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Intertwining of Requirements with Testing

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Abstract: ***This paper presents a method called AGOTRFR, i.e., an attributed goal oriented testing requirements elicitation from functional requirements. The objective of this method is twofold: (i) to elicit the testing requirements from functional requirements; and (ii) to manage the requirements change process. Therefore, two attributes are attached with the AGOTRFR graph. One attribute is used to indicate the priority of the functional requirements and the other is used to indicate the implementation status of the requirements during the requirements change process. To compute the priority of the functional requirements we used the analytic hierarchy process. During the computation of the priority, cost and effort are considered as the criteria during pair-wise comparisons among the requirements. Finally, the proposed method is demonstrated with the help of an example.***

Keywords: ***Functional requirements, Testing requirements, AND/OR graph, analytic hierarchy process, function point, and COCOMO.***

I. Introduction

Requirements engineering (RE) and software testing are two different processes for the successful development of any software product. People who are involved in these processes have different mindset. For example, the mindset of RE people is to identify, model, and analyze the need of the stakeholders [2]. On the other hand side, the objective of the testing team is to identify as many errors as possible in the software so that complete set of requirements can be delivered during different releases of software without having any error. Because of the different mindset of the people, who are working separately in RE and testing process, it is difficult to develop the software within time and budget [1]. Therefore, it is an important research issue that how to bridge the gap between the RE people and testing people so that successful software can be developed [4]. Based on our literature review, we identify the following research issues that are present in the literature of the "*goal oriented and testing process*" [1, 6, 7, 8, 9, 11, 12, 13]:

1. How to generate the testing requirements from the functional requirements?
2. How to incorporate the requirements attributes such as priority and implemented status during the requirements change process?

Therefore, to address the above research issues we proposed a method called AGOTRFR, i.e., attributed goal oriented graph for generating the testing requirements (TR) from the functional requirements (FR).

This paper is organized as follows: In section II, we present the related work. Proposed method is given in section III. Case study is given in section IV; and finally, the conclusion and future work is given in section V.

II. Related Work

In 2002, Graham [4] discussed the need to link the requirements with testing because this link was missing at that time. Therefore, keeping in view the observation of [4], in 2008, Uusitalo et al [14] presented "*a set of good practices that can be applied to bring RE and testing closer to each other*". For example, (i) "early tester participation", (ii) "tester participation in requirements reviews", (iii) "test traceability to requirements", (iv) "linking testers with requirements owner", and (v) "requirements suggestion by testers". In 2009, Kukkanen et al [6] integrate the RE process and testing to increase the quality of R&D. In their work, they also observed that when requirements engineers and testers' works together then it form a solid basis for the successful development of the software product; and it also reduces the risk of overlapping processes. In 2009, Post et al. [10] discussed the need for linking functional requirements and software verification. In 2011, Barmi et al. [1]

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conducted a systematic mapping study for the alignment of requirements specification and testing. They suggest that linking requirements and testing will help to reach a more accurate testing plan; and this testing plan helps to improve the cost and schedule of the project. In another study, Wnuk et al. [15] shared some experiences from a large company. On the basis of the discussion they identify that "*test cases can be seen as the representations of the requirements"*. Bjarnason et al. [2] investigated the agile method of using the test cases as requirements. They point out that "*the use of test cases as requirements posses both benefits and challenges when eliciting, validating, verifying, and managing the requirements*". Based on the literature review of [1], we identify that following methods support the linking of requirements with testing: model based testing, formal approaches, traceability, goal oriented approaches, etc. Among these models, goal oriented method have received less attention in linking the requirements with testing. Therefore, in order to strengthen the goal oriented methods; in this paper we proposed an *attributed goal oriented graph for generating the TR from FR (AGOTRFR).* In AGOTRFR, two attributes are attached with the goal graph, i.e., priority and implementation status. In AGOTRFR, functional requirement (FR) would be decomposed and refined into testing requirements.

III. Proposed Method

In this section, we propose a method called, AGOTRFR, i.e., *attributed goal oriented testing requirements elicitation from functional requirements*. We first explain the structure of the AGOTRFR graph; and then we discuss the following steps:

Step 1: Generating testing requirements from functional requirements (FR)

Step 2: Computation of the ranking values for each FR

Step 3: Use of requirements attributes during requirements change process

(A) Structure of the AGOTRFR graph

AGOTRFR is an AND/OR graph which is used to generate the testing requirements (TR) from functional requirements (FR). In this graph, the root node is FR and it is decomposed and refined into testing requirements (TR). TR can be visualized as AND decomposed and OR decomposed requirements. In AND decomposition, until and unless all the sub-requirements would not be achieved, their parent requirement will not be achieved. In case of OR decomposition, the parent requirement would be achieved, if any sub-requirement of the parent requirement would be achieved. In AGOTRFR, FR and TR are represented by oval and rectangle, respectively. An example of AGOTRFR graph is given in Fig. 1.

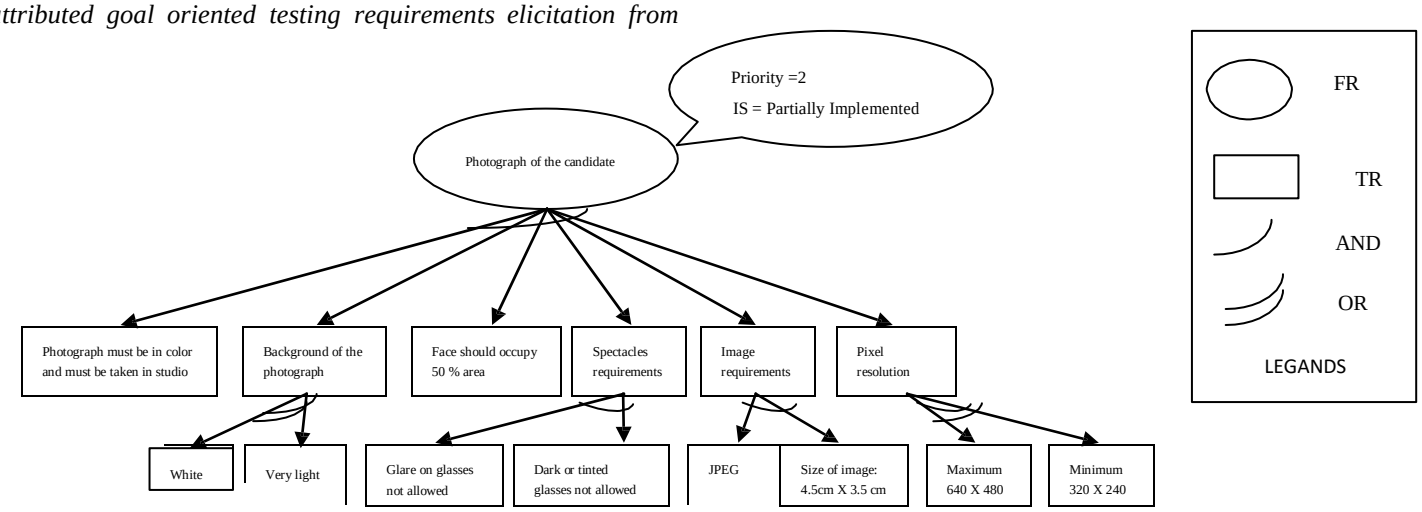

Fig.1: AGOTRFR graph

In Fig. 1, we consider one of the functional requirements (FR) of Institute Examination System, i.e., Photograph of the candidate. This requirement is decomposed and refined into the following testing requirements (TR):

TR-1: The photograph of the candidate must be in color and must be taken in studio

TR-2: Background of the photograph should be either white or very light color. Therefore, in AGOTRFR graph, it is

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represented by the OR connective. It means that, if any of the TR would be achieved, their parent node would be achieved, i.e., *Background of the photograph.*

TR-3: The face of the candidate should occupy 50% area of the photograph.

TR-4: If the candidate wear spectacles, glare on the glasses are not acceptable. Spectacles with dark and tinted glasses are not allowed. In Fig. 1, it is represented by AND connectives. It means that, if both the requirements will not be satisfied, then its parent node will not be satisfied, i.e., *Spectacles requirements*.

TR-5: The image should be in JPEG format and also in the size of 4.5 cm X 3.5 cm. In Fig. 1, it is represented by AND connective.

TR-6: The pixel resolution of the candidate photograph should be either 640 X 480 (maximum) or 320 X 240 (minimum). It is represented by OR connective in Fig.1.

In Fig. 1, there are two attributes which are connected with FR, i.e., the priority of the requirements is "*two"* and the Implementation Status (IS) is "*Partially Implemented (PI)*". When the tester will see this information through *Requirements Tracking Management* (RTM) System (see section IV for detail), then he/she will contact the project manager that FR, i.e., *Photograph of the candidate*, should be implemented on priority basis because it is partially implemented requirements. Once this requirement gets implemented, it would be tested on the basis of the testing requirements. In our case, there are six TR for one FR, i.e., *Photograph of the candidate*.

In the following sub-section, we explain the steps of the proposed method.

Step 1: Generating testing requirements from functional requirements (FR)

In this step, we draw the AGOTRFR graph by decomposing the functional requirements into testing requirements.

Step 2: Computation of the ranking values for each FR

One of the attribute of the AGOTRFR is the priority of each FR. This priority would be used to identify those requirements that would be tested on priority basis by the software testers. Therefore, to compute the ranking values of each requirement we apply the Analytic Hierarchy Process, a multi-criteria decision making method.

In AHP, a set of requirements are pair-wise compared with each other on the basis of some criteria. In this paper, we have used the *Cost* and *Effort* as the criteria for ranking the functional requirements.

Step 3: *Use of requirements attributes during requirements change process*

On the basis of the systematic literature review of [7], it has been observed that most of the research in the area of requirements evolution or requirements change process management focuses on how to deal with the evolution after it happens. Therefore, in order to address this issue in the proposed method two attributes are attached with each FR, i.e., priority and implements status. These attributes are used to manage the requirements before its evolution. The objective of the priority attribute is to select the requirements on the basis of the priority. The priorities are assigned to each requirement and there would not be any confliction among the stakeholders on the values of the priority because it has been evaluated on the basis of the Cost and Effort in the presence of different types of stakeholders. In this step we classify requirements into two types, i.e., Type 1 and Type 2.

Type 1: Requirement which has low priority and has not been implemented

Types 2: Requirement which has high priority and has already been implemented

If during the development process, if there is need to change in *Type 1 requirement;* then it can be changed according to the need of the stakeholders.

On the other hand side, if changes in Type 2 requirement occur then the cost and effort of the software will increase. Such type of change during the software development would be possible if all the stakeholders have the same opinion on changing the requirements.

Classification of requirements on the basis of Type 1 and type 2 will improve the software quality and it will also increase the satisfaction of the customers. Such type of classification will also be useful to manage the requirements before its evolution.

IV Case Study

In this section, we consider the functional requirements (FR) and testing requirements (TR) of Institute Examination System (IES).

Step 1: The objective of this step is to elicit the TR from FR. Therefore, we first elicit the FR of IES using goal oriented approach, as discussed in our previous work [11, 12]. The functional requirements of IES are given below:

FR 1: *Login Module*
FR 2: *Printout of bank receipt of student's fee*
FR 3: *View semester result.*
FR 4: *Generate examination seating arrangement.*

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FR 5: *Online conduct of examination*
FR 6: *Fill examination form*
FR 7: *Upload any exam related activities*
FR 8: *Generate examination hall ticket*
FR 9: *Approve examination form*
FR 10: *On line payment of examination fee*

Once we have identified the FR, then the testers would be allowed to participate in the requirements elicitation process to elicit the TR for IES. For each FR, an AGOTRFR graph would be drawn to elicit the TR, in the similar way as drawn in Fig. 1.

To elicit the testing requirements for FR1, i.e., Login Module, it would be first decomposed and refined into sub-requirements. Therefore, FR1 is decomposed and refined into the following sub-requirements:

(A) If already a member:

FR1A.1: User name; FR1A.2: Password; FR1A.3: Students; FR1A.4: Administration; FR1A.5: Faculty; FR1A.6: Submit

(B) For new users:

FR1B.1: Name; FR1B.2: Mother's Name; FR1B.3: Father's Name; FR1B.4: Date of Birth; FR1B.5: Date of joining of University/Institute; FR1B.6: Name of Faculty/Office; FR1B.7: Name of Department/Office

The testing requirements for the above FRs would be:

TR1A.1: The length of user name should not exceed 30 characters;

TR1A.2: The first character of the password should be Capital letter and the last character should be any special symbol like @, #, $, %, ^, &, and *. In the password there should be any three numeric values.

TR1A.3, TR1A.4, and TR1A.5 would be used to select the type of users like students, administration, and faculty.

TR1A.6: Whether *submit button* is selecting the different types of users or not. Here, we are not considering the color combinations for the buttons used in the Login module.

For the new users the testing requirements would be:

TR1B.1: The first character of the user name should be capital and should not exceed 30 characters in length followed by the following: Mr. /Ms. /Mrs. /Dr. /Post-Doc /Professor /Associate Professor/Assistant Professor;

The testing requirements for TR1B.2 and TR1B.3 would be same as TR1B.1

TR1B.4: The date of birth should follow the following format: *date/month/year.*

TR1B.5: the date of joining should be in the following format: *Time/AM or PM/some space/ date/month/year*

TR1B.6 and TR1B.7, the name of the faculty as well as the name of the department should not exceed 30 characters.

As a result, we have elicited 13 TR for the functional requirements, FR1, i.e., Login Modules.

Same process has been applied for generating the TR for the remaining FR. To find out the total number of TR for each FR, we have used "*Requirements Tracking Management* (RTM)" System. RTM system contains the list of all FR, No. of TR, priority of each FR, cost and effort of each requirement, and the implementation status (IS). The objective of RTM system is to manage the requirements change process or requirements evolution process during the software development, see step 3 for detail.

Step 2: In this step, we compute the priority for each FR. For the prioritization of requirements we used AHP, a method proposed by Saaty in 1972 [5]. In AHP, we are considering the cost and effort as the criteria. Therefore, these two criterions would be elicited first. For the elicitation of the cost, we first compute the FP value for each requirement.

To compute the FP of the requirement FR1, we first identify the following parameters, i.e. External Input (EI), External Output (EO), External Queries (EQ), Internal Logical File (ILF), and External Interface File (EIF). The value of these five parameters for FR1 is given below:

EI=24, EO =5, EI=8, ILF=10, and EIF=7.

In our study, the value of the total count is 54; so the value of FP becomes 66. In India, the cost of one FP is 125$ [3]. Therefore, the cost of FR1 is 8250 $.

After applying the COCOMO, we have the value of the effort for FR1 as 22.53 person month (PM). Similarly, we compute the values of cost and effort for the remaining FR; and the results are summarized in Table 1.

Now we apply the AHP for the ranking values of each FR. After applying the AHP, we have the following values for the requirements:

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FR1 = 0.295
FR2 = 0.0397
FR3 = 0.163
FR4 = 0.0186
FR5 = 0.2528
FR6 = 0.105
FR7 = 0.0099
FR8 = 0.0284
FR9 = 0.0099
FR10= 0.0673

Step 3: In order to manage the requirements change process, in the proposed method we used requirements tracking management (RTM) system. In Table 1, we present the RTM system for the current work in which we have the following information about the requirements: (i) List of FR; (ii) No. of TR; (iii) Cost of each FR; (iv) Effort for each FR; (v) priority; (vi) implementation status (IS) of the requirements.

Table 1: RTM system for IES

FRs	No of TRs	Cost (in $)	Effort (in PM)	Priority	IS
FR1	13	8250	22.53	1	FI
FR2	11	11875	33.06	6	NI
FR3	18	13750	38.56	3	FI
FR4	12	8875	24.33	8	UC
FR5	07	16625	47.06	2	FI
FR6	20	13625	38.19	4	PI
FR7	05	5375	14.38	9	NI
FR8	19	10750	29.76	7	UC
FR9	10	4750	12.62	9	UC
FR10	04	12500	34.89	5	NI

In RTM system, FI, PI, UC, NI represents the fully implemented, partially implemented, under consideration, and not implemented requirements of the proposed system, respectively.

In order to access the RTM system, there would be a user ID and password for all the stakeholders who are involved in the software projects. These stakeholders can easily track the status of the requirements. For example, if at time T_0, client wants to include and exclude some requirements into FR3. In order to update the requirements, client will first identify the status of the requirements. In our case, FR3 is under Type 2 requirement, i.e., *Requirement which has high priority and has already been implemented* (see Table 1). Under this condition, the client will discuss the need of the changes in the current system and the developer will calculate the extra cost and effort that would be required to make the changes. After the mutual consensus, if the decision would be positive then the corresponding requirement would be updated and implemented; otherwise the need to update the requirement FR3 would be rejected.

Those requirements which fall under the category of PI, UC, and NI can be easily updated as per the requirements of the client. The information given in Table 1 would be useful to manage the requirements change process without effecting the much cost and effort required in the development process.

Using RTM system, testers can easily find out that how many requirements would be tested for the given FR. If during testing process, the tester identify some new requirements then that requirements can easily be added in the RTM system; and the corresponding cost would be included in the RTM system as per their implementation cost.

By applying the proposed method it is possible to generate the TR from FR; and also to identify the total number of TR. In this study, we have tried to intertwine the RE process and testing process in the early phase of RE. By linking the requirements and testing, we have elicited TR. These TR are also kind of requirements that must be elicited before actual development takes place.

V Conclusion and Future Work

Different methods have been proposed in literature to strengthen the goal oriented methods like Non-Functional Requirements (NFR) framework, Knowledge Acquisition for aOtomated Specifications (KAOS), i* framework, Attributed Goal Oriented Requirements Analysis (AGORA) method, Goal Oriented Idea Generation (GOIG) Method, a method for the Prioritization of the Requirements using Fuzzy based approach in Goal Oriented Requirements Elicitation Process (PRFGORE) [11, 12, 13]. These methods are designed for some specific purposes like elicitation of the FR and NFR; selection and prioritization of the FR and NFR; modeling and reasoning of the requirements, etc.

An attempt has been made in this paper to strengthen the goal oriented method by considering the following issues: (i) how to generate the testing requirements from the functional requirements? (ii) how to incorporate the requirements attributes such as priority and implemented status during the requirements change process? Therefore, in order to address the above issue we proposed a method called AGOTRFR. In this method, we identify the TR from FR. In AGOTRFR graph, two attributes are attached with each FRs, i.e., the priority and the implement's status (IS) of each requirement, see Fig. 1. The priority of the FR is determined by using the

AHP. The priorities of the FR are determined on the basis of the cost and effort of each requirement during AHP. To compute the cost of each requirement, we compute the FP value for each requirement. COCOMO is used to compute the effort of each requirement. To manage the requirements change process, in the proposed system, RTM system is used to know the current status of the requirement during the development system (see Table 1).

There are several open problems related to goal oriented methods, for example, less attention is given in decision making process at the time of requirements elicitation process. Most of the work is focused on the reasoning and modeling of the requirements. Reasoning and modeling of requirements can be improved by considering the Soft Computing methods like Fuzzy, Genetic algorithm, Neural Networks, Swarm Intelligence, etc. In our next study, we will try to propose a fuzzy based approach for the decision making process involved in the AGOTRFR method.

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