Selection and Recommendation" (RTSR)** which uses UML diagrams (state chart diagrams and sequence diagrams) to investigate the changes, which are further used to select a subset of test cases from the initial test suite and also used to recommend new test cases for regression testing of component based software. The approach RTSR identifies the change, selects test cases from the original test suite , also recommends new test cases if needed and gives regression test suite as final output.

In UML modeling different artifacts are related with each other, therefore some modification in an artifact can lead to some modification in other artifact. Therefore it is very necessary to find out the changes in those artifacts and also identify the artifacts which are indirectly affected by those changes. Thus regression test selection includes recognizing the changes in the modified system, identifying the components of the system being affected by the changes and finally selecting those test cases which correspond to changes identified.

Fig.12 shows the basic model of the proposed approach (RTSR), describing the flow of major steps involved in the approach.

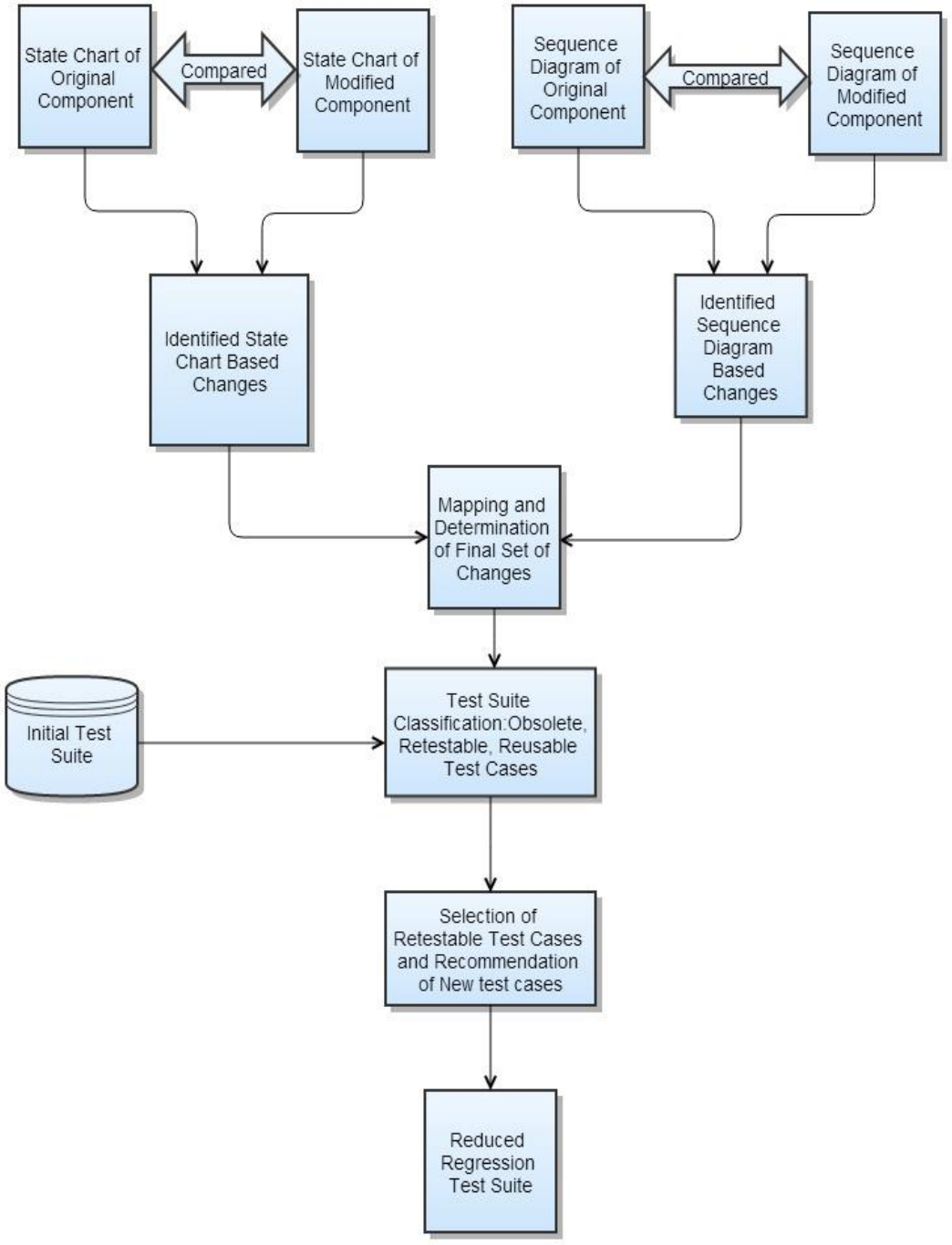


Fig. 12: Regression Test Selection and Recommendation (RTSR) Approach

The basic steps used in the approach proposed RTSR are illustrated as follows:

- **i.** The state chart diagram of the original component is compared to the state chart diagram of the modified system to identify the state chart based changes. Also the sequence diagram of the original system is compared to the sequence diagram of the modified system to identify the sequence diagram based changes.
- **ii.** Then the sequence diagram based changes are mapped with identified state chart based change to find out the associated state chart based change for each identified sequence diagram based change and then the final set of changes is determined.
- **iii.** The final analyzed changes are used to classify the original test suite into three categories: obsolete test cases, retestable test cases and reusable test cases.
- **iv.** Then some new test cases are recommended if required, i.e. when the original test suite does not contain a test case to test the added features of the system.
- **v.** Then final step is to determine regression test suite, the retestable test cases and new recommended test cases together forms the regression test suite having less number of test cases as compared to original test suite.

4.2 Detailed Description of Proposed Approach-(RTSR)

This section illustrates the proposed approach- Regression Test Selection and Recommendation in detail by elaborating all the steps used in the approach to get the regression test suite. The section is divided broadly into two sub-sections i.e. 4.2.1 and 4.2.2. The first sub section illustrates the identification of change in the system by comparing UML state chart and sequence diagrams of the original and modified version of the system, and the second sub-section illustrates the development of regression test suite by classifying the original test suite and selecting retestable test cases and recommending new test cases.

4.2.1 Change Identification and Analysis

Step 1: Identifying and Analyzing State Chart Based Changes

State chart machines describe all the states an entity undergoes and the transitions among those states which are dynamic in nature. State chart machines provide the description about the event which caused a state change, the guard condition which must be satisfied in order to make a transition eligible and the action which will take place when the transition has been fired. Here we consider following changes which will be considered under the category of state chart based changes.

i. **Addition or Removal of a State:** If there is addition of a new state or removal of some existing state in the state chart diagram of the original component, then it will be considered as a state chart based change and will also lead to addition or removal of certain transitions [40], hence we can consider this case as similar to addition or removal of transition and there is no need to consider it as a separate change for test. Fig. 13 shows the change of addition of state leading to addition of transition.

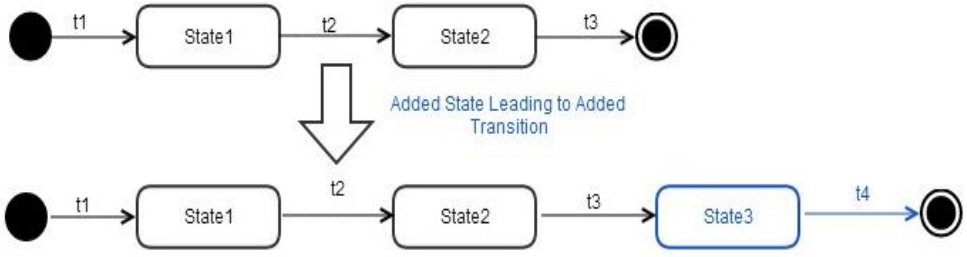


Fig. 13: Addition of a State

Fig. 14 shows the change of removal of state: state2, leading to deletion of a transition t3.

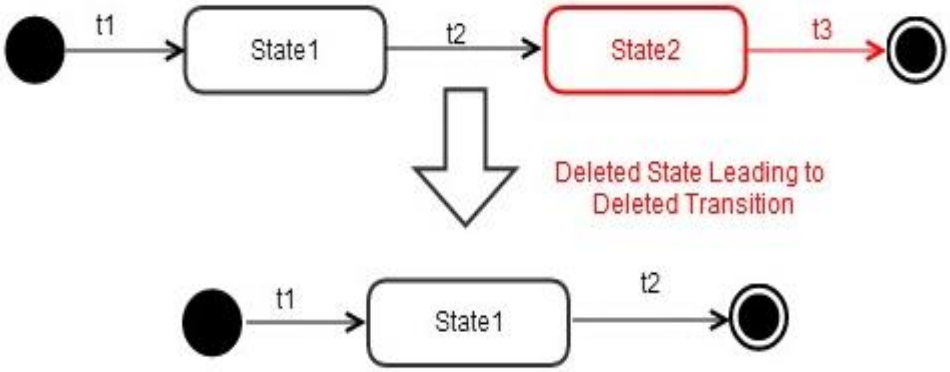


Fig. 14: Removal of a State

ii. **Addition or Removal of Transition:** In case a new transition is inserted or some existing transition is deleted, we consider it as a state chart based change. The basis on which a transition is removed can be removal of any of the states between which the transition exists or can be removal of event which triggered the transition or can be removal of other artifacts of a transition such as guard condition or action [22]. Fig. 15 shows the change addition of a transition t4.

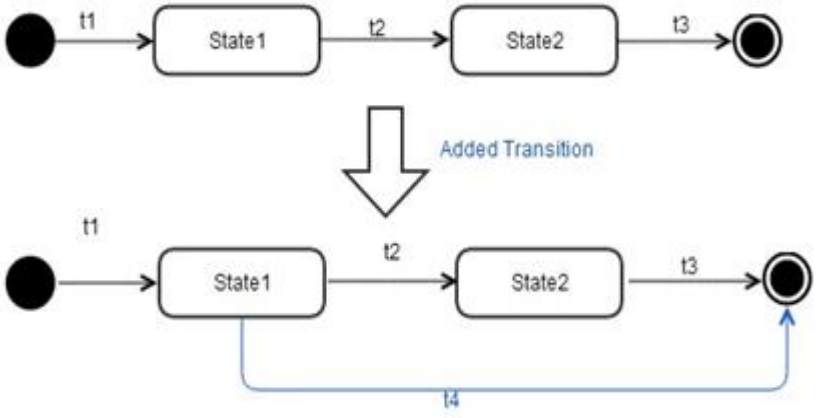


Fig. 15: Addition of a Transition

Fig. 16 shows the change of removal of a transition, t4 is deleted from original state chart diagram.

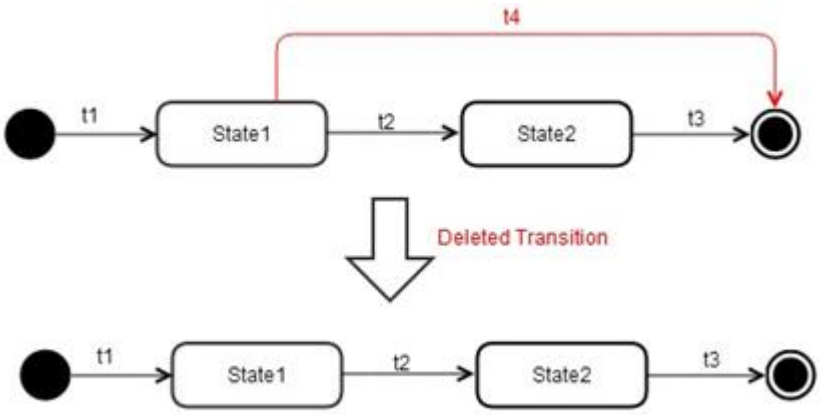


Fig. 16: Removal of a Transition

iii. **Changed Transition:** A transition is considered to be changed if there is modification in any of the artifacts of a transition i.e. if the event which triggered the transition has changed, the guard condition which the transition must satisfy is changed, the action which will take place after the transition has occurred is changed, or there is any change in any of states between which the transition exists.

iv. **Changed Event:** The events are broadly categorized into three categories namely message events, time events and change events [22].

The reason for change in message event can be change in any of the type of these events, i.e. there may be insertion or removal of any receive event, the transition consisting such events will execute for all messages excluding the ones which are not referred by another transition having same source state. Another reason for change in message events can be change in call or signal event.

Call events as the name indicates are the ones which cause a method to be invoked and the reason for change in such events can be change in the number

of parameters or type of parameters the event is taking as input or the corresponding method in sequence diagram is changed, which will be explained in next section.

Signal events are like call events but a major difference is that signal events are not synchronous in nature while on the other hand call events are synchronous and the reason for change can be change in number or type of parameters and are handled in same way as that of change in call events.

Time events, another type of event is time event- which is used for representing at what time the event must take place, which can be specified in two ways like "after" 5 seconds or "at" 10:05a.m.

Change event, another type of event is change event- which are represented using "when" and then there is a condition, like when (flag=1) or when (count<4). The reason for change in time event and change event can be change in their expression having some changed or some deleted or inserted parameter. Fig. 17 shows the change of an event of transition t4.

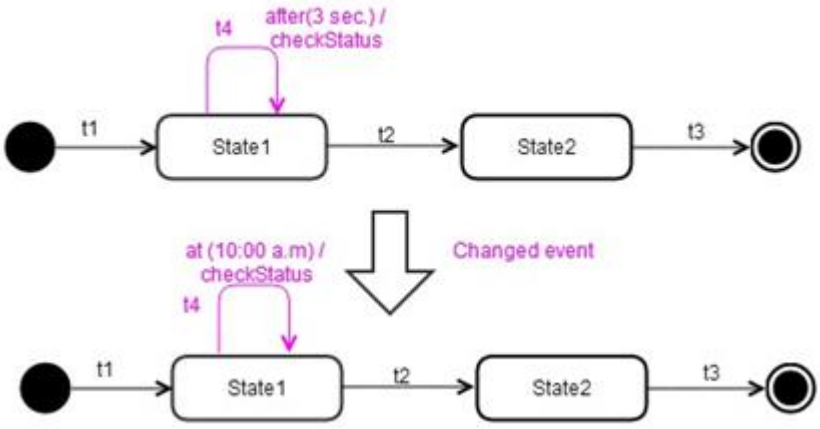


Fig. 17: Changed Event

v. **Changed Action & Changed Guard Condition:** Guard condition is a Boolean expression which is checked, if it comes out to be true then the transition will occur followed by execution of the action, else the transition will fail. The change in action or guard can be due to change in the expression or in the parameters they are using.

Fig. 18 shows the change in action and guard condition of a transition t2, the original guard condition [count<4] and if the condition comes out to be true, the action will be display(count). Changed transition has guard condition [(count<4) and (flag<2)] and if the condition comes out to be true then action is display (count,flag) .

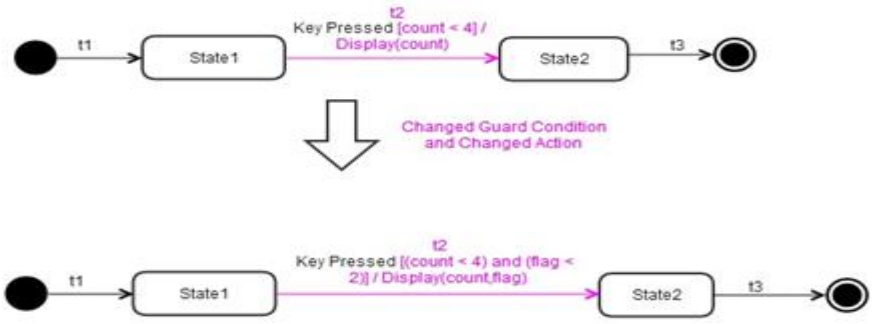


Fig. 18: Changed Action & Changed Guard Condition

Step 2: Identifying and Analyzing Sequence Diagram Based Changes

i. **Addition or Removal of Method:** If a method is added or removed in/from the existing sequence diagram then it is considered as a sequence diagram based change. Also when a synchronous message/method is added/ removed then a corresponding return message is also added / removed respectively therefore there is no need to consider it as a separate change to be tested. Fig. 19 shows the change of addition of a method Y() , resulting in addition of return message :done.

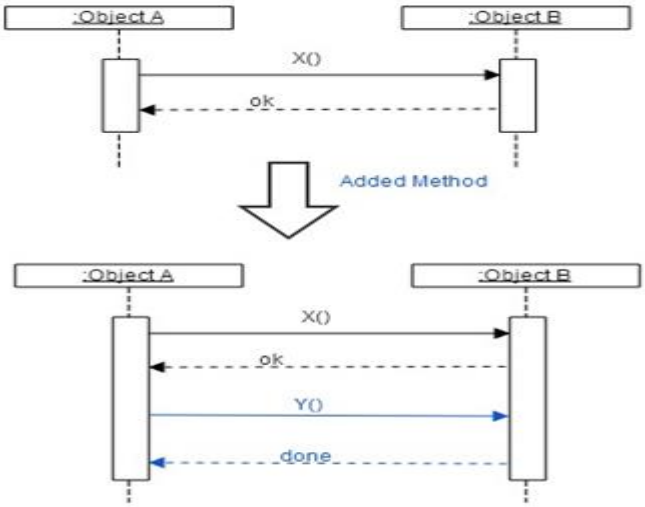


Fig. 19: Addition of Method

Fig. 20 shows the change of deletion of a method Y() , resulting in deletion of return message :done.

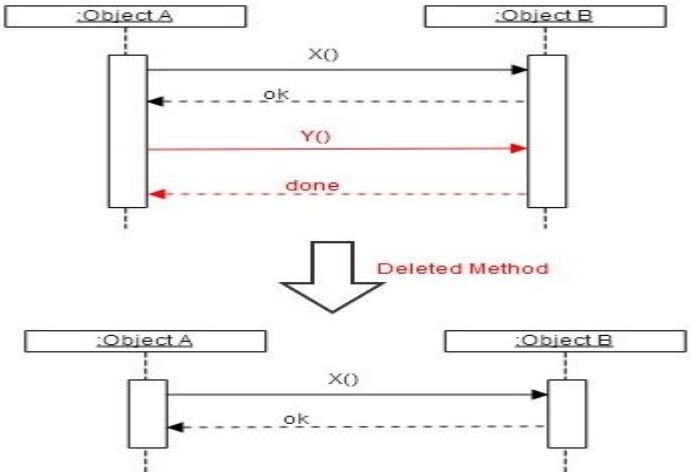


Fig. 20: Removal of Method

ii. **Modified Method:** A method when modified is considered as a sequence diagram based change, the reason for change in the method can be change in number of parameters it takes as arguments or change in the objects between which a method exists or change in the sequence of the messages or there can be some guard condition added or removed or changed in the method. Fig. 21 shows the modified method y() , i.e. from y(count) to y(count,flag).

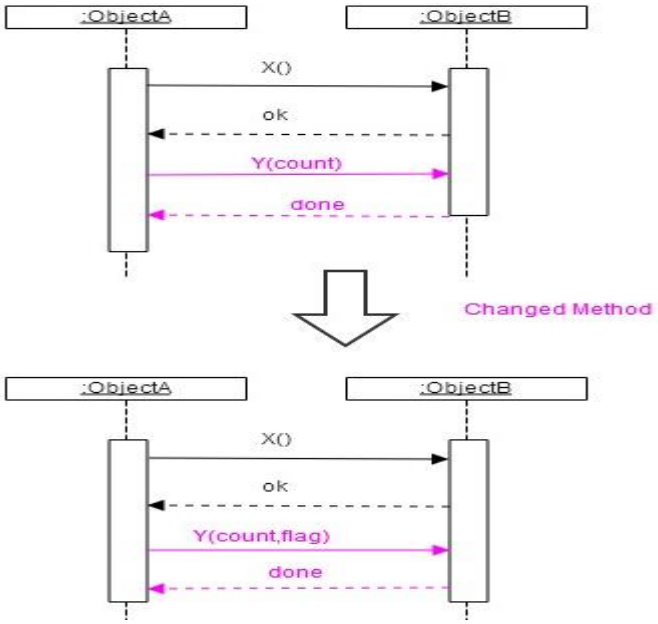


Fig. 21: Modified Method

Fig. 22 shows the change in sequence of methods earlier sequence is x(), ok, y() , done , z(), successful and later it is x(), ok, z(), successful, y(),done.

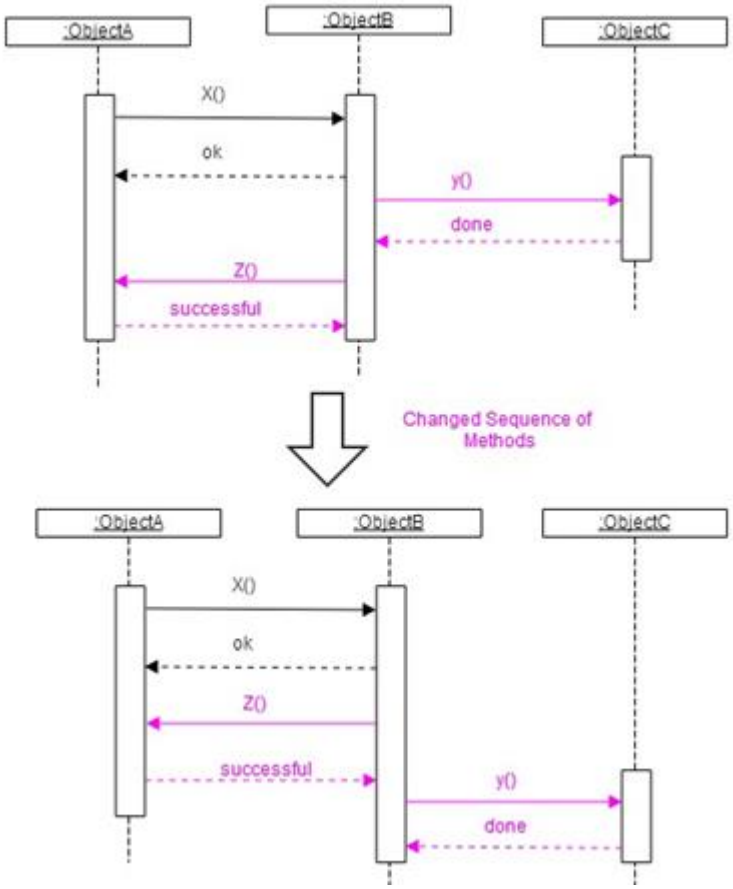


Fig. 22: Modified Sequence of Methods

iii. **Addition or Removal of Object:** If a new object is added or some existing object is removed from the sequence diagram due to may be addition or removal of some component in the system then such changes are considered under the category of sequence diagram based changes but as addition/removal of object leads to addition/removal of some method therefore there is no need to consider it as a separate change for testing.

Fig. 23 shows the change of addition of an object of type C resulting in addition of method Y() , leading to addition of return message done.

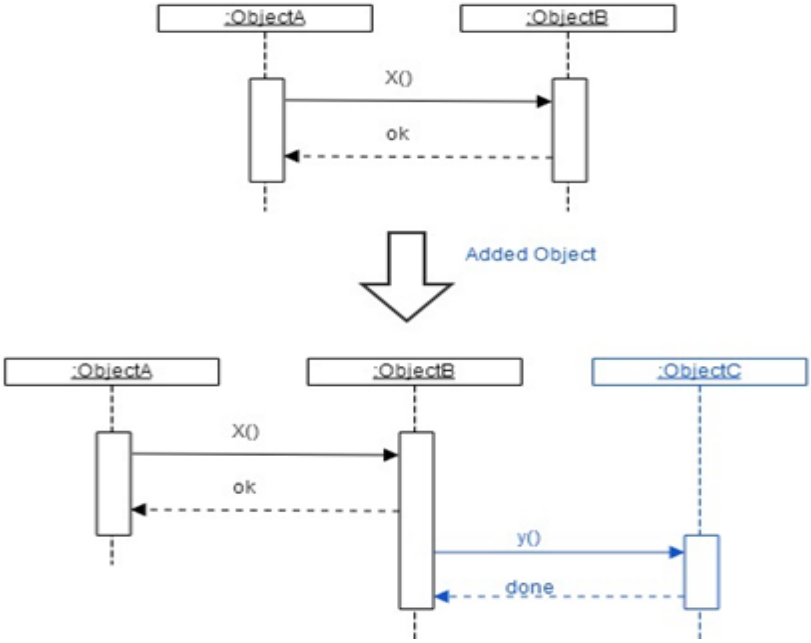


Fig. 23: Addition of Object

Fig. 24 shows the change of deletion of an object of type C resulting in deletion of method Y() , and return message done.

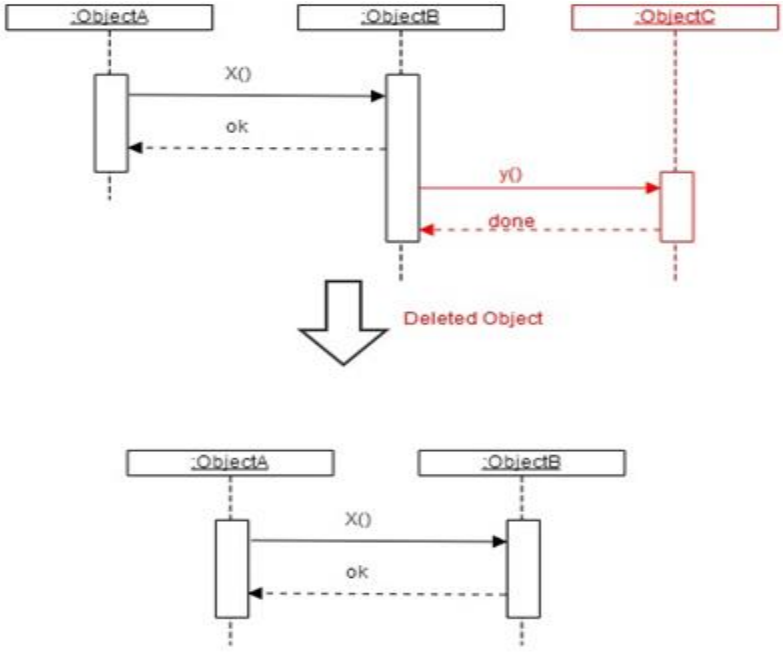


Fig. 24: Removal of Object

iv. **Addition or Removal of Combination Fragments:** In sequence diagrams there are three types of combination fragments [41] i.e. loops, opt means options and alt means alternatives. Alternatives allow the modeling of "if then else" logic , an option is used to model "if then" statement and loops are used to model repetitive sequence and the loop's guard is placed towards the top left corner of the fragment. Addition or removal of any of the combination fragment is considered as a sequence diagram based change. Fig. 25 shows the option combination is added, with a guard condition [result = ok] i.e. if the result is ok then only the methods in the fragment will be executed.

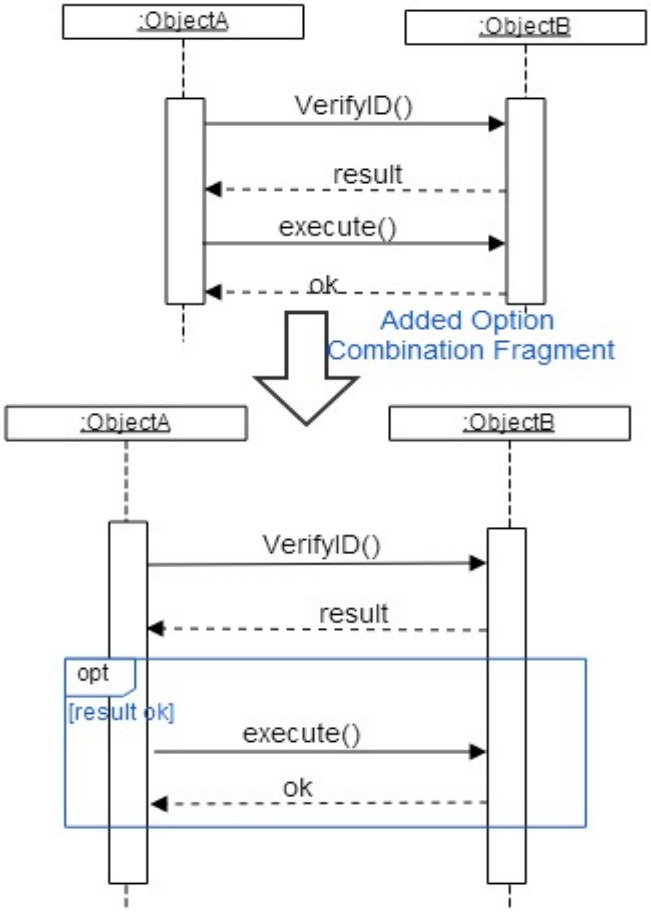


Fig. 25: Addition of Option Combination Fragment

v. **Changed Combination Fragments:** A change in a combination fragment is considered as a sequence diagram based change, the reason for change in a combination fragment can be either change in the guard condition if any or change in the methods in the fragment. Fig. 26 shows the change in guard condition of option combination fragment, earlier the guard condition is [count<4] and later it has changed to [count>0 and count<4], i.e. now the methods inside the fragment will be executed only if the value of count is greater than 0 and less than 4.

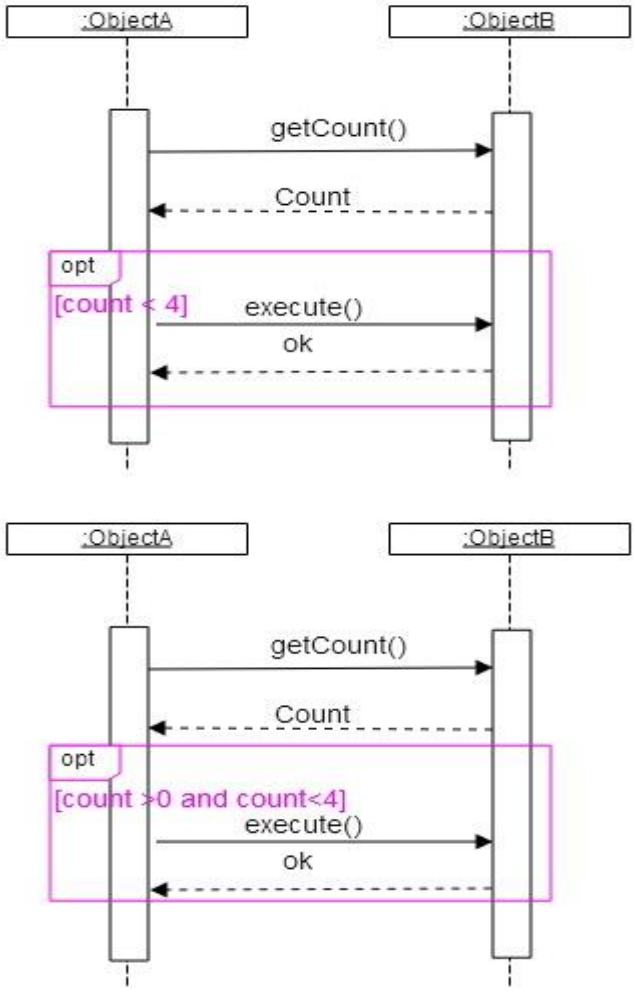


Fig. 26: Changed Option Combination Fragment

Step 3: Mapping the Sequence Diagram Based Changes with State Chart Based Changes

After the changes in the state chart diagrams of the system and the changes in the sequence diagrams of the system have been identified and analyzed, the two analyzed sets of changes are mapped with each other to determine the associated state chart based change corresponding to the sequence diagram based changes.

Consider an **example of the system: System A to** understand how the approach works**,** the fig. 27 which shows state chart diagram of original and modified systems for System A, showing that there is change in guard condition leading to change in transition t2.

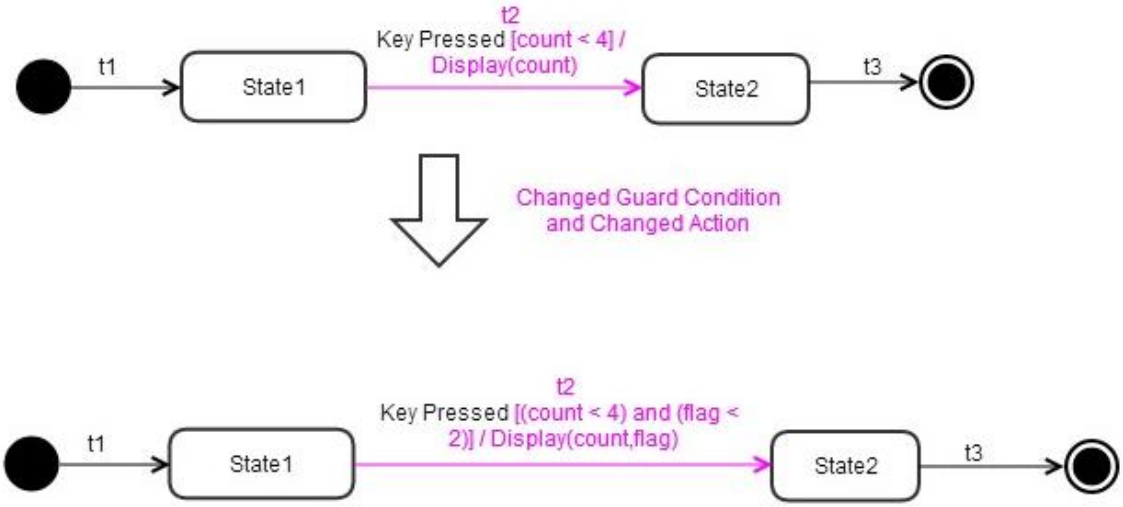


Fig. 27: Change in the State Chart Diagram for System A

Identified State Chart Diagram Based Change (SC.1)

- Changed Transition t2 – Value Entered/Display(count,flag)

Changed Transitions	t2 value entered/display(count,flag)

The fig. 28 on next page shows sequence diagram of the original and modified system for a scenario of System A, showing that there is change in display method earlier which was taking count as parameter, later it is having two parameters namely count and flag.

The method display has changed, from display(count) to display (count, flag) as shown below.

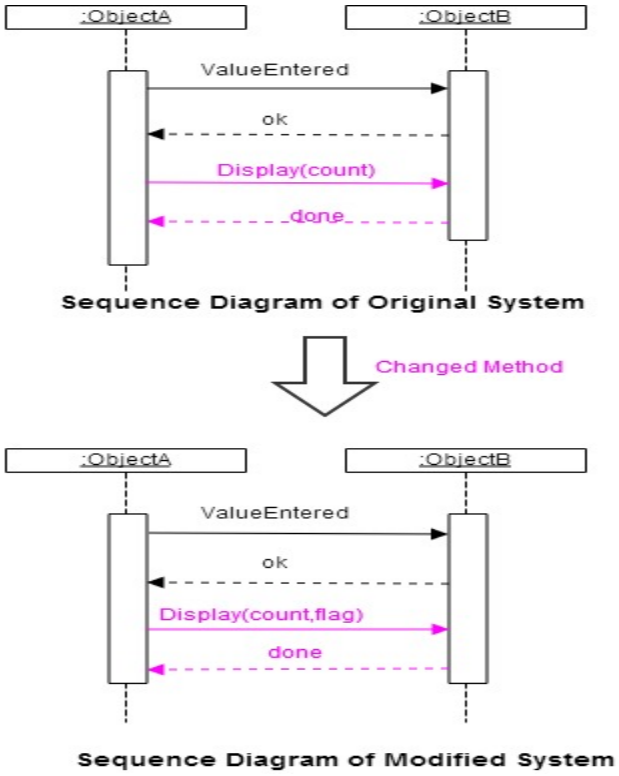


Fig. 28: Change in the Sequence Diagram for System A

Identified Sequence Diagram Based Change:

- Changed Method-Display(count,flag)

Changed Method	Display(count,flag)

Mapped Sequence Diagram Based Change with State Chart Based Change:

Now mapping the two identified changes, the sequence based change can be described in the terms of transition of state chart diagram as:

- **Sequence Diagram Based Change:** Changed Method- Display(count,flag)
- **Associated State Chart Based Changes (SC.2):** Changed Transition t2 – Value Entered/Display(count,flag)

Step 4: Determine Final Set of Changes

Now when the sequence diagram based changes are mapped with the state chart based changes to get a set of associated state chart based changes (SC.2) we will take union of (SC.2) and analyzed state chart based changes (SC.1) to determine final set of changes. Here we have got the following results after taking union as the final change:

TABLE II: Final Change Identified for System A

Deleted Transitions	None
Added Transitions	None
Changed Transitions	t2

4.2.2 Development of Regression Test Suite

The initial test suite being developed for the original system is used and from that the proposed approach selects a subset of test cases to test the change. Test cases exist in form of a table having fields namely the test case id, purpose of the test case i.e. which functionality of the system will the particular test case will test and the transitions with which the test case is associated. The Table II shows the structure of the test suite table having two randomly created test cases:

TABLE III: Test Suite* for System A

TestCaseId	Purpose	TransitionsAssociated
T1	To test display	t2
T2	To test some function	t1,t3

*The values entered in this table are randomly entered to just explain the approach.

Step1: Classification of Initial Test Suite

The initial test suite is classified into three categories three categories i.e. retestable test cases, obsolete test cases and reusable test cases [29] on the basis of final set of changes being determined:

i. **Obsolete test cases**: The test cases which are not required to be executed to test the changed system are obsolete test cases as these test cases are related with the obsolete components of the system i.e. the parts which no more exist in the new system. The test cases which contain at least one of the deleted

transitions in their associated transitions will be selected and are categorized as obsolete test cases.

ii. **Retestable test cases**: The test cases which are required to be executed again are retestable test cases, because these are related with changed components of the system. The test cases which contain at least one of the changed transitions in their associated transitions will be selected and are categorized as retestable test cases.

iii. **Reusable test cases**: The test cases which can be reused are reusable test cases as these test cases are related with the components of the system which have not been changed or modified. All the test cases in the initial test suite except obsolete test cases and retestable test cases are reusable test cases. As these test cases do not correspond to any change in the system, they are not required to be executed again but are still valid for the new system.

As the change identified listed in Table II, is of changed transitions only, hence the retestable test cases hence after classifying Test suite shown in Table III we get the results as retestable test case is T1 as test case T1 contains changed transition t2 and rest i.e. T2 is reusable test case, shown below:

Retestable Test Case:

TestCaseId: T1**, Purpose:** To test display

Reusable Test Case:

TestCaseId: T2**, Purpose:** To test some function

Step 2: Development of New Test Cases

As there may be a possibility that some component or some functionality is added in the system and the original test suite does not contain any test case to test that added functionality or added component, then the need arises to create new test cases, which will be included in regression test suite.

Here in the System A being considered, there are no added transitions in the final changes being identified therefore, there is no need to add new test case.

Step 3: Determination of Regression Test Suite

The test suite for regression testing must contain only those test cases which test the change in the system so as to perform an efficient regression testing i.e. use less time and resources and at the same time also reveals all the faults.

As obsolete test cases are the test cases which are related with those parts of the system that no more exist, therefore they are no more required and not valid anymore, hence they are **not included** in regression test suite.

As reusable test cases are the ones which are related with the components of the system which have not been modified, therefore they are not required to be executed again for regression testing as they do not relate to any change and hence they are **not included** in regression test suite.

As retestable test cases are related with changed components of the system therefore these are required to be executed for regression testing and hence they are **included** in regression test suite.

Recommended test cases are the new added test cases which are required to test the new features are **included** in the regression test suite.

Thus the regression test suite will contain union of retestable test cases and added test cases, but as the for System A being considered in previous steps, there is no added test case, hence the regression test suite will contain retestable test case as shown below:

TABLEIV: Regression Test Suite for System A

TestCaseId	Purpose
T1	To test display

Chapter 5

Implementation and Experimental Results

5.1 Overview

The case study of Automated Teller Machine (ATM) is being used to validate the proposed approach (RTSR). Before going into the details of the approach, let us have an overview of the system being considered so that we know the details about the functions it provides to the users, the components of the system, also some details regarding the working of system which are in our context. The user or customer is able to perform functions such as withdraw cash, deposit cash, make a balance inquiry, get a printed receipt of the transaction. The account can be of either savings type or of current type. User or customer is authenticated before it is allowed to make a transaction, by verifying the pin and is allowed to make only two attempts with wrong pin, if the user enters a wrong pin consecutively third time then the card is ejected out of the ATM and an error message of wrong pin or invalid pin is displayed. The system includes a user interface for interacting with the user, a slot for dispensing out cash, a keypad for allowing the user to give numerical inputs, a slot for accepting and ejecting out the card, a slot for depositing cash and a slot for ejecting out the printed receipt of the transaction. Some key terms related to the system are discussed as follows:

i. **Session:** When the user inserts the card a session starts and ends when the card is taken out of the ATM. All the actions a user performs are done in a session, which may involve user authentication or performing any kind of a transaction i.e. withdrawing of cash, making a balance inquiry and depositing some cash.

ii. **Transaction:** Any action which involves bank for its completion is known as a transaction of ATM. The system considered allows a user to make three kinds of transactions i.e. cash withdrawal, balance inquiry, depositing cash.

iii. **User Authentication:** User authentication involves verifying the pin which the user has entered, if the pin is verified then user can continue further to make a transaction but in case the user enters a wrong pin a second chance is given to the user to enter the pin again which is then verified but if for the third time consecutively a wrong pin is entered then the user is not allowed to continue further, the card is ejected out and an error message of invalid pin is displayed on the screen.

iv. **Balance Inquiry:** If the user selects balance inquiry option, the screen displays the balance in the account.

v. **Cash Withdrawal:** If user selects cash withdrawal option, the screen displays a message asking for the amount which the user wishes to withdraw. User has to enter the amount then a check is performed that the account contains balance greater than the amount being requested by the user. If the account contains balance less than the amount to be withdrawn then an error message of insufficient available balance is displayed on the screen and the user is asked to enter a valid amount again. If the account contains balance greater than the amount to be withdrawn then the account's balance is updated i.e. the withdrawn amount is deducted from the balance and the cash is dispensed out followed by a message on the screen requesting the user to take out the cash.

vi. **Deposit Cash:** If user selects deposit cash option, the screen displays a message asking for the amount which the user wishes to deposit. User enters the amount and a message requesting user to deposit the cash into the slot is displayed. The user enters the cash into the deposit slot and the account's balance is updated i.e. the deposited amount is added to the balance.

Flowchart of ATM: The Fig. 29 shows the flowchart of ATM describing the sequence of steps or the whole sequential process of ATM system:

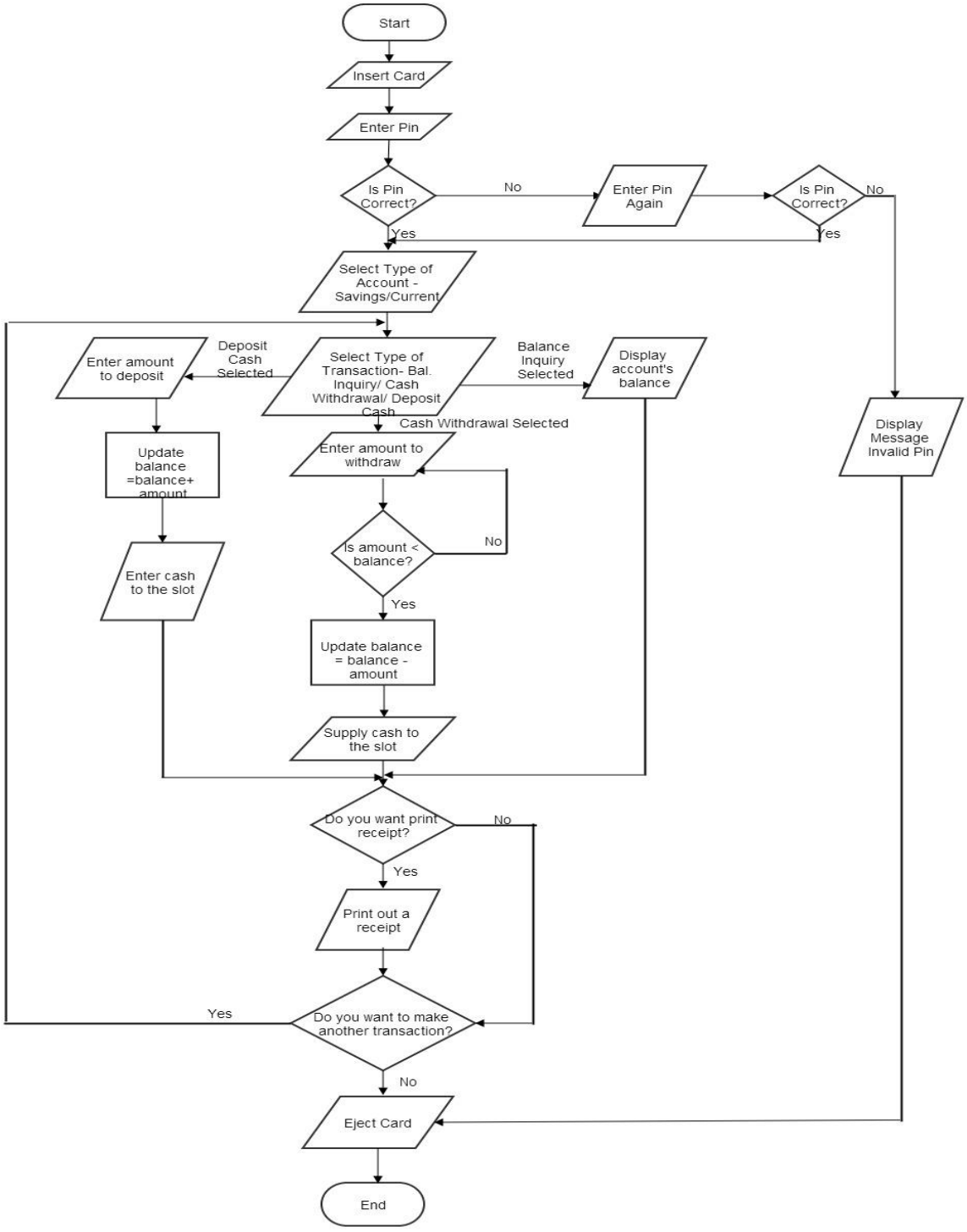


Fig. 29: Flowchart of ATM System

The step by step description of flowchart of ATM system is illustrated as follows:

i. The first step which the user has to perform is to insert the card into the slot where the card is to be inserted.

ii. Then a message is displayed on the screen requesting the user to enter pin followed by which the user enters the pin. The pin entered is then verified , if the pin entered is correct then user can continue further otherwise if wrong pin is entered then user is asked to enter pin again which is then checked but if the user enters wrong pin for the third time then an error message of invalid pin is displayed and the card is ejected.

iii. Once the pin is validated, then the user is asked to select the type of account i.e. savings account or current account.

iv. When the type of account is selected, then a selection of type of transaction is to be done i.e. cash withdrawal or deposit cash or balance enquiry.

v. If user selects balance enquiry option, then screen displays the balance in the account.

vi. If user selects cash withdrawal option, then the user is asked for the amount to be withdrawn followed by which user enters the amount then a condition is checked that the account's balance is greater than the amount being requested by the user. If the account contains balance less than the amount to be withdrawn then an error message of insufficient available balance is displayed on the screen and the user is asked to enter the amount again. If the account contains balance greater than the amount to be withdrawn then the account's balance is updated i.e. the withdrawn amount is deducted from the balance and the cash is supplied to the slot which dispenses out cash.

vii. If user selects deposit cash option, the screen displays a message asking for the amount which the user wishes to deposit. User enters the amount, the account's balance is updated i.e. the deposited amount is added to the balance and user is required to deposit the cash into the appropriate slot.

viii. After the transaction is done, user is asked about whether he needs a printed receipt of the transaction being done. If the user selects yes then the receipt is printed, if no then control moves to next step.

ix. Then the user is asked about whether he wants to do another transaction, if yes then the control goes to the step iv of asking about the type of transaction and all the steps are to be performed in the same sequence as described above, but if the user enters no then the card is ejected.

Changes in the Original System:

When a system is in its maintenance phase it has to go through a lot of changes according to the changing needs and requirements of the user .The changes required to meet the desired functioning of the system as explained before are described as follows:

i. **User authentication:** The user authentication requires that if a user enters a wrong pin instead of ejecting out the card at the first time, a check must be kept at the number of attempts a user has made so that if a user has made three wrong attempts then only the card must be ejected out and a message of invalid pin must be shown on the screen. While if the count of number of attempts has not reached to three the system must again ask the user to enter the pin and must verify it again so that user can continue to use the system.

ii. **Print Receipt:** The another change in the previous version of the system required is a new functionality of giving the user an option to get a printed receipt of the transaction made, so that details of the transaction can be known to the user. If the user selects yes, then the receipt is printed and ejected and the user is asked about whether he wishes to continue to make another transaction or not and finally the card is ejected. Also if a user wants to simply just perform the transaction and does not want a print receipt that option must also be available i.e. if the user selects no , then the user is asked about whether you want to continue to make another transaction or not and the card is ejected.

iii. **Cash Withdrawal:** The transaction of cash withdrawal needs to be changed as earlier it was not making changes in the balance of the account (savings account) leading to an incomplete and incorrect transaction.

4EThus after a transaction of withdrawing cash is done the amount of cash withdrawn must be deducted from the account's balance and written to the database of bank.

iv. **One Account of One User in the Bank:** Another change was that a user can have only one account in the bank, earlier the system provides the functionality to allow another transaction with another account therefore when user selects yes to continue another transaction system asks user to select type of account, but now when a user can have only one account in the bank when the user selects yes to continue another transaction then system asks user about type of transaction user want to do and not about the type of account.

5.2 Application of Proposed Approach: Regression Test Selection and Recommendation (RTSR)

In order to validate the approach, let us consider the ATM system being illustrated in the previous section. The following section explains how the proposed approach (RTSR) is used to test the changes being mentioned in the previous section. In order to use the approach we have to perform certain steps which are as follows:

Step 1: Change Identification and Analysis

The first step is to identify and analyze change, which will be used further to develop regression test suite and in order to do so the steps which are required to be performed are illustrated below.

Step 1.1: To Identify and Analyze State Chart Diagram Based Changes

The first step is to identify the changes in state chart diagrams of the original and modified system by comparing the two state chart diagrams and then analyzing the changes to determine set of state chart based changes of the system being considered.

Fig. 30 shows the state chart of the original ATM describing the various states of the machine, the transitions between those states and the events which triggers the transitions, the guard conditions which if evaluates to true then transition will get fired and the resulting action which will take place after a transition is fired.

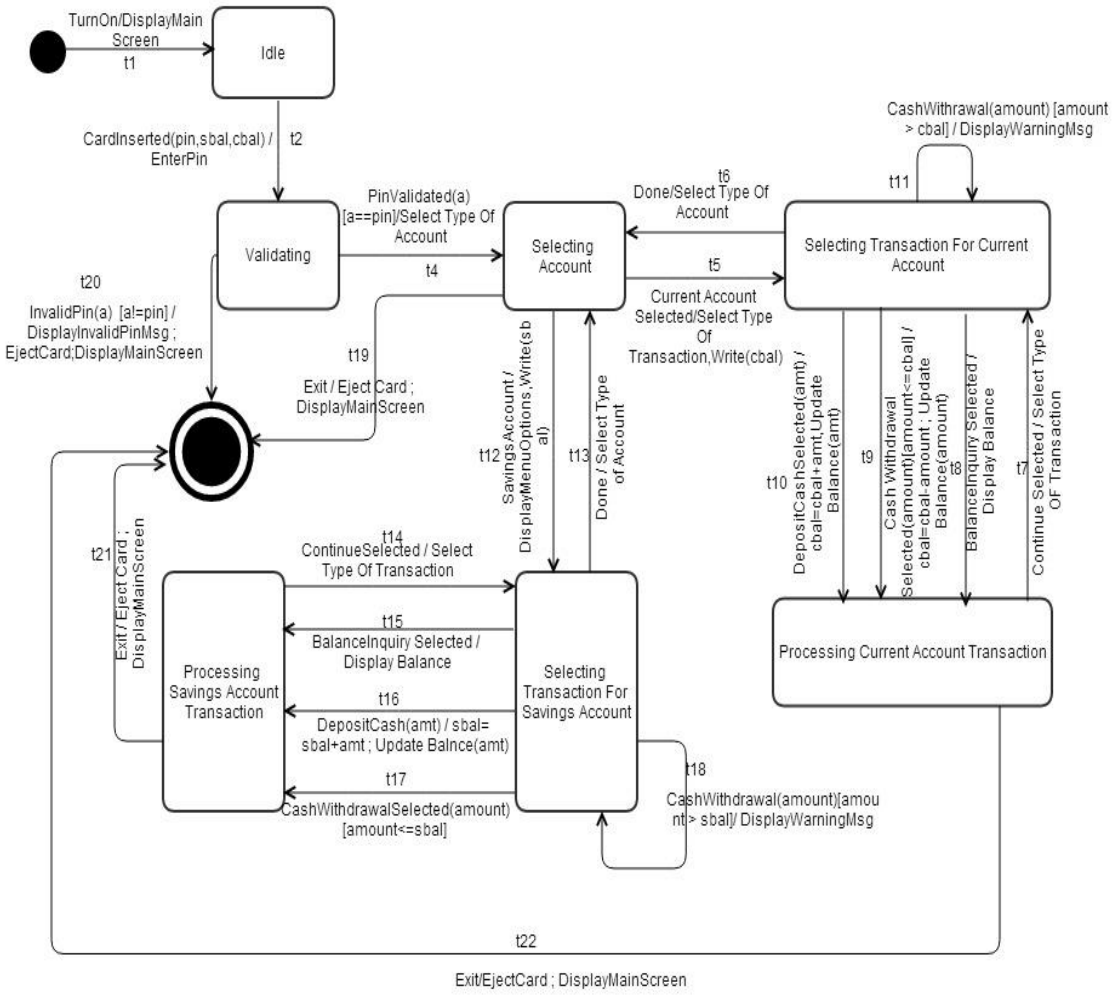


Fig. 30: State Chart Diagram of Original ATM

The details about how the machine changes from one to another state are illustrated as follows:

i. **Idle:** The machine when turned on is in idle state and displays main screen and waits for user to perform an action.

ii. **Validating:** When the card is inserted the machine the state is changed to validating, asking the user to enter pin.

iii. **Selecting Account**: After that if the pin is validated the state changes to selecting account, asking user to select type of account – savings or current. Also if user has done a transition then also machine switches to this state to allow a user to make another transaction with different account.

iv. **Selecting Transaction for Current Account**: When user selects current account, state changes to selecting transaction for current account and asks user to select type of transaction- cash withdrawal, cash deposit or balance inquiry and also allows user to continue another transaction with same account. Also if a user selects cash withdrawal a check is performed that balance in the account is greater than amount to be withdrawn, if not machine continues to be in the same state.

v. **Processing Current Account Transaction**: After the user has selected type of transaction, machine switches to this state and does the required processing for the type of transaction selected.

vi. **Selecting Transaction for Savings Account**: When user selects savings account, state changes to selecting transaction for savings account and asks user to select type of transaction- cash withdrawal, cash deposit or balance inquiry and also allows user to continue another transaction with same account. If a user selects cash withdrawal a check is performed that balance in the account is greater than amount to be withdrawn, if not machine continues to be in the same state.

vii. **Processing Savings Account Transaction**: After the user has selected type of transaction, machine switches to this state and does the required processing for the type of transaction selected. Here if the cash withdrawal is selected processing just involves checking the sufficiency of balance and not updating the balance in the account.

viii. **Final State**: The machines comes to final state either when transaction processing is finished and user wishes to exit resulting in ejecting card and displaying main screen or when wrong pin is entered followed by actions ejecting card , display invalid pin message and display main screen.

Fig. 31 shows the state chart diagram of the modified ATM describing the various states of the machine and the transitions between those states. To identify the changes, the two state chart diagrams Fig. 30 and Fig. 31 of original and modified system respectively are compared.

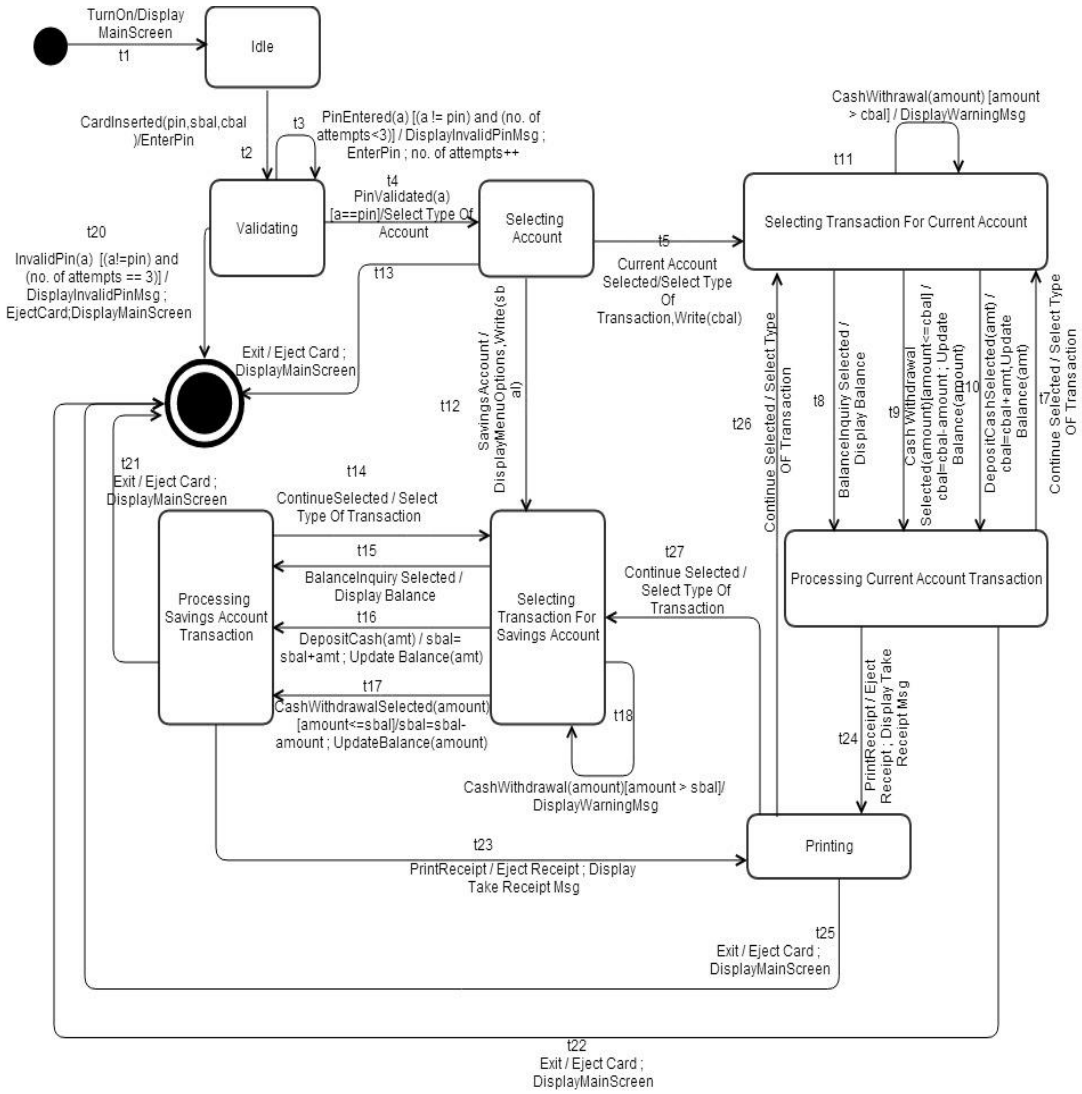


Fig. 31: State Chart Diagram of Modified ATM

.Identifying and Analyzing State Chart Based Changes

A change will be considered as a state chart based change if it falls under any of the category being mentioned in the section 4.1.

After comparing the two state chart diagrams of original and modified version as shown in Fig. 30 and Fig. 31 respectively, we have encountered the changes illustrated as follows:

i. **Deleted Transitions**: The transitions t6 and t13 have been deleted from the state chart diagram of the system. The transitions are deleted so as to meet the constraint that a user can have only one account in the bank. As a user can have one account in the bank, there cannot be functionality in the system which allows user to do a transaction from one account and then continue to do a transaction from another account. Hence there is no need of the transitions t6 and t13 and thus are removed from the state chart diagram.

ii. **Added State**: A new state named "Printing" is added, leading to addition of new transitions which are t23, t24, t25, t26, t27. This state is added so as to meet the functionality of providing a print receipt of the transaction as it will allow the user to know about the details of the transaction which he has committed. Due to addition of this state new transitions are also added, t23 to allow a user to get the print receipt of a transaction with savings account, t24 to allow a user to get the print receipt of a transaction with current account, t25 to eject the card after the receipt has been printed and the transaction is completed, t26 and t27 to allow a user to continue with another transaction for the same account being previously selected for the previous transaction.

   Therefore if we consider these added transitions as change, the change of addition of "Printing" state will be automatically considered, hence there is no need to consider it as a separate change.

iii. **Added Transitions**: The transitions which have been added to the state chart diagram of the system are t3, t23, t24, t25, t26, t27.

   The transition t3 is added to provide user authentication in a better way, by checking the number of attempts a user has made with the wrong pin. If the user has entered an incorrect pin, the system will display a message of invalid pin and will ask the user to enter the pin again and will verify it but even if for the third time user enters a wrong pin then card is ejected with a message of invalid pin.

If the number of attempts are less than three and the pin is verified the user is allowed to continue to make a transaction.

The transitions t23, t24, t25, t26, t27 are added with the addition of new state named Printing and the reasons for which have been explained above.

iv. **Changed Transitions:** The transitions which have been changed are t20 and t17.

In t20 the guard condition has changed earlier the condition will be true if the pin being entered by the user is not equal to the actual pin but later the condition will satisfy if two sub conditions will be true i.e. the pin entered by the user must be equal to the actual pin and also the number of attempts a user has made with the wrong pin must be equal to three. This transition is changed so as to provide the functionality that a user can make only two attempts with a wrong pin, if for the third time a user does so the card will be ejected and a message of invalid pin will be displayed.

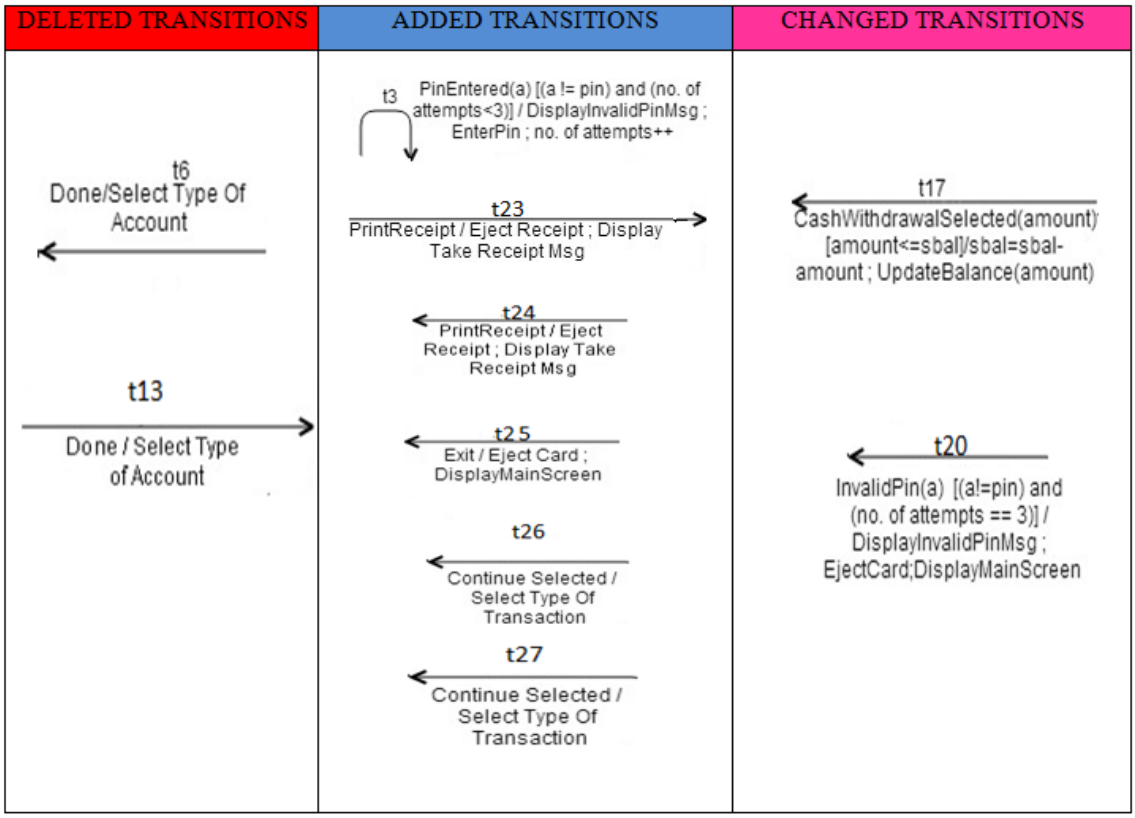
In t17 there is change in the action part of the transition. The transition corresponds to the cash withdrawal transaction from savings account, earlier the transition was not deducting the amount withdrawn from the balance of the account, but as a change this functionality is provided so as to complete the transaction.

Analyzed Set of State Chart Based Changes

After identifying and analyzing changes in the state chart diagrams of original and modified system so that all the changes are considered and also no change is considered unnecessarily for testing we will get the analyzed set of state chart based changes and it is named as (SC.1), which will be further used in the next steps of the approach for the development of the test suite for regression testing.

After identifying and analyzing we have encountered following as set of state chart based changes (SC.1) as shown in Table V.

TABLEV: STATE CHART BASED CHANGES (SC.1)



Step 1.2: To Identify and Analyze Sequence Diagram Based Changes

The next step is to identify the changes in sequence diagrams of the original and modified system by comparing the two sequence diagrams and then analyzing the changes to determine set of state chart based changes of the system being considered.

The sequence diagrams for some scenarios such as validate pin, invalid pin, making a cash withdrawal transaction from savings account are considered to describe the sequence in which messages are exchanged between the different objects of the ATM system for each scenario.

The Fig. 32 shows the sequence diagram for scenario validate pin of the original version of the system, which remains same for the modified version of the system as well. The sequence of message exchange is described as follows:

i. User sends card is inserted message to ATM, resulting in creating an object of Session type by ATM.

ii. Session sends enter pin message to User, after which User sends pin entered to Session. Then Session sends validate pin message to Bank. Bank after verifying sends valid pin return message to Session.

iii. Session then after receiving valid pin message forwards it to ATM.

iv. ATM upon receiving valid pin message forwards it to User to notify that the pin is validated, now the user can continue to use the system further.

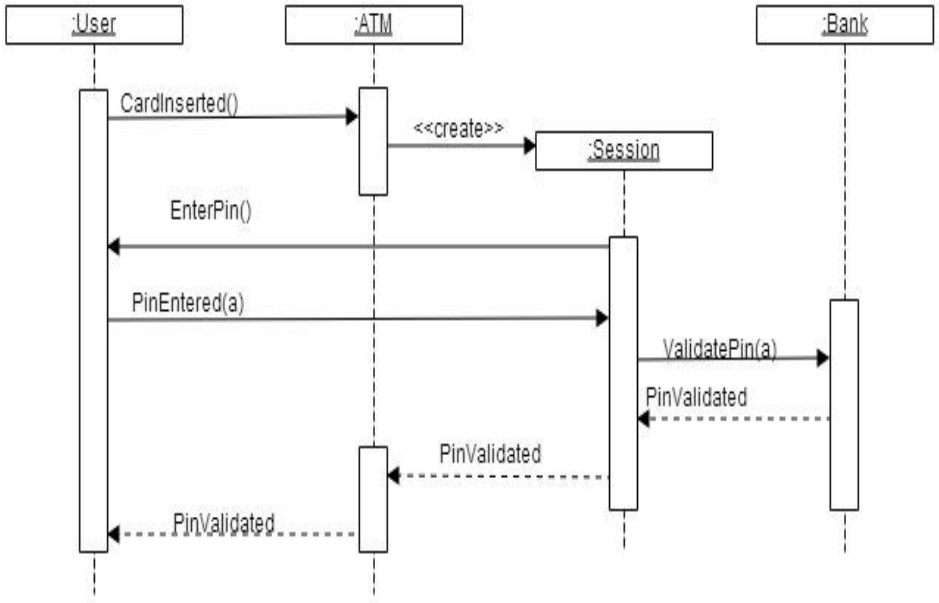


Fig. 32: Sequence Diagram of Valid Pin of ATM System

INVALID PIN SCENARIO

Fig. 33 shows the sequence diagram for scenario of invalid pin of the original version of the ATM system i.e. if the user enters a wrong pin then the sequence of messages exchanged between the involved objects are described as follows:

i. User sends card is inserted message to ATM, resulting in creating an object of Session type by ATM.

ii. Session sends enter pin message to User, after which User sends pin entered to Session. Then Session sends validate pin message to Bank. Bank after verifying sends invalid pin return message to Session to notify that the user is not authenticated.

iii. Session sends display invalid pin message to User to notify user that the pin entered is incorrect and sends eject card message to ATM, so that ATM can eject out card.

iv. ATM sends card ejected message and display main screen message to User.

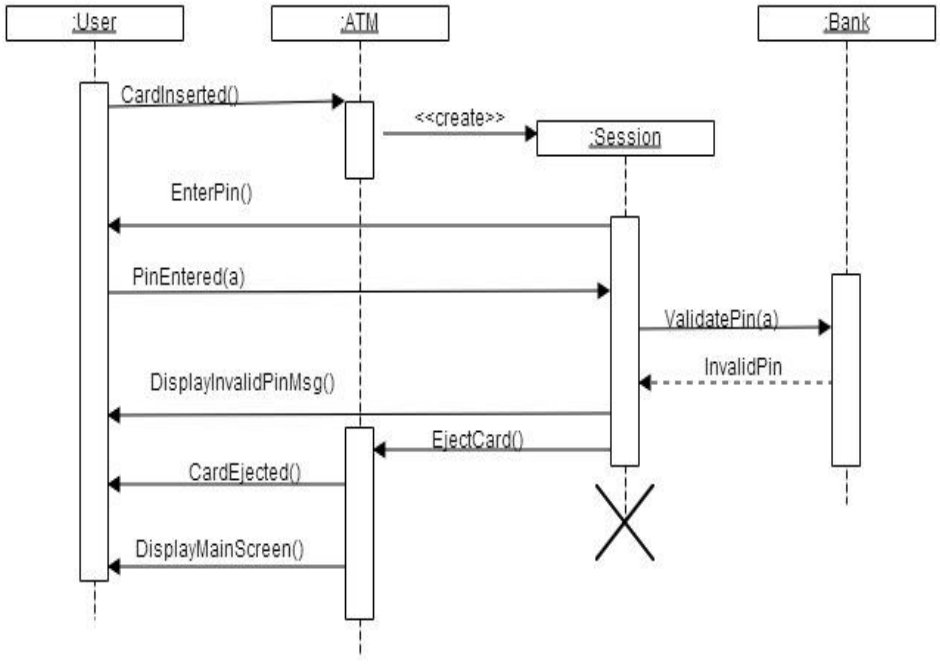


Fig. 33: Sequence Diagram of Invalid Pin of Original ATM System

Fig. 34 shows the sequence diagram of modified system for scenario of invalid pin. To identify the changes, the two sequence diagrams of original and modified system are compared. A change will be considered as a sequence diagram based change if it falls under any of the category being mentioned in the section 4.1.

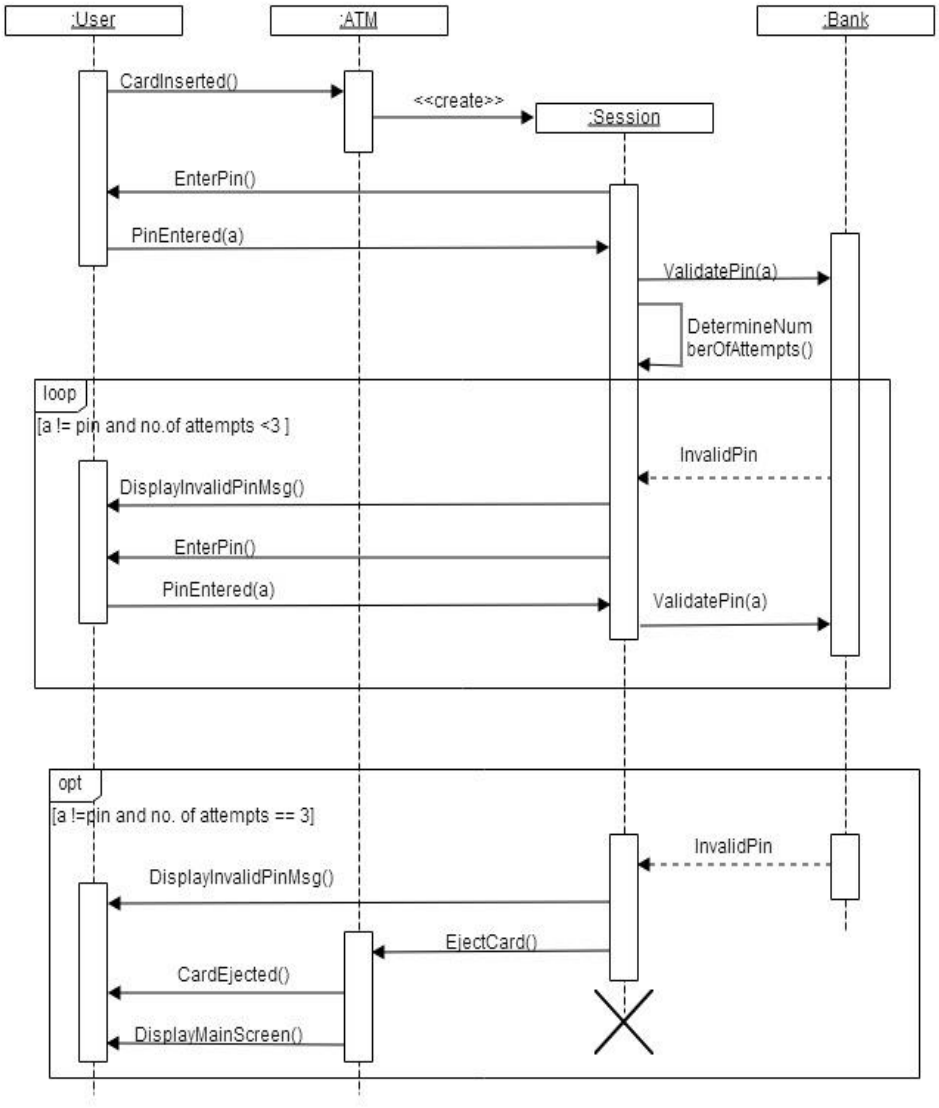


Fig. 34: Sequence Diagram of Invalid Pin of Modified ATM System

Identifying and Analyzing Sequence Diagram Based Changes for Invalid Pin Scenario

After comparing the two sequence diagrams for invalid pin scenario of original and modified version as shown in Fig.33 and Fig.34 respectively, we have identified and analyzed the changes as follows:

i. **Added Method:** A new method named "determine the number of attempts" is added in the sequence diagram of modified version of the system to keep a check on number of attempts a user has made. As the added combination fragments illustrated below, uses number of attempts in their guard condition hence if we are considering them as a change, there is no need to consider it a separate change.

ii. **Added Combination Fragments - (loop, option):** A loop combination fragment with a guard condition checking the number of attempts is less than three and (a != pin) condition i.e. the pin entered by the user is incorrect, is added and a option combination fragment with a guard condition checking the number of attempts are equal to three and invalid pin i.e. (a != pin) is also added. The changes have been done to provide functionality to the users that if user enters a wrong pin, the system must ask user to enter pin again but if this happens for the third time then the card must be ejected out and a message of invalid pin must be displayed.

CASH WITHDRAWAL from SAVINGS ACCOUNT SCENARIO

Now considering the scenario of making a transaction to withdraw cash from savings account, let us find out the changes which have occurred in the ATM system with respect to making cash withdrawal from savings account by comparing the sequence diagrams for this scenario of the original and modified system.

Fig. 35 shows the sequence diagram for scenario of making a transaction to withdraw cash from savings account for the original ATM system.

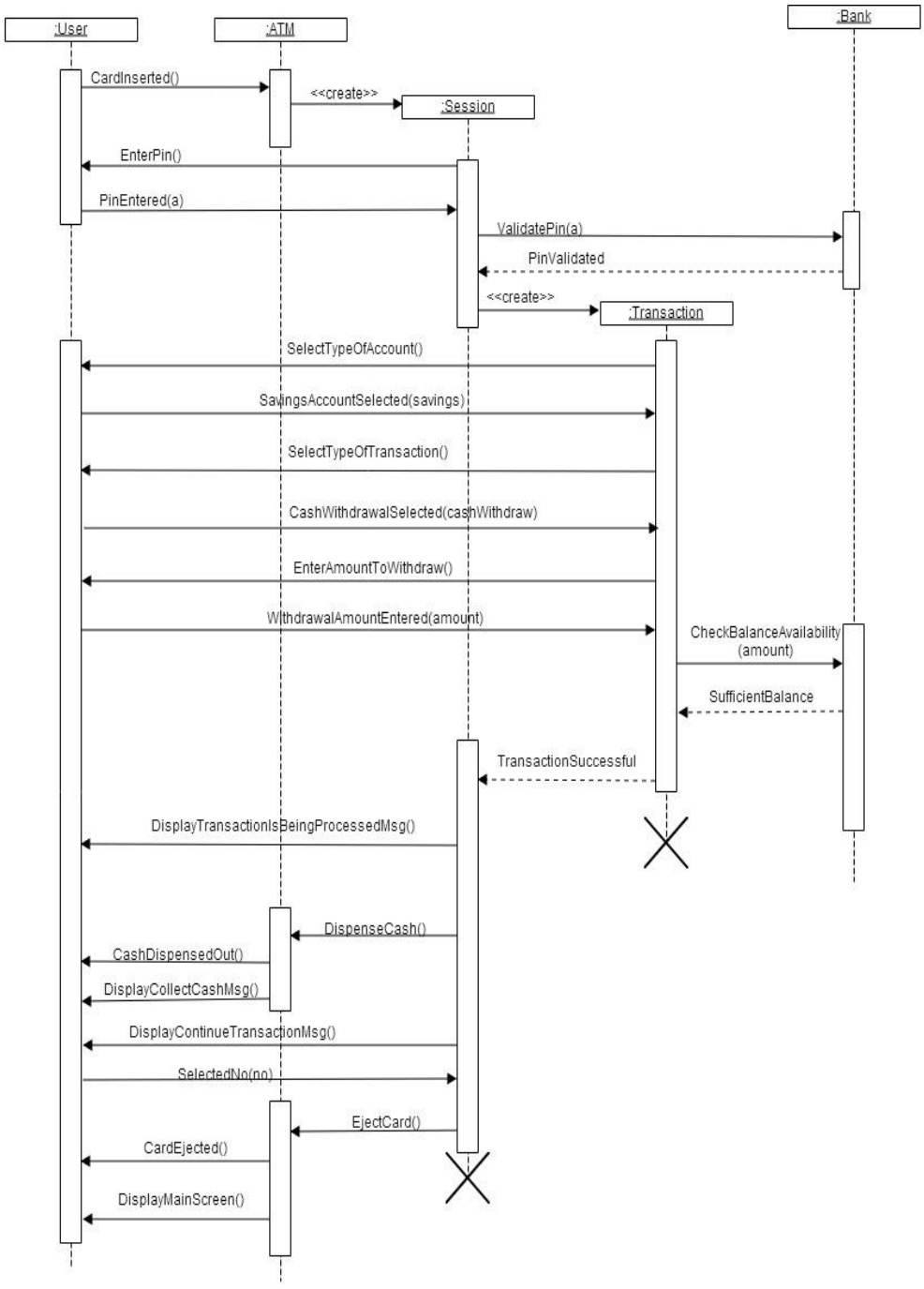


Fig. 35: Sequence Diagram of Cash Withdrawal from Savings of Original ATM System

The sequence of messages exchanged between the involved objects for making a cash withdrawal transaction from savings account as shown in Fig. 35 are described as follows:

i. Firstly user authentication is done by validating the pin and the sequence of messages used for validating pin is same as described earlier with the sequence diagram of validate pin.

ii. When the Session receives return message from Bank, it creates a new object of type Transaction. Then Transaction sends select type of account message to User, after which User sends savings account selected message to Transaction.

iii. Then Transaction sends message asking User to select type of transaction, after which User sends message to Transaction notifying that cash withdrawal is selected as type of transaction. Then Transaction asks User to enter the amount to be withdrawn after which User sends message to Transaction that amount is entered.

iv. Then Transaction sends message to Bank that check availability of balance, to which Bank sends return message notifying that there is sufficient balance. Upon receiving this message it sends transaction successful message to Session.

v. Session then sends a message to User to notify that the transaction is being processed and after then sends dispense cash message to ATM.

vi. ATM sends message to User that cash is dispensed out and requests user to take cash. After which Session asks User that whether it wishes to continue, then if User sends message no, Session sends message to ATM to eject card, and the Session type object is destroyed.

vii. Finally ATM sends User message that card is ejected and displays main screen.

Fig. 36 shows the sequence diagram for scenario of making a transaction to withdraw cash from savings account for the modified system.

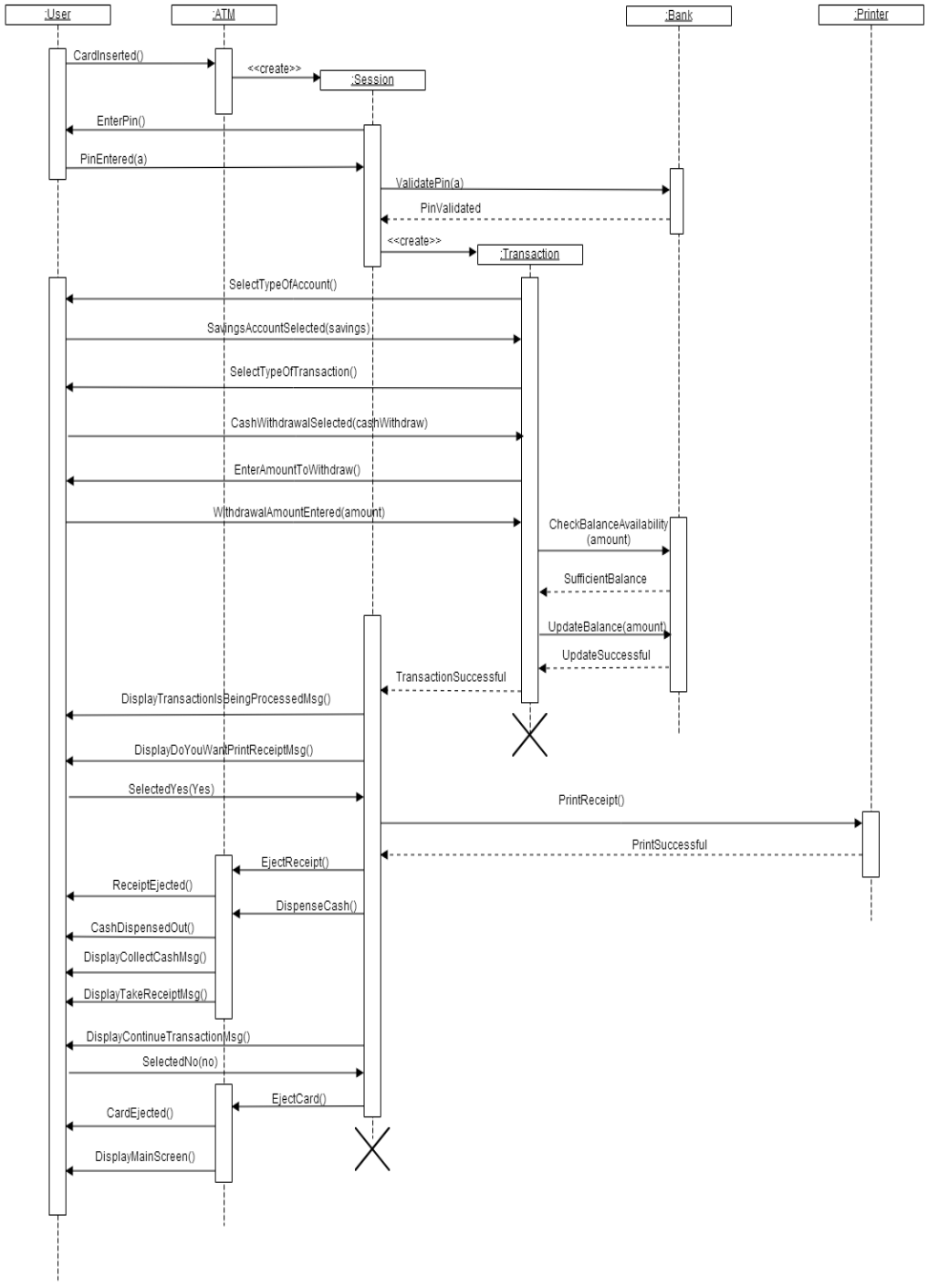


Fig. 36: Sequence Diagram of Cash Withdrawal from Savings of Modified ATM System

Identifying and Analyzing Sequence Diagram Based Changes for Cash Withdrawal from Savings Account Scenario

In order to identify the sequence diagram based changes we need to compare the two sequence diagrams for making a cash withdrawal transaction from savings account for original and modified version of the ATM system as shown in Fig.35 and Fig.36 respectively, and after comparing them we have encountered the following changes:

i. **Added Methods:** The method named UpdateBalance(amount) is added so that when the user withdraws cash, the balance of the account is updated i.e. the amount is deducted from the balance. Also a return message UpdateSuccessful is added but as it is a result of addition of update balance (amount) method, hence there is no need to consider it as a separate change.

   In order to allow a user to make a choice about he wants a print receipt or not for the transaction some methods are added such as a method named DisplayDoYouWantPrintReceiptMsg() is added to ask a user for the print receipt, a method named SelectedYes(yes) is added to allow a user to select yes if he needs a print receipt, then PrintReceipt() method is added to issue a request to printer, as a result of which a return message PrintSuccessful is added hence there is no need to consider it as a separate change ,EjectReceipt() is added to indicate the system to eject out the receipt, ReceiptEjected() to indicate the user entity that receipt has been ejected out and DisplayTakeReceiptMsg() to display a message requesting user to take out the receipt.

ii. **Added Object**: A new object is added of type "Printer" so as to allow the user to get a print receipt of the transaction done, which has lead to addition of methods related with the print functionality being considered in the added methods change. Therefore if we are considering above added methods as change, the change of addition of "Printer" type object will be automatically considered, hence there is no need to consider it as a separate change.

Analyzed Set of Sequence Diagram Based Changes for Cash Withdrawal from Savings Account Scenario and Invalid Pin Scenario

After identifying and analyzing changes in the sequence diagrams of the scenarios invalid pin and making a cash withdrawal transaction from of original and modified system we have encountered following as final set of sequence diagram based changes. Table VI shows the set sequence diagram based changes for ATM system.

TABLEVI: SEQUENCE DIAGRAM BASED CHANGES

ADDED METHODS	ADDED COMBINATION FRAGMENTS
UpdateBalance(amount) DisplayDoYouWant Print ReceiptMsg() SelectedYes(Yes) PrintReceipt() EjectReceipt() ReceiptEjected() DisplayTakeReceiptMsg()	loop [a != pin and no.of attempts <3] opt [a !=pin and no. of attempts == 3]

Step 1.3: Mapping the Analyzed Sequence Diagram Based Changes with State Chart Based Changes

After the changes in the state chart diagrams of the system and the changes in the sequence diagrams of the system have been identified and analyzed, the two analyzed sets of changes are mapped with each other to determine the associated state chart based change corresponding to the sequence diagram based changes.

i. **Mapping of Added Combination Fragments with State Chart Based Changes**: Two combination fragments are added, loop and option now considering these changes, we will find out the corresponding changes in the state chart diagram by checking that which transitions of the modified state chart diagram consists of same guard condition which exits in the added option or loop combination fragment. After determining that we found out that the corresponding transitions are **t3 and t20.**

   a. Transition t3 contains guard condition i.e. ((a! = pin) and (no. of attempts < 3)) i.e. the pin which user entered doesn't match the actual pin and number of attempts user has made are less than three, which is same as of guard condition of loop combination fragment also i.e. ((a! = pin) and (no. of attempts < 3)), therefore the change in sequence diagram of loop combination fragment corresponds to transition t3 of changed state chart diagram.

   b. Transition t20 modified, has guard condition ((a! = pin) and (no. of attempts = =3)) which is same as that of the guard condition of option combination fragment in the changed sequence diagram i.e. ((a! = pin) and (no. of attempts = =3)), therefore the change in sequence diagram of option combination fragment corresponds to transition t20 of the changed state chart diagram.

ii. **Mapping Added Methods Change with State Chart Based Changes:** Now considering the change of all added methods, we will find out the corresponding changes in the state chart diagram by checking that which transitions of the modified state chart diagram consists of these methods. After checking that we found out that the corresponding transitions are **t17, t23 and t24.**

   a. UpdateBalance(amount) methods corresponds to transition t17 as the action part of transition t17 consists of this method.

   b. Other added methods related with the print functionality such as PrintReceipt( ), EjectReceipt( ) and other listed in the analyzed set of sequence based changed corresponds to transitions t23 and t24 which also

provide a print receipt functionality, as their event and action part consists of these added methods.

Mapped Sequence Diagram Based Changes with State Chart Based Changes

The Table VII shows the analyzed sequence diagram based changes and associated state chart based changes.

TABLEVII: MAPPED SEQUENCE DIAGRAM BASED CHANGES WITH STATE CHART BASED CHANGES

Sequence Diagram Based Change	Associated State Chart Based Changes (SC.2)
Added Combination Fragments (loop, option)	Added Transition t3, Changed Transition t20
Added Methods Change	Added Transitions t23,t24

Step 1.4: Determine Final Set of Changes

Now when the sequence diagram based changes are mapped with the state chart based changes to get a set of associated state chart based changes (SC.2) we will take union of SC2 and analyzed state chart based changes (SC.1) to determine final set of changes. After taking the union of the two sets of changes SC.1 and SC.2 we get the final changes as shown in Table VIII.

TABLEVIII: FINAL SET OF CHANGES FOR ATM SYSTEM

Deleted Transitions	**t6 and t13**
Added Transitions	**t3, t23, t24, t25, t26 and t27**
Changed Transitions	**t20 and t17**

Step 2: Regression Test Suite Development

Now when we have identified the final set of changes, next step is development of regression test suite to test the changes being identified. We have the original test suite (Test Suite 1) to test the features of the original ATM system. The Test Suite has three fields i.e. test case Id - a unique ID for each test case. Purpose which states the functionality of test case i.e. which feature of the system is tested by the particular test case and transitions associated which describes the involved transitions of the original state chart diagram of the ATM in executing the particular test case. Table IX shows the TestSuite1 as follows:

TABLE IX: ORIGINAL TEST SUITE 1 FOR ATM SYSTEM

Test Case Id	Purpose	Transitions Associated
T1	To test failed user authentication	t1 t2 t20
T2	To test an immediate exit after authentication	t1 t2 t4 t19
T3	To test cash withdrawal from current account	t1 t2 t4 t5 t9
T4	To test cash deposit in current account	t1 t2 t4 t5 t10
T5	To test balance inquiry from current account	t1 t2 t4 t5 t8
T6	To test cash withdrawal from savings account	t1 t2 t4 t12 t17
T7	To test cash deposit in savings account	t1 t2 t4 t12 t16
T8	To test balance enquiry from savings account	t1 t2 t4 t12 t15
T9	To test continue another transaction from same account after cash withdrawal from savings	t1 t2 t4 t12 t17 t14
T10	To test continue another transaction from same account after cash deposit from savings	t1 t2 t4 t12 t16 t14
T11	To test continue another transaction from same account after bal. inquiry from savings	t1 t2 t4 t12 t15 t14
T12	To test continue another transaction from same account after cash withdrawal from current	t1 t2 t4 t5 t9 t7
T13	To test continue another transaction after cash deposit from current	t1 t2 t4 t5 t10 t7

T14	To test continue another transaction from same account after bal. inquiry from current	t1 t2 t4 t5 t8 t7
T15	To test a successful authentication	t1 t2 t4
T16	To test cash withdrawal with savings account then continue with different account	t1 t2 t4 t12 t17 t14 t13
T17	To test cash deposit with savings account then continue with different account	t1 t2 t4 t12 t16 t14 t13
T18	To test balance inquiry with savings account then continue with different account	t1 t2 t4 t12 t15 t14 t13
T19	To test cash withdrawal from current account then continue with different account	t1 t2 t4 t5 t9 t7 t6
T20	To test cash deposit with current account then continue with different account	t1 t2 t4 t5 t10 t7 t6
T21	To test balance inquiry with current account then continue with different account	t1 t2 t4 t5 t8 t7 t6

In order to validate the approach Regression Test Selection and Recommendation (RTSR) , an application is designed which provides the following features :

i. Classification of the original test suite (Test Suite 1) as illustrated above, by determining the obsolete test cases, retestable test cases and reusable test cases.

ii. Recommendation of new test cases by allowing user to add a new test case, when the original test suite does not contain test case to test a newly added feature of the system.

iii. To determine the regression test suite consisting of retestable test cases and newly added test cases (if any).

The Fig. 37 shows the home page of the application designed for validating the approach Regression Test Selection and Recommendation (RTSR), providing options to determine the obsolete test cases, retestable test cases, reusable test cases, add a new test case and determine the regression test suite.

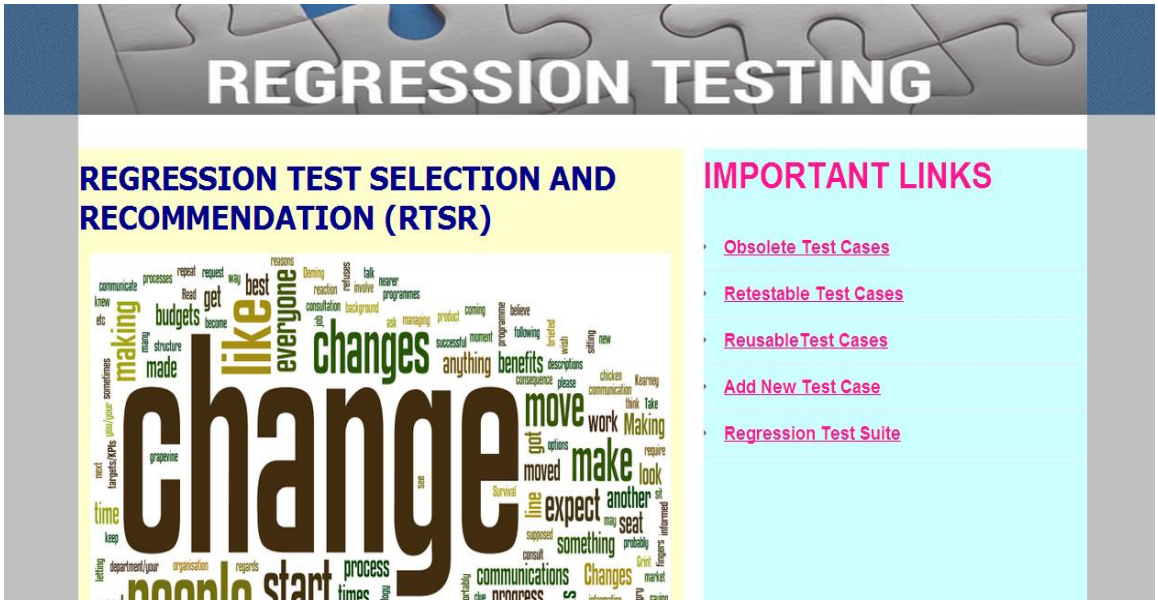


Fig. 37: Home Page

Step2.1: Classification of Original Test Suite

Now when we have identified the final set of changes, we will classify the original test suite into three categories i.e. retestable test cases, obsolete test cases and reusable test cases [29] by using the change information found out in step 1.

Step 2.1.1: To Determine Obsolete Test Cases.

The test cases which are not required to be executed to test the changed system are obsolete test cases, the test cases which contain at least one of the deleted transitions in their associated transitions will be selected and are categorized as obsolete test cases.

In order to determine obsolete test cases, deleted transitions – t6, t13 being determined in step 1 in the final set of changes listed in Table VIII have to be entered . Fig. 38 shows the page for entering deleted transitions and once submit button is clicked, page will be redirected to the page displaying obsolete test cases.

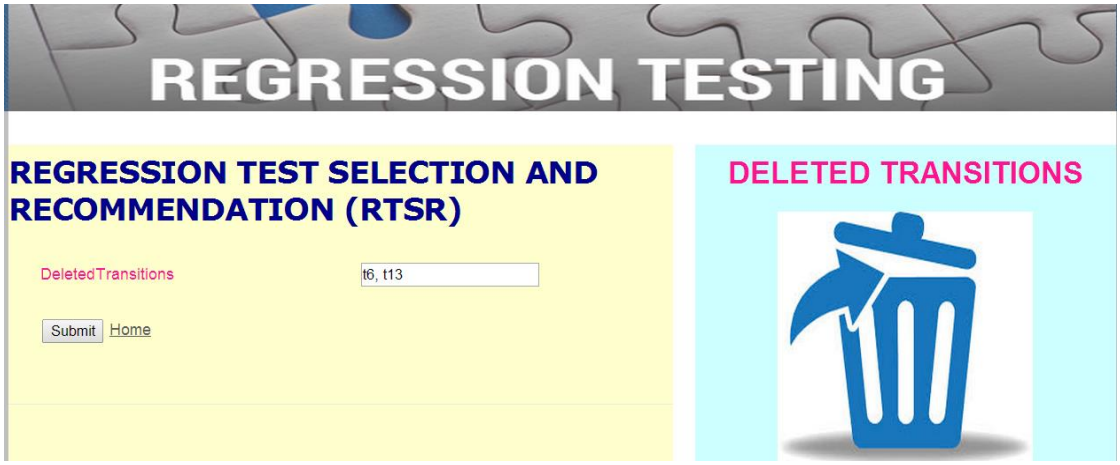
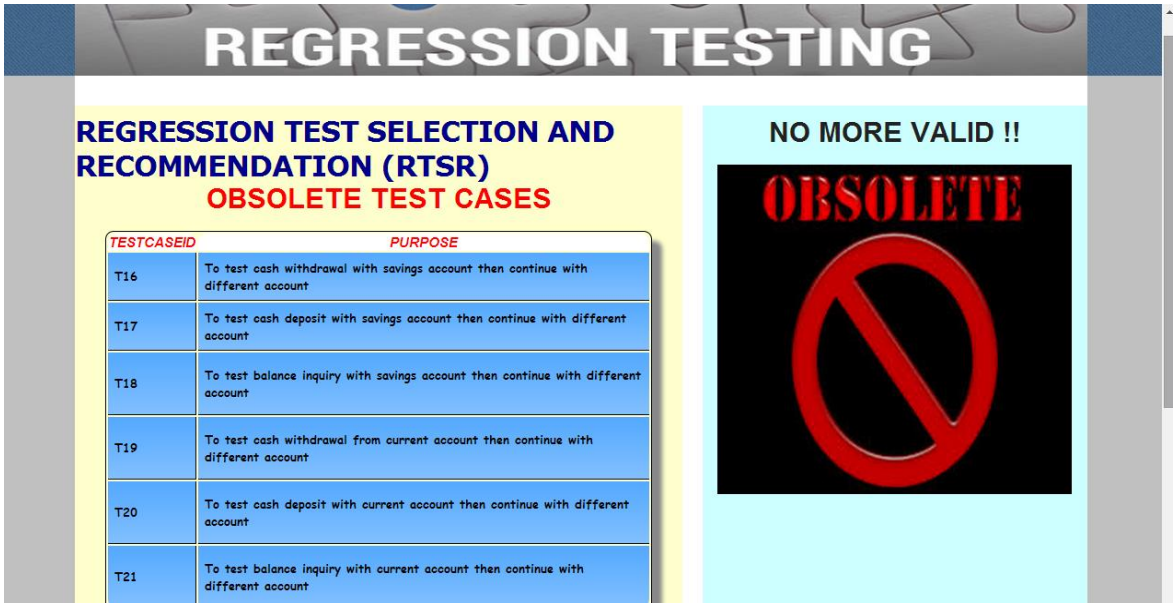


Fig. 38: Deleted Transitions

Fig. 39 shows the page displaying the obsolete test cases, these test cases are no more valid for the modified system as they correspond to those parts of the system which no more exists and therfore will not form the part of regression test suite.



TESTCASEID	PURPOSE
T16	To test cash withdrawal with savings account then continue with different account
T17	To test cash deposit with savings account then continue with different account
T18	To test balance inquiry with savings account then continue with different account
T19	To test cash withdrawal from current account then continue with different account
T20	To test cash deposit with current account then continue with different account
T21	To test balance inquiry with current account then continue with different account

Fig. 39: Obsolete Test Cases

Step 2.1.2: To Determine Retestable Test Cases.

In order to determine retestable test cases, we have to enter the changed transitions t20, t17 being listed in Table VIII in final set of changes determined in step 1. Fig. 40 shows the page for entering the changed transitions, where after entering the changed transitions if we click submit it will redirect us to page displaying retestable test cases.

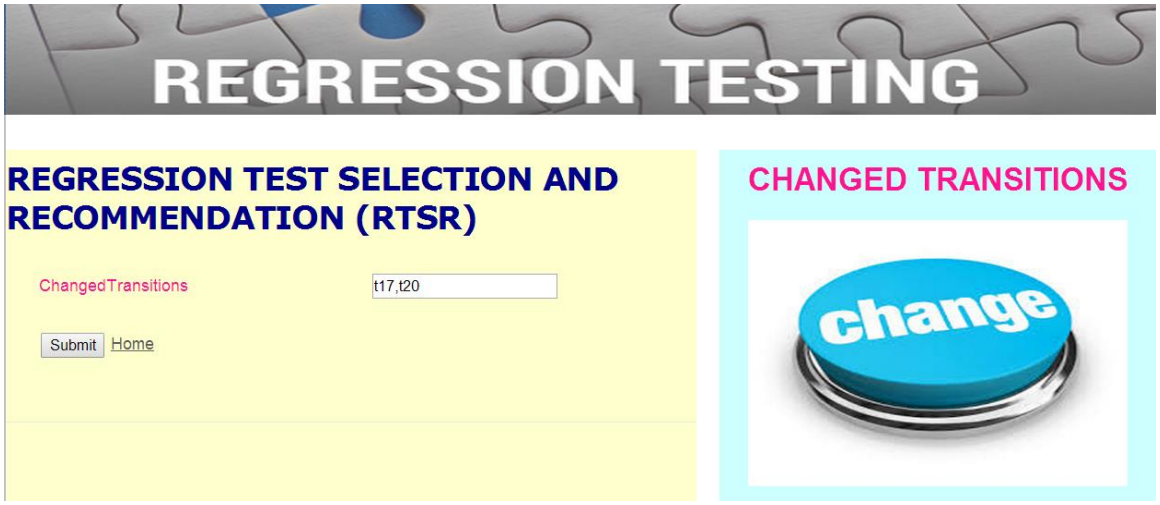


Fig. 40: Changed Transitions

Fig. 41 shows the page displaying the retestable test cases, the test cases which contain at least one of the changed transitions in their associated transitions will be selected and are categorized as retestable test cases.

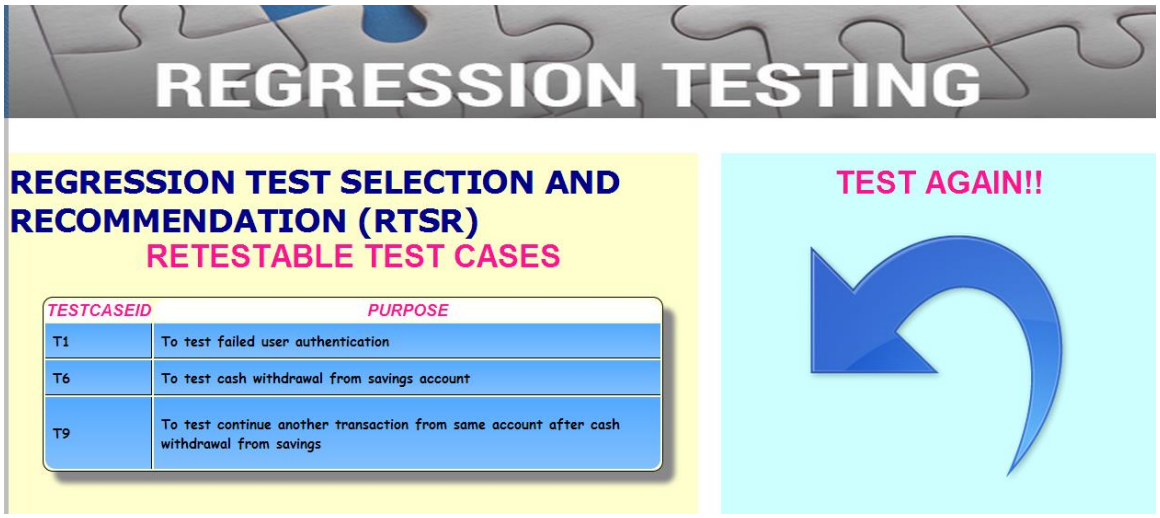


Fig. 41: Retestable Test Cases

Step 2.1.3: To Determine Reusable Test Cases

Fig. 42 shows the page displaying the reusable test cases. The test cases which can be reused are reusable test cases as these test cases are related with the components of the system which have not been changed or modified. All the test cases in the initial test suite except obsolete test cases and retestable test cases are reusable test cases. As these test cases do not correspond to any change in the system, they are not required to be executed again hence are not included in regression test suite but are still valid for the new system.

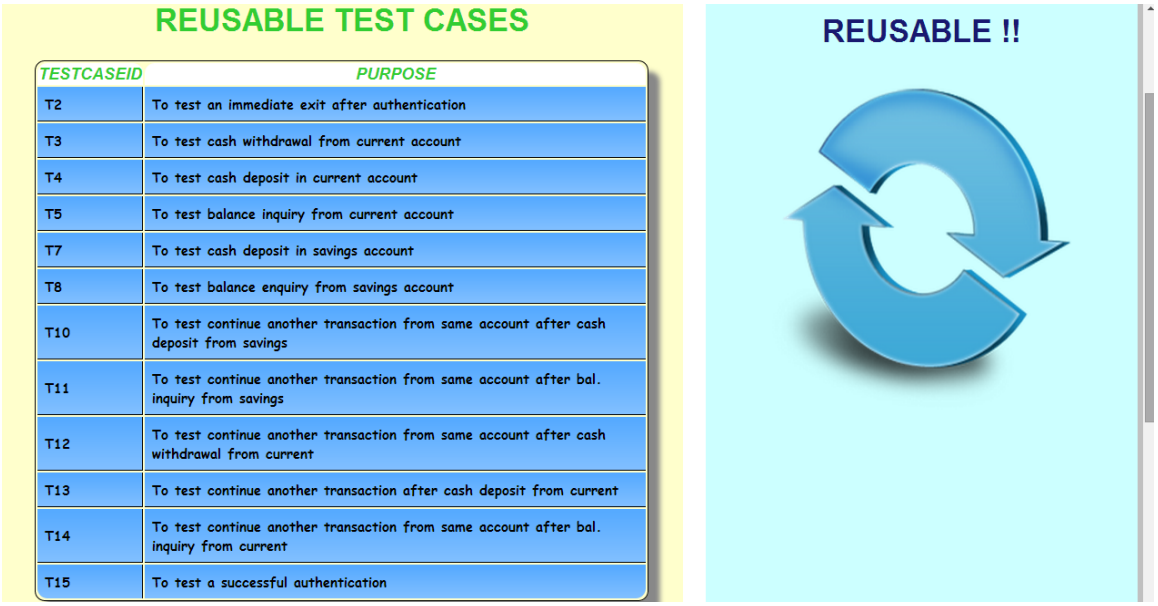


Fig. 42: Reusable Test Cases

Step 2.2: Addition of new test cases (if required)

As there may be a possibility that some component or some functionality is added in the system and the original test suite (Test Suite 1) does not contain any test case to test that added functionality or added component, then the need arises to create new test cases, which will be included in regression test suite. Considering the changes in the ATM system, the transitions which correspond to added functionality or added component **i.e. added transitions** are **t3, t23, t24, t25, t26 and t27** as listed in TABLEVIII. To test these changes, we will create new test cases which will be added into regression test suite. The new test cases are illustrated as follows:

i. **Transition t3:** Corresponding to transition t3, a new test case is added , the purpose of which is to test the feature that if user enters invalid pin and the number of attempts made with wrong pin are less than three, then user is asked to enter pin again and if verified the user is allowed to continue further to use system.

TestCaseID	Purpose	TransitionsAssociated
T22	To enter invalid pin less than three times	t1, t2,t3,t3,t4.

ii. **Transitions t23, t25**: Corresponding to transitions t23, t25 a new test case added the purpose of which is to test the feature of getting a print receipt for a transaction with savings account.

TestCaseID	Purpose	TransitionsAssociated
T23	To test getting a print receipt for a balance enquiry transaction with savings account.	t1, t2, t4, t12, t15, t23, t25

iii. **Transitions t24, t25:** Corresponding to transitions t24, t25 a new test case added the purpose of which is to test the feature of getting a print receipt for a transaction with current account.

TestCaseID	Purpose	TransitionsAssociated
T24	To test getting a print receipt for a balance enquiry transaction with current account	t1, t2, t4, t5, t8, t24, t25

iv. **Transition t26** : Corresponding to transition t26 a new test case added the purpose of which is to test the feature of getting a print receipt for a transaction with current account and continue to make another transaction from same account.

TestCaseID	Purpose	TransitionsAssociated
T25	To test getting a print receipt for a balance enquiry transaction followed by cash withdrawal with same current account	t1, t2, t4, t5, t8, t24, t26,t9,t22

v. **Transition t27** :Corresponding to transition t27 a new test case added the purpose of which is to test the feature of getting a print receipt for a transaction with savings account and continue to make another transaction from same account.

TestCaseID	Purpose	TransitionsAssociated
T26	To test getting a print receipt for a balance enquiry transaction followed by cash deposit with same savings account	t1, t2, t4, t12, t15, t23, t27,t16,t21

Fig. 43 shows the page to add a test case, with Test Case ID T23 and purpose to test getting a print receipt for a balance enquiry transaction with savings account.

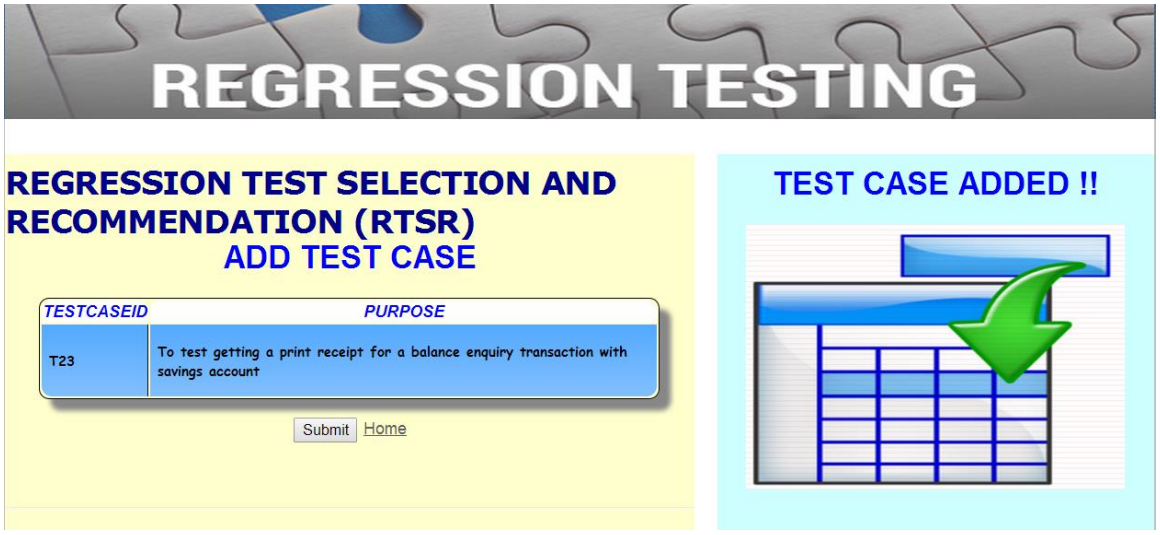


Fig. 43: Add Test Case

Step 2.3 Determination of Regression Test Suite

Fig. 44 shows the page displaying the final reduced regression test suite as compared to original test suite The test suite for regression testing must contain only those test cases which test the change in the system so as to perform an efficient regression testing i.e. use less time and resources and at the same time also reveals all the faults. The regression test suite will consist of retestable test cases and newly added test cases.

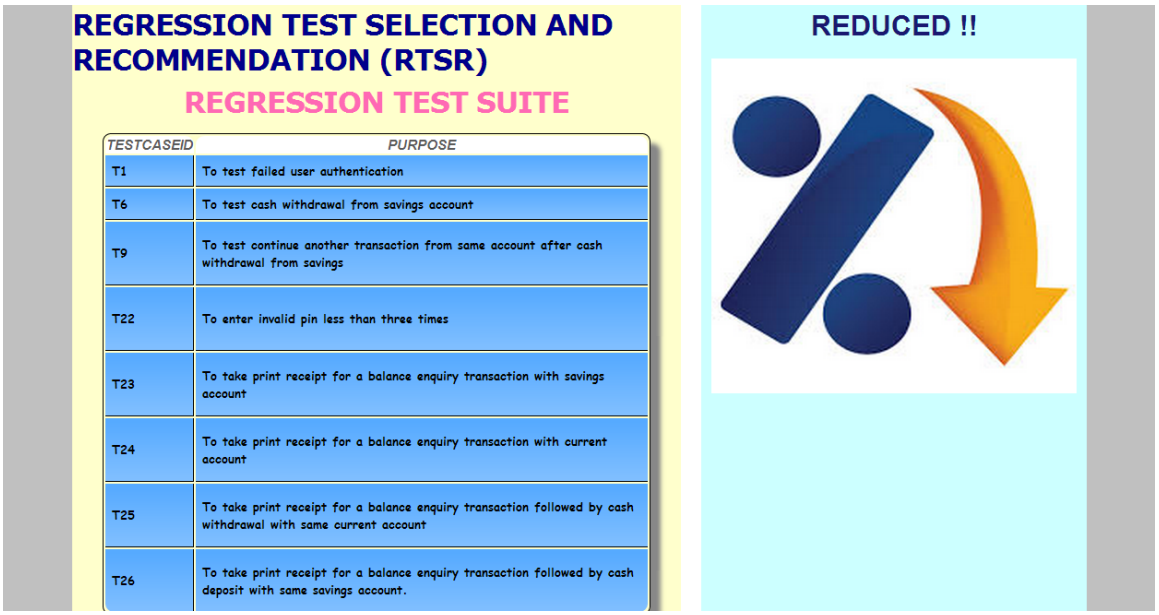


Fig. 44: Regression Test Suite

5.3 RESULTS

After applying the proposed approach- RTSR using the case study of Automated Teller Machine, we have got the following results:

i. Classification of Original Test Suite

The approach RTSR has classified the original test suite into three categories, Table X shows the no. of test cases in each category.

TABLE X: CLASSIFICATION OF ORIGINAL TEST SUITE

OBSOLETE TEST CASES	RETESTABLE TEST CASES	REUSABLE TEST CASES
6	3	12

Fig. 45 shows the pie chart for classification of original test suite showing the percentages of each category of test cases, obsolete test cases forms 29 % of the original test suite, retestable test cases forms 14% of the original test suite and reusable test cases forms 57 % of the original test suite, therefore it can inferred that a large part of original test suite is reusable and only 14 percent of the test cases are required to be tested again, which will result in reducing the time and cost of testing.

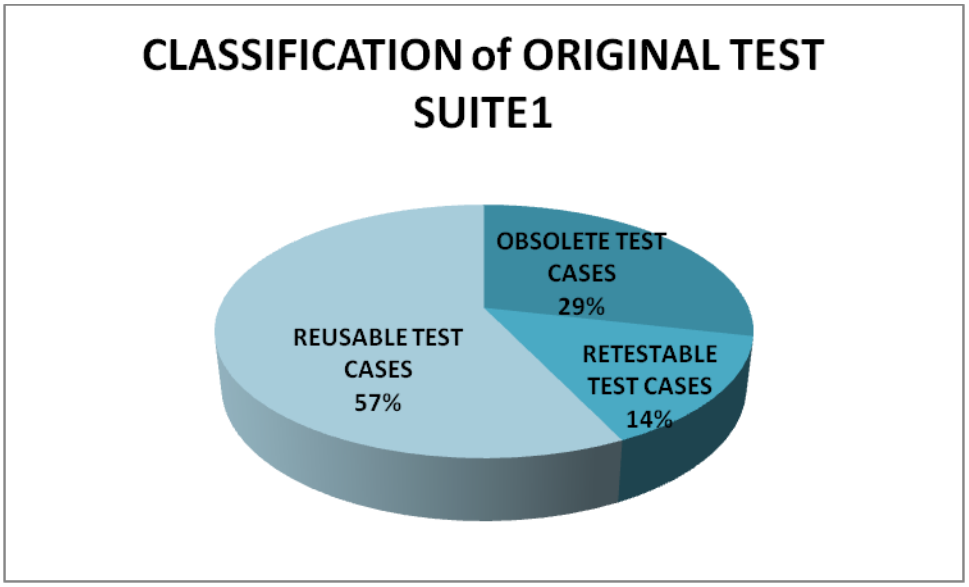


Fig. 45: Classification of Original Test Suite

ii. Recommendation of New Test Cases

The approach RTSR has recommended five new test cases to test the new features being added to the ATM system. The test cases being recommended are illustrated in the previous section.

iii. Reduction in Regression Test Suite

The approach RTSR has resulted in producing a regression test suite consisting of eight test cases, therefore the percentage reduction in regression test suite is 61.9%, which can be calculated using formula:

% Reduction = (No. of test cases in Original Test Suite - No. of test cases in Regression Test Suite)*100/ No. of test cases in Original Test Suite

% Reduction = (21-8)*100/21

% Reduction = 61.9 %

Fig. 46 shows the bar graph describing the number of test cases in original test suite and regression test suite being produced by using RTSR approach, also shows the percentage reduction in the regression test suite.

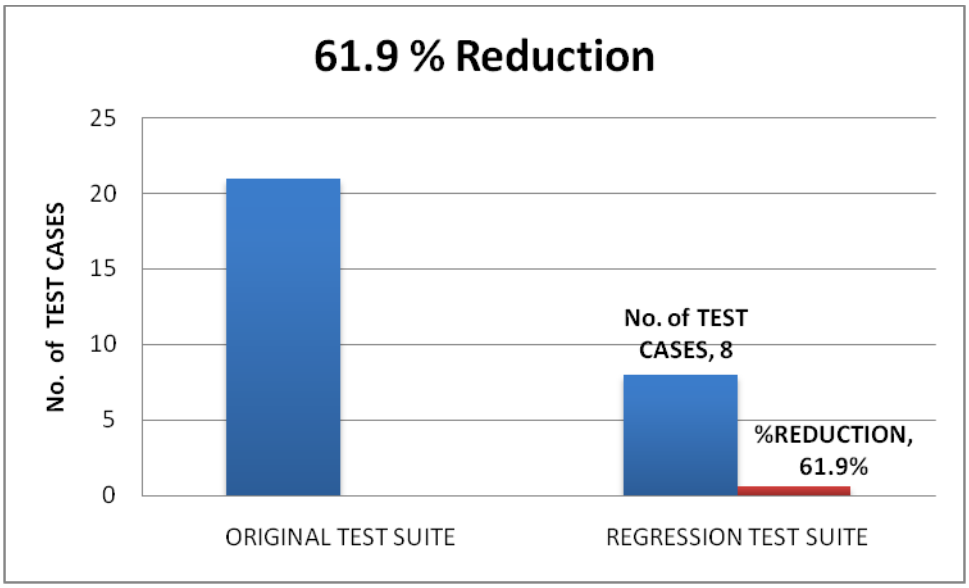


Fig. 46: Percentage Reduction

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

The objectives set in chapter 3 have been fulfilled successfully. The approach proposed RTSR is successfully validated and does appropriate selection and recommendation of test cases. The experimental results indicate that RTSR selects lower number of test cases than original test suite and a percentage reduction of 61.9 % is achieved in the regression test suite and also all the changes are tested successfully proving that the approach is efficient. The approach assumes strong correspondence between state chart and sequence diagrams, hence will be more efficient if there is strong correspondence between state chart and sequence diagrams of the system being considered.

6.2 Contribution

A new approach RTSR based on UML to perform regression testing of component based software using UML is proposed. The approach uses UML state chart diagrams and sequence diagrams to identify the changes in the system. The change information collected is used to select the test cases for regression testing from the initial test suite and recommend new test cases if required to form regression test suite. An application is designed to validate the approach using the case study of automated teller machine and has successfully resulted in a regression test suite for the system being considered, having less number of test cases as compared to original test suite. After the results are analyzed it can be inferred that a percentage reduction of 61.9 % is attained.

6.3 Future Scope

The future work aims to develop a fully automated tool which can identify the changes by comparing the state chart and sequence diagrams of the original and modified system and produce a reduced and effective regression test suite.

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international conference on Automated software engineering, ASE '07, pages 567–570. ACM, November 2007.

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List of Publications

i. Janhavi Puniani and Ashima Singh, "Survey on Regression Testing of Component-Based Software," *in Proceedings of IEEE Sixth International Conference on Computational Intelligence, Communication Systems and Networks,* 2014.

[accepted]

ii. Janhavi Puniani and Ashima Singh, " Regression Test Selection Approach for Component Based Software using UML State Chart and Sequence Diagrams," *in Proceedings of IEEE Seventh International Conference on Contemporary Computing(IC3),*2014.

[communicated]

iii. Janhavi Puniani and Ashima Singh, "Development of Component Repository," in *International Journal of Advanced Research in Computer Science and Software Engineering* 3 (4), March - 2013, pp. 1-6.

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