Constructing Use Case Model by Using a Systematic Approach: Description of a Study

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Abstract. *This paper presents the results of a feasability study that was carried out to evaluate the construction of Use Case Models by comparing the models with groups that used the GUCCRA techniques and groups that did not use them, that is, they only used their experience (Ad-Hoc). GUCCRA – Guidelines for Use Case Construction and Requirements document Analysis – is a set of two reading techniques that helps the elaboration of Use Case Models and, simultaneously, provides an opportunity to identify defects in the Requirements Document. The results of the study showed that applying a systematic and procedural technique to construct Use Case Models, a larger standardization may be reached and the construction process becomes more independent from the designer's subjectivity and experience.*

Keywords: use case construction, empirical study, requirements modeling

1. Introduction

The Use Case Model is a broadly used technique to model the user requirements established in the Requirements Document.

The Requirements Document as well as the models that represent it, as Use Case Model, deserve special attention since it is in the Requirement Engineering phase where substantial communication difficulties concentrate and hence, during this phase, many defects may be introduced in the artifacts. To reduce this problem one can introduce formal revision activities, as inspection activity, since the beginning of the software development.

To support the inspection process, many reading techniques were developed in order to attend the various artifacts. Considering the Requirements Document and the Use Case Model (in this paper, based on UML notation [1]) there are some techniques in the literature to support the inspection process and some of them are particularly interesting for this work. They are: i) Perspective-Based Reading (PBR) [2][3][4], for

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Requirements Document, which is a scenario based technique that gives the inspector a procedure to follow during the Requirements Document inspection which will help him to detect defects. PBR was defined for three different perspectives – user, tester and designer. In the case of PBR-User the Use Case Model is used as the underlying model; ii) Object-Oriented Reading Techniques for ProDeS (OORTs/ProDeS) [5] which are a set of reading techniques to support validation and verification activities on UML models used within a specific Object Oriented development process.

In relation to PBR we observe that the application of PBR-User generates a Use Case Model that could be a preliminary version of the definitive system's Use Case. But, the elaboration of the Use Case Model is an intuitive activity that depends on the developer's experience so that this model can properly represent the user's requirements. Different Use Case Models referent to the same Requirements Document are frequently generated when different people elaborate them. In relation to OORTs/ProDeS we observe that the application of RE1 (Requirements Engineering 1), one of its techniques, generates a discrepancy report as it validates a Use Case Model already constructed in relation to the Requirements Document which generates the model. When this technique is applied, some aspects are evaluated aiming at verifying if the requirements modeling is as adequate as it should be.

The Use Case Model proposed in UML was based on Jacobson's proposal [6], which proposes that this model is the center of the software development process. Although Jacobson was the forerunner of this idea, his suggestions only help in identifying the actors and use case of the model under construction. He does not mention guidelines that could support the writing of the Use Case Specification. Another approach for Use Case elaboration can be found in Kulak's and Schneider's work [7][8], although neither of them provide complete suggestions that could be used to construct the Use Case Model. For example, Kulak [7] suggests an iterative manner to evolve the Use Case Model. However, he does not provide guidelines for Use Case identification and specification. Schneider et al [8] provided some questions that help actor identification and some suggestions to create Use Cases like CRUD (Create, Read, Update and Delete). As in other works they do not provide guidelines that could support the writing of the Use Case Specification. Although Cockburn [9] provides some suggestions that can be used to write the Use Case Specifications as well as some guidelines to create certain Use Case types he does not establish any link between the Use Cases and the Requirements Document. In Anchor's work [10] there are some suggestions about the style and the content that should be used in the Use Case Specification. However, during an experiment conducted by Anchor et al., they observed that these suggestions are not enough to improve this task.

In summary, it can be said that although there are some suggestions and guidelines for Use Case Models (Use Case Diagram and Use Case Specification) construction, they are not written in a procedural way such that the expertise and the subjectivity of the designer be as minimal as possible.

Therefore, with the purpose of supplying a more effective systematic during the construction of Use Case Model and taking advantage of its elaboration to carry out an inspection (a PBR-User inspection) of the Requirements Document, a set of reading techniques, named GUCCRA – *Guidelines for Use Case Construction and Requirements document Analysis* – was defined.

Due to the importance of the characterization of available techniques in the literature, experimentation has been widely employed to provide a knowledge base that supports the choice among different methods, techniques, languages and tools. Initiatives in this direction may be seen and an example of this is the *Readers Project: A Collaborative Research to Develop, Validate and Package Reading Techniques for Software Defect Detection* [11], where the context of this work is included. In this manner, to evaluate the GUCCRA techniques, an experiment comparing the elaboration of Use Case Model by groups that used GUCCRA and by groups that used an Ad-Hoc approach was carried out and the main objective of this paper is to discuss them.

The paper is organized as follows: in Section 2 an overview of the Reading Techniques (AGRT and UCRT) that compose GUCCRA techniques are presented; in Section 3 the experiment that was conducted aiming to compare GUCCRA techniques and Ad-Hoc approach is shown and in Section 4 the conclusions and future works are presented.

2. An Overview of GUCCRA techniques

The Use Case Model construction is not an easy task. One of the main difficulties is to create and specify Use Cases because the subjectivity and the designer experience always undergo this task. Thus, aiming at reducing the subjectivity degree and the need for designer expertise, GUCCRA (*Guidelines for Use Case Construction and Requirements document Analysis*) techniques were developed, providing procedures that lead to more standardization. As the Use Case Model is being constructed, these techniques also provide an opportunity to inspect the Requirements Document under a point of view similar to PBR-User technique. GUCCRA techniques are composed of two readings: AGRT (Actor-Goal Reading Technique) and UCRT (Use Case Reading Technique).

It is worthwhile to notice that Requirements Document must be written in an adequate manner, for example, the IEEE standard [13]. Therefore, this document must have at least one section that contains the functional requirements, another one that contains the main functionalities of the system to be implemented and yet another one where the user characteristics that interact with the system are declared.

The objective of AGRT is to identify the candidates to be actors and their goals taking into account, respectively, the nouns and the verbs assigned in the Requirements Document, which is the input to this technique. The output of the AGRT application is a form, named Actor-Goal Form (AGF), that was based on the Actor-Goal List, proposed by Cockburn [9], whose objective is to be an initial point to deal with the stakeholders, when the system requirements elicitation is being carried out. The outputs of AGRT are the Defect Report that contains the defects found on the Requirements Document and the AGF that contains the relation of actors and their goals, which is used as one of the inputs for the application of the UCRT.

The objective of UCRT is to elaborate the Use Case Model which is composed of the Use Case Diagram and the Use Case Specifications. The input to this technique is the AGF, since the Use Cases are defined taking into account the goals related in this form, and the Requirements Document. During UCRT application the preliminary

Use Cases created are recorded in the Preliminary Use Case Form (PUCF) and the Use Case Specifications are recorded in the template based on the several authors [7][8][9] and [14]. At the end of UCRT application, the Use Case Diagram could be instantiated from the Use Case Specification Templates.

3. The Feasability Study

The feasability study was carried out to evaluate the use of GUCCRA for Use Case construction. This study was planned as an experiment and was based on the experimentation software process proposed by Wohlin et al. [15].

3.1. Experiment Definition

Analyze……	GUCCRA techniques and Ad-Hoc approach for Use Case Model construction
For the purpose of……	evaluation
With respect to.....…	effectiveness and efficiency
From the point of view of.	researcher
In the context of……...	undergraduate students

3.2. Goals of the Study

The objective of this experiment is to compare the generated Use Case Models when using GUCCRA and Ad-Hoc techniques. In order to allow this comparison an Oracle Model of the Use Case Model was elaborated for each Requirements Document used in the experiment. This Oracle was constructed by a person that knew GUCCRA and followed the technique step by step. This decision was taken based on two reasons: i) a similar technique for Use Case Model construction was not found in the literature and ii) the intention was to evaluate de understandability of the technique besides its effectiveness. Hence, based on this model it is possible to evaluate some characteristics such as if the subjects that used GUCCRA techniques identified different Use Cases of the Oracle Model than the groups that used Ad-Hoc approach. The following questions are explored:

Q1) Is there a time difference between the GUCCRA techniques and an Ad-Hoc approach?

Q2) Is there a difference in the number of 'Actor/Use-Case' association identified by subjects who applied GUCCRA techniques and subjects who applied Ad-Hoc approach?

Q3) Is there a difference in the effectiveness and efficiency by subjects who applied GUCCRA techniques and Ad-Hoc approach?

3.3. Planning

Context Selection: The experiment was executed by 18 undergraduate students of the Computer Science course during Software Engineering classes. They were aware of the importance in participating of the experiment.

Variables Selection:

- **Independent Variables:**
  - ***Methodology used*:** In the first session, the Ad-Hoc approach was used and in the second and third sessions, the GUCCRA techniques were used.
  - ***Students experience*:** the students had no previous experience with Use Case modeling.

- **Dependent Variables:**
  - ***'Actor/Use-Case' Association***: the number of 'Actor/Use Case' association of the Oracle Model found by the subject. (An 'Actor/Use-Case' association corresponds to a link between an actor and a Use Case, even if the Use Case is related with the actor indirectly, by means of an <<include>> or <<extend>> stereotypes)
  - ***Time**:* time spent (in hours) to apply the techniques.
  - ***Occurrences of 'Actor/Use-Case' Association***: the number times the 'Actor/Use Case' association was found (each subject has a chance to find the 'Actor/Use-Case' association). The maximum number of occurrences for an 'Actor/Use-Case' association is the number of subjects. The total number of occurrences of all 'Actor/Use-Case' association (TotalOc) is calculated as follows:

$$\text{TotalOc} = \sum_{i=1}^{n}(x_i)$$ where x_i is the number of 'Actor/Use-Case' association found by the subject *i*.

  - ***Effectiveness***: the average percentage of 'Actor/Use-Case' association found by a group of subjects. The effectiveness is calculated as follows:

$$(\sum_{i=1}^{n}(x_i / y))*100/n$$ where x_i is the number of 'Actor/Use-Case' association found by the subject *i*; *y* is the total number of 'Actor/Use-Case' association in the Use Case Model and *n* is the number of subjects in the group.

  - ***Efficiency***: the average of 'Actor/Use-Case' association found by each subject per hour. The efficiency is calculated as follows:

$$(\sum_{i=1}^{n}(x_i / k_i))/n$$ where x_i is the number of 'Actor/Use-Case' association found by the subject *i*; k_i is the effort (in hours) used by subject *i* and *n* is the number of subjects in the group.

Experimental Design: Figure 1 shows the experimental design. The six Requirement Documents used during the experiment were built by the students. It is important to notice that the group who created the Requirements Document did not use it for the Ad-Hoc or GUCCRA application.

Group A **3 subjects**	Group B **3 subjects**	Group C **3 subjects**	Group D **3 subjects**	Group E **3 subjects**	Group F **3 subjects**
Training in Use Case Modeling (Ad-Hoc)					
Req. Doc. D	Req. Doc. F	Req. Doc. B	Req. Doc. A	Req. Doc. C	Req. Doc. E
Training in Actor Goal Reading Technique					
Req. Doc. C	Req. Doc. D	Req. Doc. F	Req. Doc. E	Req. Doc. A	Req. Doc. B
Training in Use Case Reading Technique					
Req. Doc. C	Req. Doc. D	Req. Doc. F	Req. Doc. E	Req. Doc. A	Req. Doc. B

Figure 1. Experimental Design

Validity Evaluation:

- **Internal Validity:**
  - The grading of the Software Engineering course was based only on experiment participation and not based on the subject performance. Hence, the subjects had nothing to gain from the actual outcome of the experiment.
  - The communication among the subjects could not be controlled.
  - The technique used to construct the Oracle Model was GUCCRA, the same technique used by the subjects during the experiment, due to the reasons mentioned earlier.
  - A possible learning effect on the subjects produced by the Ad-Hoc application may have an impact on the results of GUCCRA application.

- **External Validity:**
  - As this study was run with subjects that were not experienced in Use Case modeling it is not possible to arrive at any conclusion regarding the use of these techniques by subjects that have more experience in Use Case modeling.

3.4. Operation

Execution: The experiment was conducted in three sessions: the first one was the Ad-Hoc training that lasted 45 minutes. The Ad-Hoc approach corresponds to the construction of the Use Case based on the suggestions presented in the literature and mentioned in Section 1. To illustrate the concepts generic examples were used. The second session was conducted fifteen days later and the subjects were trained in the Actor Goal Reading Technique (AGRT) during 90 minutes. The third session was conducted fifteen days after AGRT training and the subjects were trained in the Use Case Reading Technique (UCRT) during 120 minutes. For both training techniques the same Requirements Document were used. It is important to notice that the technique complexities was the reason for the trainning time to be different for each technique.

The guidelines used for Use Case Diagram and Specification were the same in the Ad-Hoc approach and GUCCRA techniques. Thus, the subjects were trained in the

Use Case modeling with UML notation [1] and Cockburn's [9] and Anchor's [10] guidelines.

After each session, the students applied the techniques in the Requirements Documents they received. It began in the software engineering class and finished as homework. The subjects had permission to clear their doubts during the entire time. They had to deliver the artifacts generated from each technique application before the the next session's training. They used different Requirements Document to apply Ad-Hoc and GUCCRA techniques and they registered the total time they spent to apply them.

3.5. Analysis and Interpretation

The analysis and interpretation of this experiment address each of the three questions posed earlier. This section will be organized around them.

Q1) Is there a time difference between the GUCCRA technique and an Ad-Hoc approach?

H0: There is no time difference between the GUCCRA technique and an Ad-Hoc approach.
Ha: There is a time difference between the GUCCRA technique and an Ad-Hoc approach.

To evaluate the Ad-Hoc and GUCCRA application time ANOVA one-way was used. Considering a significance level of 95%, the null hypothesis H0 can be rejected (p-value = 0.013), which means that the variable reading techniques influenced the results.

According to Figure 2, the GUCCRA application time, in average, is greater than Ad-Hoc application time for all Requirements Documents. It can be observed that the smallest difference between these averages occurred for document B and the biggest difference occurred for document E. Furthermore, despite these average differences, it can be observed in Figure 3 that the GUCCRA effectiveness (B-93.75%; E-83.33%) in both documents is greater than Ad-Hoc effectiveness (B-47.92%; E-66.67%).

Although the time average of GUCCRA application in Requirements Document E was considered discrepant in relation to the other ones, it is important to notice that this document was the biggest. However, its size did not influence GUCCRA effectiveness.

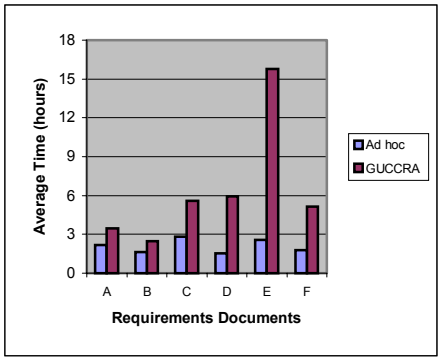

Figure 2. Ad-Hoc and GUCCRA average applicaton time

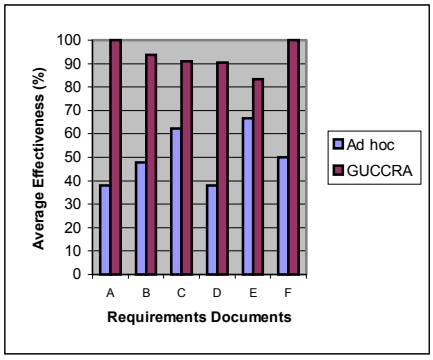

Figure 3. Ad-Hoc and GUCCRA average effectiveness

Q2) Is there a difference in the number of 'Actor/Use-Case' association identified by subjects who applied GUCCRA techniques and subjects who applied Ad-Hoc approach?

H0: There is no 'Actor/Use-Case' association number difference between the GUCCRA technique and an Ad-Hoc approach.

Ha: There is an 'Actor/Use-Case' association number difference between the GUCCRA technique and an Ad-Hoc approach.

To evaluate the difference in the number of 'Actor/Use-Case' association identified by subjects who applied GUCCRA techniques and subjetcs who applied Ad-Hoc approach ANOVA one-way was used. Considering a significance level of 95%, the null hypothesis H0 can be rejected (p-value = 0.018) for the number of 'Actor/Use-Case' associations, which means that the variable reading techniques influenced the results.

Thus, analzying the Use Case Models created during the experiment, it can be observed that there are many Use Cases created by Ad-Hoc approach which are not necessary for the system being modeled (probably, they should be steps of another Use Cases).

Q3) Is there a difference in the effectiveness and efficiency by subjects who applied GUCCRA techniques and Ad-Hoc approach?

When analyzing the data for individual subjects, we performed a statistical analysis. The objective of the statistical analysis was to determine whether individual subjects performed differently when using GUCCRA techniques than when using Ad-Hoc approach. The dependent variables were individual effectiveness and efficiency. Because the experimental groups had the same number of subjects, the ANOVA for balanced design was used. The signficance level used was 95%. This analysis involved two different factors, or treatments: the reading technique (RT) and the

Requirements Document (DOC). Three sets of hypotheses were tested with relation to effectiveness and to efficiency.

RT X DOC interaction effect

H0: There is no difference between subjects applying GUCCRA techniques and subjects applying Ad-Hoc approach with respect to individual effectiveness/efficiency.

Ha: There is a difference between subjects applying GUCCRA techniques and subjects applying Ad-Hoc approach with respect to individual effectiveness/efficiency.

Main effect RT

H0: There is no difference between subjects using GUCCRA techniques and subjects using Ad-Hoc approach with respect to individual effectiveness/efficiency.

Ha: There is a difference between subjects using GUCCRA techniques and subjects using Ad-Hoc approach with respect to individual effectiveness/efficiency.

Main effect DOC

H0: There is no difference between subjects reading different Requirements Document with respect to individual effectiveness/efficiency.

Ha: There is a difference between subjects reading different Requirements Document with respect to individual effectiveness/efficiency.

For the effectiveness, based on the results in Table 1, H0 can be rejected for interaction effect and for the main effect RT, which means that the variables influenced the results. Conversely, H0 cannot be rejected for the main effect DOC, which means that it cannot be shown that the variables have an influence on the results.

For the efficiency, based on the results in Table 1, H0 can be rejected for interaction effect and for the main effect DOC, which means that the variable influenced the results. Conversely, we cannot conclude that the variable RT had any influence on the results.

Table 1. ANOVA p-values with respect to effectiveness and efficiency

Independent Variables	Effectiveness (p-value)	Efficiency(p-value)
RT X DOC	0.028✓	< 0.001✓
RT	< 0.001✓	0.231
DOC	0.983	< 0.001✓

To further study the question of whether GUCCRA techniques or Ad-Hoc approach is more effective and efficient, Table 2 summarizes the data collected concerning the 'Actor/Use-Case' associations found (union of 'Actor/Use-Case' association found by individual subjects), as well as average subject effectiveness and efficiency. The total number of 'Actor/Use-Case' association is obtained from the Oracle Model that was developed for each Requirements Document. In the "Average of Total Use Cases" column the average number of Use Cases constructed is

presented, despite beeing coincident with the ones of the Oracle Model. In the sequence, these results are evaluated from a quantitative point of view.

An interesting result from the experiment is related to Requirement Documents A and F. In both documents the subjects that used GUCCRA were 100% effective in the Use Case construction, that is, the identified Use Cases were the same as the ones of the Oracle Model. On the other hand, subjects that used Ad-Hoc approach were about 50% effective in the Use Case construction. For document F the subjects identified many Use Cases that were not relevant for the system, i.e., from the average of total |Use Cases (5), only one was coincident with the Oracle Model. These results are an indicative of the standadization reached when GUCCRA is applied. We observed that document A was better elaborated than document F, meaning, more complete, more consistent, etc. It would be a good idea to investigate both documents in order to evaluate the analysis aspect of these techniques, that is, to verify if in document F, that was not elaborated in a properly manner, many defects were found when applying GUCCRA.

Table 2. Comparing the results for Requirement Documents

DOC	TEC	('Actor/Use-Case' Association) / ('Actor/Use-Case' Association Total)	(Occurrences of 'Actor/Use-Case' Association) / (TotalOc)	Effectiveness	Efficiency	Average of Total Use Cases
A	GUCCRA	7/7 (100%)	21/21	100	2.15	7
	Ad-Hoc	4/7 (57%)	8/21	38.10	1.20	14
B	GUCCRA	16/16 (100%)	45/48	93.75	6.10	16
	Ad-Hoc	13/16 (81%)	23/48	47.92	4.78	16
C	GUCCRA	14/15 (93%)	41/45	91.11	2.61	14
	Ad-Hoc	14/15 (93%)	28/45	62.22	3.47	25
D	GUCCRA	14/14 (100%)	38/42	90.48	2.24	14
	Ad-Hoc	11/14 (78%)	16/42	38.10	3.71	19
E	GUCCRA	22/24 (91%)	60/72	83.3	1.28	22
	Ad-Hoc	22/24 (91%)	48/72	66.67	6.39	20
F	GUCCRA	2/2 (100%)	6/6	100	0.41	2
	Ad-Hoc	1/2 (50%)	3/6	50	0.57	5

Another result that should be evaluated is related to the number of Use Cases created by GUCCRA techniques. In some documents this number was greater than the Use Cases of the Oracle Model. It may be that this situation is related to the application of the first technique (AGRT), since it is considered that there is a subjectiveness degree in the identification of the goals associated with the actors in the Requirements Document, which may lead to different interpretations on possible uses that the actor needs of the system. This last point could be treated, respectively, introducing more formalism in the writing of the functional requirements of the Requirements Document. Besides, this subjectiveness may influence the threat to validity related to the construction of the Oracle Model.

In relation to the order that the techniques were applied and the learning effect established as one of the threats to validity, it is important to observe that to apply

GUCCRA technique it is necessary that the subjects have minimal knowledge regarding Use Case Model concepts. Thus, we can consider that the Ad-Hoc modeling contributed for this purpose.

4. Conclusions

This paper provided an overview of GUCCRA techniques (*Guidelines for Use Case Construction and Requirement document Analysis*). These techniques aim at supplying guidelines to construct Use Case Models, also providing an opportunity to inspect the Requirements Document. GUCCRA is composed of two readings: AGRT (*Actor Goal Reading Technique*) that generates a list of actors and the goals with which the actors will use the system and the UCRT (*Use Case Reading Technique*) which supports the construction of Use Case Models (Diagram and Use Case Specifications).

In this paper, the feasability of applying these techniques and the positive results of applying them was explored through the presentation of an experiment that was carried out where the construction of Use Case Models was compared with groups that used GUCCRA and groups that did not use them, that is, they only used their experience (Ad-Hoc). The main conclusions derived from the results presented in this paper were:

1. GUCCRA makes the identification of most standardized Use Cases easier, as the designer has a clear set of steps to follow;
2. GUCCRA increases the effectiveness in identifying Use Cases and helps decision making in relation to functionality grouping or splitting;
3. the Use Cases identified by GUCCRA are a more accurate representation of the Requirements Document since GUCCRA techniques avoid similar functionalities in more than one Use Case and extra functionalities that could be supposed by the designer.

In this manner such reading techniques make the elaboration of Use Case Model more systematic making this activity less dependent on the designer's subjectiveness and experience.

For the future the intention is to evaluate the effectiveness of these techniques in relation to the subjective aspects earlier mentioned, aiming at contributing with other works under development at present and whose objectives are related to the writing format both in the Requirements Document as well as in the Use Case Specification. Furthermore, another future step to be carried out shortly is the conduction of another experiment that will explore the analysis aspect of the GUCCRA techniques, that is, an experiment that evaluates the similarity and the complementary aspects between GUCCRA techniques and the PBR-User technique in respect to defect detection in the Requirements Document.

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