Towards the Reliable Integration Testing: UML-based Scenario Analysis using an Automatic Prototype Generation Tool

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Abstract: One key to success for high quality enterprise information systems development is to validate the customers' requirements sufficiently at the early stage. Scenarios are an effective means to an end because they make it possible to represent various situations of system usage. Most scenarios are defined by using a natural language or such a formal language as Unified Modeling Language (UML) and describe normal, alternative, and exceptional service flows from the point of view of system usage. As a result, scenarios make it easy for the customers to confirm their requirements intuitively because of the concreteness. On the other hand, based on the V-model, which is well-known software development process and denotes the correspondence of requirement analysis stage to integration test stage, it is desirable that the testers should test the system by using the test cases derived from the validated scenarios. We have proposed a UML-based requirements analysis (RA) model with automatic prototype system generation for enterprise Web application development. This paper proposes a way to efficiently create reliable test cases from the scenarios that have been validated by the customers using the prototype system which was generated by the RA model.

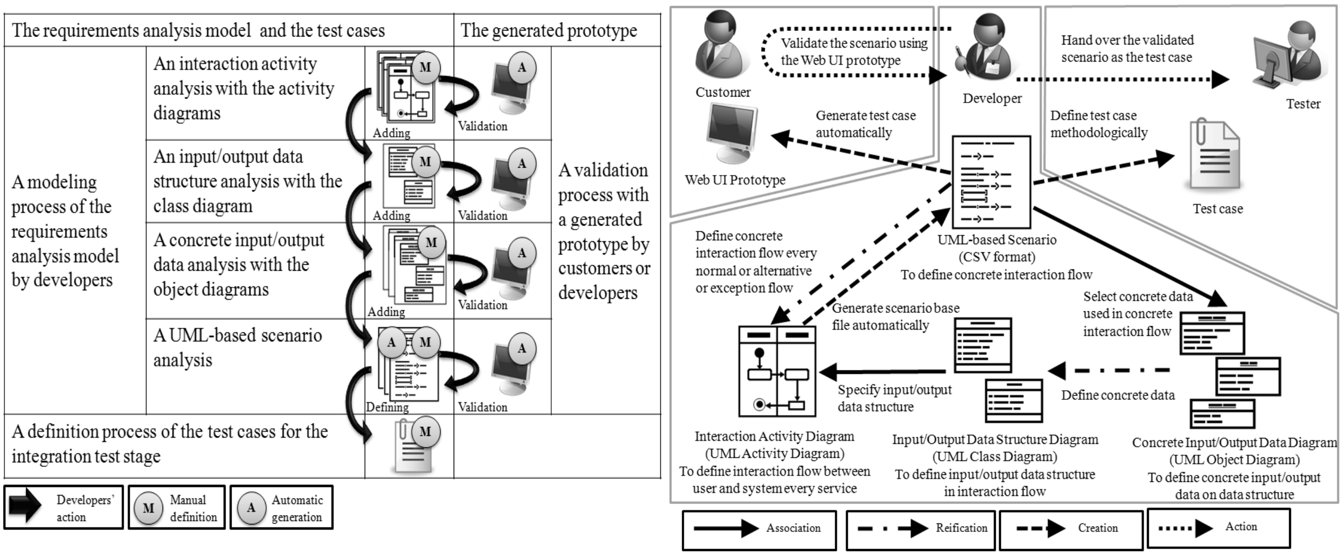
Key-Words: Unified Modeling Language, Web Application, Scenario, Test Case for Integration Testing

1 Introduction

One key to success for high quality enterprise information systems development is to validate the customers' requirements sufficiently at the early stage. Scenarios are an effective means to an end because they make it possible to represent various situations of system usage. Most scenarios [1-5] are defined by using a natural language or such a formal language as Unified Modeling Language (UML) [6] and describe normal, alternative, and exceptional service flows from the point of view of system usage. As a result, scenarios make it easy for the customers to confirm their requirements intuitively because of the concreteness. On the other hand, based on the V-model, which is well-known software development process and denotes the correspondence of requirement analysis stage to integration test stage, it is desirable that the testers should test the system by using the test cases derived from the validated scenarios.

Several researchers [1-3] have made use of their scenarios to generate user Interface prototype automatically so that they can define and validate requirements specification efficiently. On the other hand, to decrease the time cost of test phase or to support exhaustive testing, several researchers have handled scenarios as the source to generate test cases [7-9] or test codes [9, 10] or test path [5].

We have proposed a UML-based requirements analysis (RA) model with automatic prototype system generation for enterprise Web application development In this paper, we propose a way to efficiently create reliable test cases from the scenarios that have been validated by the customers using the prototype system which was generated by the RA model The RA model consists of activity diagrams, class diagram, object diagrams and UML-based scenarios. The activity diagrams represent all flows which include normal, alternative and exceptional flows for every user authority and every service exhaustively. The class diagram represents data structures used in the flows of the activity diagrams. The object diagrams represent concrete data corresponding to the data structure of the class



The relation among each diagram, scenario and test case.

The entire flow of the requirements analysis model and test case definition.

Fig.1 The Overview of Our Approach from the Requirements Analysis to Test Case Definition

diagram. The UML-based scenarios represent a concrete flow by selecting and supplementing the appropriate part of exhaustive flows, data structures and concrete data extracted from the above-mentioned three kinds of models. Scenarios are defined in a Comma Separated Value (CSV) format. There are three strong points in our approach. First, a non-functional Web UI prototype which is described in Hyper Text Markup Language (HTML) can be generated automatically from the RA model stepwise at each stage adding a kind of diagram or scenarios [11, 12] so that the developer can validate their model iteratively with the generated prototype from very early stage defining only one kind of diagrams. The advantage of the UI prototype [13, 14] is mainly to enable the validation of the service flow in the both view of UI transitions and input/output data represented on UI by customers. Secondly, concrete data specified in the object diagram can be reflected into the generated prototype [11, 12] so that the customers can validate the services with the prototype intuitively and easily. Thirdly, the test cases can be defined semi-automatically according to the RA model in which the customers have approved the contents of the services through the generated prototype. As a result, the tester can carry out the integration testing systematically by using the test cases derived from the validated scenarios.

The remainder of the paper is organized as follows. Section 2 explains the overview of the entire flow in our approach, and section 3 describes the RA model in detail. Section 4 explains the Web UI prototype generated automatically from the RA model, especially at the stage defining the UML-based scenario. Section 5 describes the process to define the test cases according to the UML-based scenario and discuss the effectiveness of our approach applying an order management system development for a confectionery. Section 6 describes comparing with the related works, and finally, section 7 describes the conclusions and future works.

2 Overview: from Requirements Analysis Process to Test Case Definition Process

As shown by the entire flow of the requirements analysis model and test case definition in Fig.1, there are five steps to define the RA model or the test case. At the former four steps, the developers define and validate and refine the RA model iteratively. To make it possible to validate the RA model effectively by introducing the prototyping into our approach, we have developed an automatic prototype generation tool which can generate a Web UI prototype automatically at each stage adding a kind of diagram or scenarios. Therefore, the developers can validate the RA model iteratively by such stepwise automatic prototype generation. In the latter step, as shown by the relation among each diagram, scenario and test case, the developers can define the test cases methodologically from the UML-based scenario which is defined by using the validated RA model fully in the viewpoint of both behavior and data structure. It notes that the developers need to obtain a set of services which are equal to the concept of use case from requirements of the customers before the first step. The following sections illustrate these steps in detail with the RA model of an order management system.

3 The Modeling Process of the Requirements Analysis Model

The RA model consists of activity diagrams, a class diagram and object diagrams in UML 2.0, and UML-based scenarios in the CSV format. Three kinds of the UML diagrams notation in the RA model correspond completely with the original UML notation. Also, they are defined by Astah* [15] which is an analysis or design support tool and which supports UML modeling. The following sections describe the three kinds of diagrams and the UML-based scenario along with the RA model example of the order management system development for a confectionery.

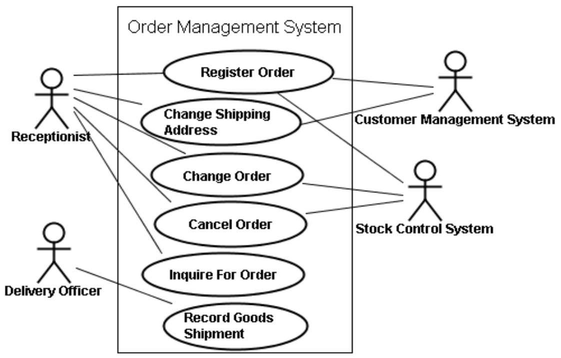


Fig.2 The Use Case Diagram of an Order Management System for a Confectionery

Fig.2 represents a use case diagram of the system. This system manages order information for confectionery. Also it handles customer information and stock information by interacting the Customer Management System and the Stock Control System. On the other hand, there are two kinds of user of the system. One is the Receptionist who receives a telephone call or an order mail to receive an order, the other is the Delivery Officer who records shipment of orders. As the overview of workflow, at the first step, the receptionist receives an order from a customer and registers the order into the system. Then, after the receptionist finished inputting the order, the system sends shipment sheets to the delivery officer of each distribution center. Finally, the delivery officer instructs the deliverer to ship the goods to the customer. Also, the delivery officer records goods shipment. If there is a request for changing or canceling orders or changing the shipment address of the customer, the receptionist conducts the work using the system. In this paper, the following sections illustrates about the service of "Change Shipping Address" in detail.

3.1 The Interaction Activity Analysis

The activity diagrams, which we call Interaction Activity Diagrams (IADs), define interaction among a user and systems every user authority and every service. The IAD defines all normal, alternative and exceptional flows. The developer should define IAD according to the following rules, so that they can define the interaction clearly and enough.

(1) To define who performs each action, define partitions in an IAD which are named after a user authority or systems. And all nodes of the IAD should be defined within the partitions.

(2) To define the interaction as sequence of the actions which is performed by a user and systems by turns, do not define concurrent flows over several partitions.

(3) To clarify responsibility of actions every partition, define each action of a user as an input action to a system. Also, define each action of the system as an output action to the user or an internal logic action.

(4) To avoid defining a complex action, define the content of an action with a simple sentence. Therefore, we have specified the simple format "<verb> <noun>" for the action. For example, an action which follows the format is "input password". In an action of a user, the verb defines input behavior toward a system. And the noun defines a target of the behavior such as an input item. On the other, in an action of the systems, the <verb> defines output behavior toward the user or logic behavior such as CRUD (Create, Read, Update and Delete). And the <noun> defines a target of the behavior such as an output item or a message.

(5) To clarify input/output data provided to the user, define the object node in the middle of the control flow which strides the boundary of a user partition and a system partition.

(6) To clarify the conditions on control flow branches, define guard conditions on the control flows just behind a decision node.

(7) To clarify pre and post conditions precisely when a service is executed, define a note, which its content starts with "pre-condition:", as the pre-condition for an initial node. And define a note, which its content starts with "post-condition:", as the post-condition for an activity final node.

(8) To distinguish normal flows from exceptional flows, define a partition named "Interaction". The control flow, which reaches the node in the "Interaction" partition just after a conditional branch in the system or "Interaction" partition, are handled as the exceptional flows.

About the noun of the rule of (4), we have given a simple format to the noun to indentify clearly and uniquely an input/output item which belongs to a data structure represented by an object node (see Fig.3). Actually, it is possible to assume a class as input/output data structure because the object node on Astah* can assign a class as the base class. In Fig.3, an “object_node_name” is the name of an object node which corresponds to the root name of data structure defined by the base class. A “parent_item_name” and an “item_name” are the name of a structured item represented by an attribute of the base class. The “parent_item_name” implicates the name of the structured item which is in the middle-layer if the data structure has multi-layer.

Fig.4 represents the interaction flow of the service of "Change Shipment Address". As the explanation of the flow, at the first step, a receptionist executes the service by selecting "Change shipment address". Next, to identify the customer data that shipping address would be changed, the receptionist input the ID of the customer to the system and makes the system start search by selecting "search". Then, if the expected data was found, the receptionist inputs new shipping address for the customer data and selects "update". Next, the system asks the receptionist whether the edited data is correct. If the receptionist confirmed the data, he selects "update". Finally, after the system updated the internal data correctly, it finishes the service.

```
<noun> := object_node_name "::::" item | item
item := parent_item_name "::" item | item_name
object_node_name := string
parent_item_name := string
item_name := string
string := ("[^();,]")+
```

Fig.3 The Formal Grammar of the <noun>

3.2 The Input/Output Data Structure Analysis

The class diagram, which we call Input/Output Data Structure Diagram (IODSD), defines data structure based on input/output data represented as object nodes in the IAD. Therefore, the IODSD is expected to define essential data which must be handled on UI. Since the data handling on UI include generally a lot of entity data which are referred by the boundary, it can regards a defined input/output data structure as a class candidate and a defined input/output item as a class or attribute candidate. Since some of them are not entity data which means the persistent data, but data handling on UI only, the developers can elicit these candidates for not only entity classes but also

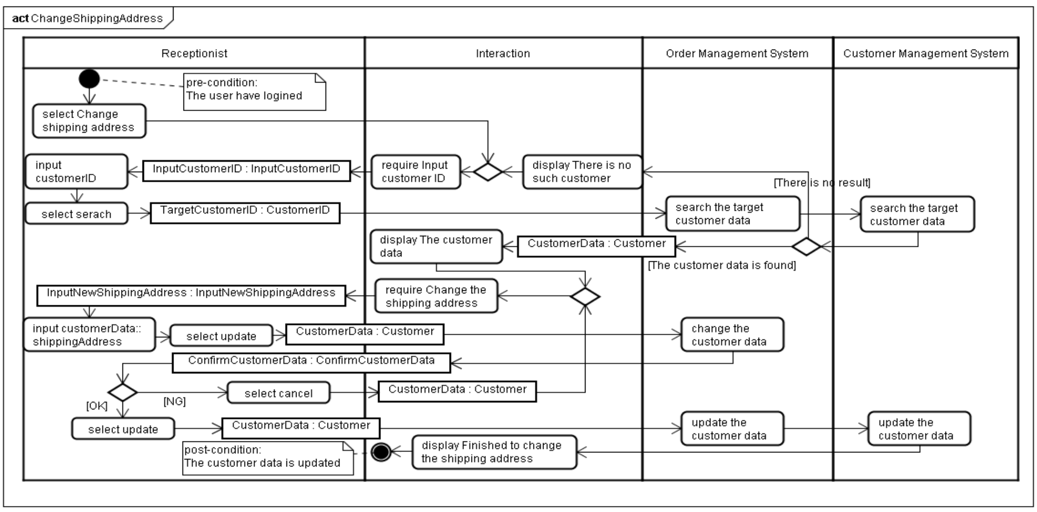


Fig.4 The Interaction Activity Diagram of a Service of “Change Shipping

boundary classes. Just after the stage assigning classes to the object nodes, the IODSD may include the same candidates among the resultant class and attribute candidates. The developers elaborate an appropriate class diagram to integrate the candidates properly. Fig.5 represents an example of the IODSD.

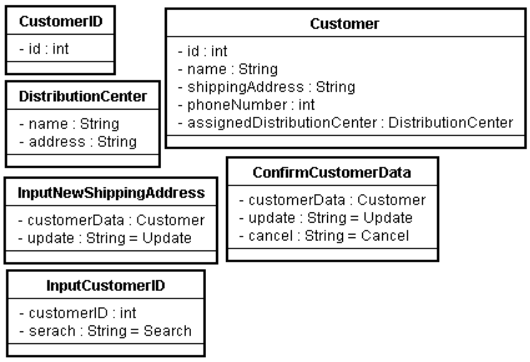


Fig.5 The Input/Output Data Structure Diagram Related to the Service of "Change Shipping Address"

3.3 The Concrete Input/Output Data Analysis

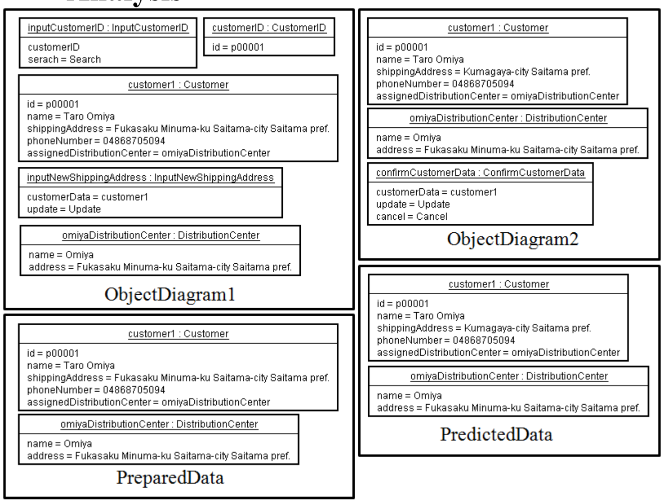


Fig.6 The Concrete Input/Output Data Diagrams Related to the Service of "Change Shipping Address"

The object diagrams, we called Concrete Input/Output Data Diagrams (CIODDs), define concrete data of the input/output data structure defined by an IODSD. By defining the concrete data needed when the usage situation of a service such as a normal or alternative or exceptional flow is presumed, the developers can validate the RA model in the viewpoint of both data structure and behavior. For example, a data structure which can't describe required data or a flow which can't represent required data is improper model. However, these problems are difficult to be detected from abstract data structure such as a class diagram and make the possibility of creating misunderstandings about the data constraints between the developers without a specification about concrete data. Therefore, we have adopted the CIODD into the RA model specifically. In our approach, to define multiple concrete data to one slot, comma as the separator between the data is inserted. Also, to define a concrete data into a slot which has a class type, the object name of instance specifications which has the class type is defined into the slot. Fig.6 represents examples of the CIODD.

3.4 The UML-based Scenario Analysis

In the above-mentioned three steps, the developers have defined three kinds diagram of the RA model; the IAD represents the exhaustive interaction flow; the IODSD represents the input/output data structure needed in the interaction flow; the CIODD represents the concrete input/output data, which can be used to validate the RA model in the viewpoint of the validation of data structure. Then, the UML-based scenarios define concrete flow paths to validate the exhaustive interaction flow in the viewpoint of behavior, using concrete input/output data. Concretely, the UML-based scenarios are defined for every normal, alternative and exceptional flow. Also, they define the prepared and predicted data which are the internal system data before and after the service execution to clarify the usage situation of the system. These scenarios are defined by the CSV format and consist of the following elements. It notes that the Transition Condition is a set of guard expressions which specifies a flow path through the "Interaction" and system partition.

(a) A Service Name is the name of the service which corresponds to the name of an IAD.
(b) A Scenario Name is the name of a scenario for the above-mentioned service.
(c) Prepared Data are the internal system data needed to execute the scenario, which define the data related only to the scenario to execute.
(d) Predicted Data are the internal system data after the scenario execution, which define the data related only to the executed scenario.
(e) Scenario Steps consist of the sequence of UIT trigger actions and transition conditions and object nodes. The UIT trigger actions and transition conditions specify a concrete normal or

alternative or exceptional flow path of an IAD. On the other hand, the object nodes specify a concrete data using in the scenario such as an input/output data or internal system data.

Our automatic prototype generation tool can generate automatically a base scenario file which is given a format to define above-mentioned elements. On the base scenario file, the above (a) is defined completely; the above (c) and (d) define a form that completes if an object diagram is specified; the above (e) defines all candidates, which are the elements to specify a flow path uniquely or the object nodes, for each service. To complete the base scenario file, the developer edits it by the following steps.

(1) Define the appropriate scenario name related to a flow type such as a normal or alternative or exceptional flow.

(2) In order to specify a flow path which is considered by the developers referring to the IAD, edit the scenario step candidates by copying or arranging or deleting parts of the candidates.

(3) In order to define the concrete data according to the usage situation of scenario, define the CIODDs into the prepared and predicted data, and into the object nodes which are in the scenario steps.

Fig.7 represents the normal scenario of the service of "Change Shipment Address" which was edited according to the above-mentioned steps.

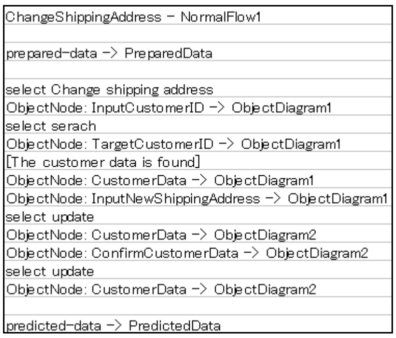


Fig.7 A Normal Scenario of the Service of "Change Shipping Address"

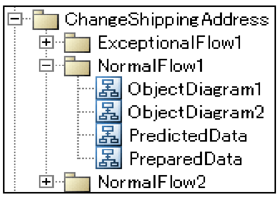


Fig.8. The Structure Tree of Object Diagrams

This scenario used only the data defined in Fig.4, Fig.5, Fig.6 and Fig.8 except for the scenario name. In particular, the CIODDs on the scenario must be defined in the Astah* Structure Tree View with the structure which consists of the service name, the scenario name and the CIODD as shown in Fig.8. Concretely, the service name package includes the scenario name packages, and the scenario name package includes the CIODDs.

The scenario named "NormalFlow1" in Fig.7 specifies the flow that the shipping address of a customer changes "Fukasaku Minuma-ku Saitama-city Saitama pref." into "Kumagaya-city Saitama pref.". In "ObjectDiagram1", there is the customer data before changing the shipping address. On the other hand, in "ObjectDiagram2", there is the customer data after changing the shipping address. About the resultant instance specifications of the CIODDs in a scenario, these can be categorized automatically as the following Table 1.

Table 1 The Categorization of the Instance Specification on a Scenario

Categories of instance specification	Kinds of CIODD on the scenario		
	Prepared data	Predicted data	Object nodes of scenario steps
Input/output data on UI only	DA	DA	A
Created system data	DA	A	NR
Remaining system data	A	A	NR
Updated system data	A	A*	NR
Deleted system data	A	DA	NR

A = Appeared, DA = DisAppeared, NR = NoRelated, A* = Appeared (For an instance specification, the object name and type remained, but the slots are updated)

4 The Scenario-based Prototype Generation

In our approach, the scenario-based prototype can be generated automatically from the RA model defined until former steps. Originally, in our approach, the prototype can be generated at each stage adding a kind of diagram [11]. In this paper, the scenario-based prototype only is explained. Fig.9 shows the sample of a Web UI prototype which is generated from the RA model.

In spite of the non-functional prototype, the prototype which is generated from the RA model that includes the scenario can represent the change of output data as if the prototype had a function. Then, using such scenario-based prototype, the developers can validate the RA model which meets the customers' requirements by discussing with the customers.

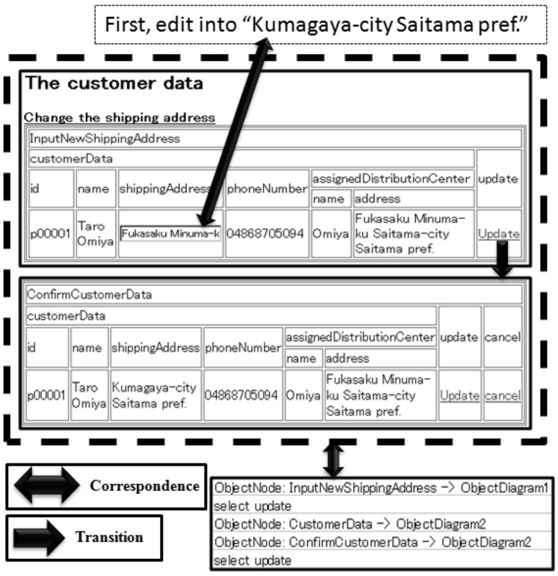


Fig.9 A part of Scenario-based Prototype of the NormalFlow1 Scenario of "Change Shipping Address"

5 The Definition process of the Test Case for the Integration Test Stage

Until former steps, the UML-based scenarios have been defined for every normal or alternative or exceptional flow and have specified concrete input/output data for each object node of the scenario steps and for the prepared and predicted data. Thus, these scenarios are similar to test cases exceedingly in the viewpoint of not only specifying the concrete flow path but also containing the concrete data. Furthermore, these scenarios are expected to be validated by the customers and developers using the generated prototype in the validation process. Since such validated scenario must be achieved by the system correctly and completely, the system must be tested according to the validated scenarios. Therefore, it is important for the developer and tester to create the test cases which correspond to the validated scenarios without any inference in the definition process of them. In this paper, we have attempted to create methodologically the test cases for the integration test stage using the RA model.

According to [16], the test case is documentation specifying inputs, predicted results, and a set of execution conditions for a test item. Therefore, we make the UML-based scenario correspond to the test case as follows.

(1) The Inputs correspond to the action sequence of a user in an IAD along a specified normal or exceptional flow path. Furthermore, the concrete data input by the user are assumed as the instance specifications which are categorized into the "input/output data on UI only" in Table 1.

(2) The Predicted Results correspond to two kinds of the resultant object in the RA. One is the generated prototype so that the tester can confirm whether predicted data is represented on the UI by executing the scenario. The other is a set of the difference data which is expected to be changed (such as created or updated or deleted) by the system operation and user manipulation and which is discovered as the result of comparing the predicted data with the prepared data so that the tester can confirm what is changed among the internal system data by executing the scenario. Also, the predicted results must satisfy the post-condition in the service if the flow type of test case is normal flow.

(3) The set of Execution Conditions correspond to the prepared data of the UML-based scenario which enumerates the required data to execute the scenario. Also, the set of execution conditions must satisfy the pre-condition in the service.

There is an important thing to define the test cases. That is, the defined test cases are whether they cover testing for exhaustive flows. In our approach, in related to above (1), the test cases covering exhaustive flow can be defined methodologically since the IAD defines exhaustive flows every service. Fig.10 represents an example of the test case corresponding to the UML-based scenario in Fig.7.

Test Case:	ChangeShippingAddress - NormalFlow1	
Flow Type	Normal	
Execution Conditions:	pre-condition:	The user have logined
	Initial Data:	customer1 : Customer [id=p00001 ;name=Taro Omiya;shippingAddress=Fukasaku Minuma-ku Saitama-city Saitama pref.;phoneNumber=04868705094;assignedDistributionCenter=omiyaDistributionCenter]
		omiyaDistributionCenter : DistributionCenter [name=Omiya;address=Fukasaku Minuma-ku Saitama-city Saitama pref.]
Inputs:	1.	select Change shipping address
	2.	input “p00001” as customerID
	3.	select “Search” as search
	4.	input “Kumagaya-city Saitama pref.” as customerData::shippingAddress
	5.	select “Update” as update
	6.	select “Update” as update
Predicted Result:	post-condition:	The customer data is updated
	[updated]	“Fukasaku Minuma-ku Saitama-city Saitama pref.” -> “Kumagaya-city Saitama pref.” : shipping address of customer1

Fig.10 The Test Case corresponding to the NormalFlow1 Scenario

We have defined manually the test case in Fig.10. However, almost of the elements can be defined methodologically. The content of the "Test Case" equals the scenario name of the UML-based scenario. The content of the "Flow Type" becomes "Normal" because the flow path of the scenario has no control flow fulfilling the (8) of the list in section 3.1. In the contents of the "Execution Conditions", the "pre-condition" equals the pre-condition of the IAD. And, the set of "Initial Data" is defined according to the prepared data of the scenario every instance specification. The contents of "Inputs" enumerate the action sequence of the user in the IAD according to the flow path of the scenario. About the part of "<concrete data> as", the concrete data is defined according to the instance specifications which are categorized into "input/output data on UI only" and which are in adequate position for the actions. In the content of the "Predicted Result", the "post-condition" equals the post-condition of the IAD. And, the set of "[<change>]" (<change> := "created" | "updated" | "deleted") is defined according to the difference data discovered by comparing the predicted data with the prepared data in the scenario every instance specification.

However, a few points cannot be defined methodologically as is. It is to define the concrete data into the contents of "Inputs". In an IAD, a user inputs for the object node which is reached from the system. However, the concrete data should reflect into the contents of "Inputs" is defined to the object node which is sent to the system. Therefore, the input item which is sent to the system should correspond to the output item which is reached from the system properly. For example, this problem can be resolved by defining the correspondence between the input item and the output item, using tagged value.

6 Related Work

Several researchers [5, 7-10] have proposed to generate specification or code for test stage from mainly UML behavioral model such as activity diagram and/or sequence diagram and/or state machine diagram. Some of these works [5, 9] introduce contracts, which are pre-/post-conditions related to service execution, into the use cases or the messages of a sequence diagram. Then, the contracts are defined by the constraint language such as Object Constraint Language (OCL) or OCL like languages.

These works [5, 7-10] have strongly focused on measuring the test coverage based on the idea of generating test cases from the behavioral model which represents exhaustive flows or the sets of scenario which consists of normal and exceptional flows. On the other hand, in our approach, it is important that the UML-based scenarios are satisfactory and adequate for the customers. After validating the scenarios through generated UI prototype, the test cases are semi-automatically defined by the concrete data derived from the validated scenarios. Also, from the viewpoint of test coverage, an IAD (Interaction Activity Diagram) exhaustively defines all flows for each service, so that the testers can get all test case templates for the service. Furthermore, the works [5, 7-10] do not specify how to confirm the predicted results of the scenario. In our approach, the predicted results can be specified via following two ways. The scenario-based prototype makes it possible to confirm it by the data represented on UI. The CIODD (Concrete Input/Output Data Diagram) of the UML-based scenario makes it possible to confirm the internal system data which would be changed partially by the scenario execution.

7 Conclusion and Future Work

In this paper, we have proposed the definition process of reliable test cases from the scenarios that have been validated by the customers using the prototype system which was generated by the RA model. As RA model includes the specification of concrete data, the test cases can methodologically define concrete inputs data and the expected result data. Therefore, the developers can hand over the validated scenario conforming to the test specification to the tester precisely. Moreover, our approach can support exhaustive testing for the testers.

As the future work, to support the integrated system testing, we introduce the model which represents how to integrate services into the RA model. Also, we introduce the order of priority into the flows every conditional branch in the IAD to clarify the flows which the developers want the testers to test preponderantly.

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