Fraunhofer Institut
Experimentelles
Software Engineering

Guidelines - Creating Use Cases for Embedded Systems

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Supported by the BMBF under the grant number VFG0004A ("QUASAR") and by Provincia Autonoma di Trento in the "Forpics" project

IESE-Report No. 078.03/E
Version 1.0
September 17, 2003

A publication by Fraunhofer IESE

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Abstract

In the automotive domain, the increasing complexity of software demands a requirements process that is tailored to the needs of the stakeholders involved in the development process. UCs and Statecharts are commonly used as specification techniques in many projects. In this report we present guidelines to derive UCs for embedded systems in a systematic, repeatable und verifiable way. We illustrate them with a case study for developing an electronic control unit for a car. These guidelines have been collected from literature and from several case studies. In the second part of the report we describe in detail an evaluation of these guidelines in the context of a Praktikum at the University of Kaiserslautern in summer term 2003.

Keywords: Requirements Specification, UCs, Monitored Variables, Controlled Vari ables, QUASAR

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1 Introduction

UCs are an important means for elicitation and specification of functional requirements. In particular they help to understand the system from the user point of view. Only with this understanding the system will be adequate for its context.
Thus, a UC specification is on purpose different from a system function specification. The latter describes in detail the behavior of the system, while the former describes how the system can be used by the user to support the user tasks.
The guidelines presented here should help developers creating UCs for embedded systems. We do not presuppose any specific basis documents for creating UCs. Typically, a short problem statement will exist capturing why a system has to be built. Or a business process description that captures the processes in which the system should be used. In case of embedded systems, systems are typically not built from scratch. Thus, often there exist quite detailed system function specification of similar systems. In this case UCs help to focus on the overall purpose of the system and support not to get lost in the details [WW03].
The UCs created with these guidelines are typically part of the requirements specification (german: Lastenheft) and used as input for deriving a more refined system specification (german: Pflichtenheft). In general, we do not recommend including all details of the system specification into the UCs, since they will get too long. In any case one should make sure that the system details are separated from the main UC description. QUASAR UCs are part of the requirements specification, while statecharts are used for functional requirements in the system specification [KKP01]. [D+02] gives guidelines how to systematically derive statecharts from the UCs.
We have collected the guidelines from literature and our experiences in the QUASAR project. Guidelines that are reported in the literature are referenced. Examples are taken from the QUASAR case study "door control unit" [HP01].
It is assumed that the readers have basic knowledge of UCs (see e.g. [Co01]. This report is not an introduction to UCs, but should help readers to systematically derive UCs.
The report is structured as follows: first we collect general guidelines for text documents. In chapter 3 we describe the 5 steps of the guidelines. Their evaluation is discussed in chapter 4. We conclude with the lessons learned. The appendix contains the questionnaires used for the evaluation.

2 General Guidelines for Text Documents

Since textual documents are prone to misunderstandings and inconsistencies, it is important to be especially careful with the wording. In the following we list the most basic hints wrt. clear wording and structure.

- Use appropriate terminology [RB98]. Explain important terms from the domain in a glossary. Explain abbreviations before their use.
- Use terminology consistently. Avoid synonyms (two names for the same thing) and homonyms (one name for two different things). [RB98]
- Avoid anaphoric references (where the reference point is not clear) [RB98] E.g. not "The system controls temperature and heat. It should not be…." What is "It", the system, the temperature or the heat?
- Avoid negated sentences [RB98]
- Avoid modalities (german: Modalverben) that means verbs which only can be used in connection with other verbs (like "would", must" etc). [RB98]. Sometimes in requirements documents these verbs are used on purpose, where e.g. "must" describes the most important requirements and "should" optional requirements. In this case it is important to use these conventions consistently.
- Use short sentences. Avoid subordinate sentences (german: Nebensätze).

3 Deriving Use Cases

This chapter describes the steps for the creation of UCs and of a UC diagram for an embedded system.

In the following all guidelines are listed with a bullet. The other text gives basic explanations helpful to understand the guidelines and their purpose.

3.1 Step 1: Create list of actors

Actors are roles or external systems that use the system that should be developed. A role abstracts from specific persons and concentrates on their responsibilities. A sensor or actuator does not use the system, therefore is not an external system and thus not an actor.

- Create a list of actors. Do not confuse actors with the devices they use [BS03]. E.g. the triggering actor of a fire detection system is the actor who is interested in the system reaction and the fire is an input to the system.

3.2 Step 2: Create list of tasks of the actors and visualize as UC diagram

Tasks are characterized through goals actors want to achieve. To capture the user point of view it is important to abstract as much as possible from technical solutions.

Tasks should pass the "coffee test" [La03]. That means the actor has deserved a cup of coffee after finishing a task. So they are more comprehensive than just system functions. For embedded systems a task is typically a condition of the system that the user wants to achieve. E.g. for a car "adjust seat position" or "making window clear" is a task The major tasks are also called *function blocks.* (in [Co01] they are called sea-level UCs).

Tasks are visualized in UC diagrams (e.g. see Figure 1). In contrast to ordinary UC diagrams we distinguish two kinds of tasks visualizations: The tasks that are mainly influenced by the user are visualized as bubbles crossing the border between system and environment. Tasks that mainly concern system reaction are shown inside the border. For embedded systems this means that the triggering and the achievement of a condition of the system is the border crossing task while the major system reaction is depicted inside the border. In this step only the former are elicited.

A UC is triggered by the *primary actor;* that is, the actor the UC is written for, but it may involve other actors which are called *secondary or supporting actors* (e.g. a supporting actor proSees information the system needs to perform a certain function that is not given by the primary actor).

- Think about the major tasks of the actors (that are function blocks). Elicit the user tasks within the function block. The achievement of these tasks need to be visible in the environment and should abstract as much as possible from system states.

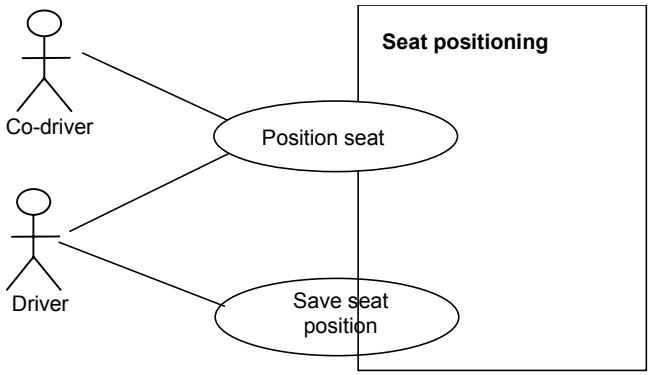

Figure 1: UC Diagram for function block "seat positioning".

- The name should reflect the intention of the actor. Use <predicate> <object> for tasks and <object> <predicate> for function blocks, e.g. "Seat positioning" in Figure 1 is a function block and "Position seat" a task. Often it is helpful to make the goal of the actor explicit, e.g. "achieve comfortable seat position".

A UC diagram connects actors with their tasks (see Figure 1).

- Create a UC diagram. Do not forget the supporting actors [BS03].
- Do not use relationships between UCs at this stage, because this bears the risk that the UCs get too fine-grained (like system functions).

3.3 Step 3: Define inputs (monitored variables) and outputs (controlled variables) of the function blocks and create context diagram

Inputs (also called *Monitored Variables)* capture the quantities that can influence the system behavior. These are different possibilities of the actors to trigger the system and environmental (through sensors) or internal (through storage) information.

Outputs (also called *Controlled Variables*) are quantities controlled by the system. These are information to the actor and to the parts controlled (through ac-

tuators) and internal data updates. These variables can be identified from the tasks. The context diagram connects the inputs and outputs to a function block.

Name	Description
Actual seat position	The actual position of the seat consists of: • Distance between steering-wheel and seat • Seat area front • Seat area rear • Seat casing • Back angle
Direct seat position input	Any seat position input by the user inside the vehicle. The seat position consists of: • Distance between steering-wheel and seat • Seat area front • Seat area rear • Seat casing • Back angle
Actual speed	The vehicle's actual speed.
External identification input	User identification input outside the vehicle for recalling saved values.
Internal identification input	User identification input inside the vehicle for recalling saved values.
Door-open	Indicates if a door, belonging to the system, is open.
Seat-taken	Indicates if a seat, belonging to the system, is taken.
Memory input	Special input medium for saving the actual seat position
Child security -active	Indicates if child security is activated.
Window pane position input	User input for the desired window pane position: • Direction of movement up/down • Movement type partial/total At partial movement, the window pane is moving as long as the user holds the key. At total movement, the window pane closes or opens completely dependent on the movement direction.
Actual window pane movement	Indicates if the window pane is moving. Needed for the jamming protection.
Saved seat position	The seat position, which is saved for different user identifications, consists of: • Distance between steering-wheel and seat • Seat area front • Seat area rear • Seat casing • Back angle

Figure 2: Monitored Variable list

In Figure 2 "Internal identification input" and "External identification input" are different ways to input the user identification (either from inside the car or from outside). "Door-open" is system data relevant for the behavior, as several functions of the seat positioning are not possible if the driver door is open and others are only possible with the door opened.

Name	Description
New seat position	The seat's new position after accomplishing the seat movement consists of: • Distance between steering-wheel and seat • Seat area front • Seat area rear • Seat casing • Back angle
Saved seat position	The seat position, which is saved for different user identifications, consists of: • Distance between steering-wheel and seat • Seat area front • Seat area rear • Seat casing • Back angle

Figure 3: Controlled Variable List

"New seat position" is the controlled quantity. "Saved seat position" is data to be stored within the system. Both are outputs and thus described in a list for the controlled variables as shown in Figure 3.

Note that "Saved seat position" is also described in Figure 2. The reason for that is that this variable is a monitored and controlled variable at the same time. Such variables should be described in both lists.

It is also helpful to visualize the association between variables and function blocks in a context diagram as in Figure 4.

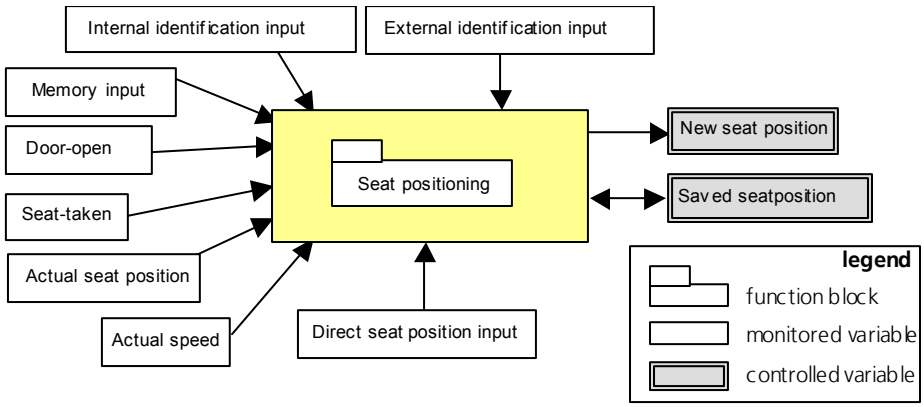

Figure 4: Context Diagram for "Seat positioning"

- Create list of monitored and controlled variables, which captures the name and the description (see Figure 2 and Figure 3).
- Variables that are monitored and controlled at the same time should be described in both tables.

- Use complex variables, e.g. "Actual seat position". Do not differentiate in parts, if the behavior does not differ significantly (e.g. do not differentiate "Seat area front" und "seat area back"). For outputs show the actor's intent, not the detailed system reaction [AM01].
- Identify actor inputs with a name " <object> input", e.g. "External identification input".
- Abstract from inputs due to technical problems (e.g. "no movement of the seat" is not an input, but a condition to be dealt with in the UC).
- Do not separate inputs which are needed to trigger one task (that is, both inputs are needed to trigger the same task) . E.g. "Internal identification input" comprises the selection of the "Position seat" function as well as the "Identification" given by the actor.
- Abstract from user interface details [Co01]. E.g. do not use "seat_position_button", unless it is required that this is a button (e.g. instead of a touch screen).
- Create a context diagram for each function block

These inputs and outputs help to delineate the system boundary [Li99], but do not fix the details of the man – machine interface. It is important to keep these details separate from the UC description, because this often changes over time and between different releases. Thus, abstraction supports maintenance and reuse of the UC description. The detailed decision for the user interface can be captured in separate tables, associating variables with specific devices (e.g. "external identification input" with a button on the driver key) or parts of a screen.

3.4 Step 4: Refine tasks according to monitored/controlled variables and refine UC diagram and context diagram accordingly

Typically the tasks need to be refined when looking at the detailed behavior. In particular, there are several variations to be considered.

- Think of the typical performances of the UC. If you identify variations, either in actor or in system behavior, distinguish three cases:
  - If the variation is quite likely and results in significantly different behavior of actor or system, then define new UCs for the different variations. These new UCs should be included by the general UC.
  - If the variation is quite likely, but can easily be described as a case distinction, include this distinction in the UCs.
  - If the variation is not likely, include it as an exception in the UCs.

- These cases cannot be sharply distinguished. The main driver for the decision should be the understandability from the viewpoint of the user.
- Typical variations result from:
  - other inputs (also from other actors), e.g. the "Driver" can use different inputs to trigger the "Seat positioning". So one input could interrupt the execution of the current UC. In Figure 5 the actor can input "Direct seat position input" to interrupt the system reaction to "Internal identification input".
  - changing system data (e.g. if the speed changes, the system reaction to "Internal identification input" has to stop). This includes changes in the environment sensed by the system.
  - problems in carrying out the system reaction (e.g. if there is a technical problem, the system will not react as expected from the user)
  - reaching limit positions (e.g. if the seat angle has reached its limit, the system cannot react any more)
  - major modes of operations of the system (e.g. a "comfort use" and a "normal use").

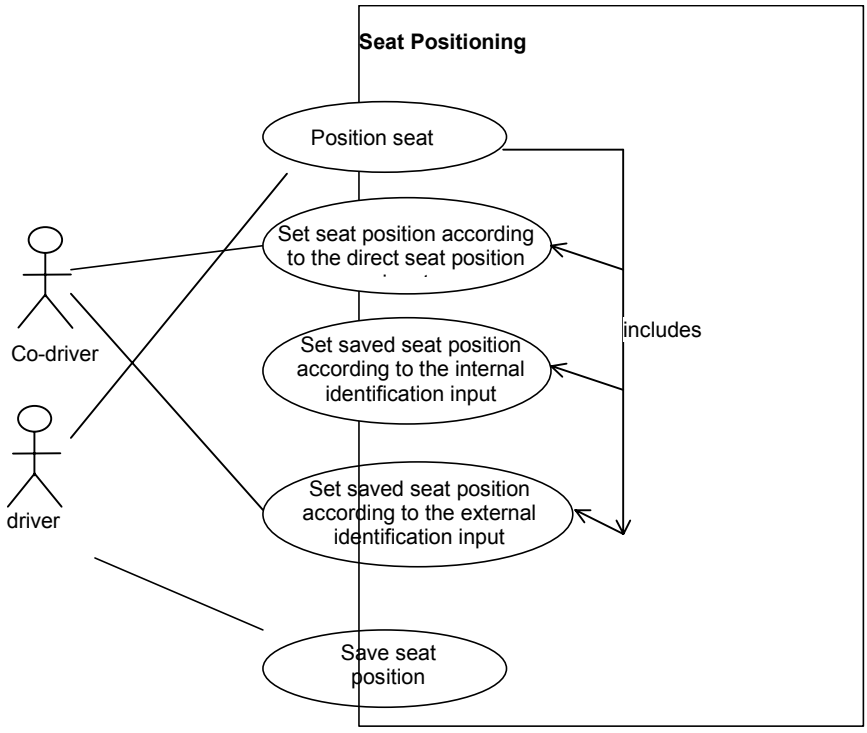

Figure 5: Refined UC diagram "seat positioning"

- To decide, whether the behavior differs, informally sketch the behavior:
  - Describe system reaction informally for each monitored variable and each tasks especially focusing on exceptions.
  - If the reaction differs (in terms of steps executed by the system or in terms of exceptions) for the cases distinguished below, then refine tasks into different subtasks and include them in the UC diagram (as separate UCs related to the major task with "includes"). "Extends"-relationships can be used to show that one UC extends the behavior of another UC. The following cases should be considered (for an example see Figure 5 which refines Figure 2). The behavior differs for
    - different monitored variables (e.g. the reaction of "Internal identification input" and "External identification input" differs because for the former also the current speed has to be considered) or
    - different actors (e.g. the reaction for "Driver" und "Co-driver" differs, because only the "Driver" can use "Internal identification input") or
    - different parts of the controlled variable (no example in Figure 5, one possible example would be different behavior for the "Back angle" or "Seat area back". Then "Set back angle" should be distinguished from "Set seat area back")

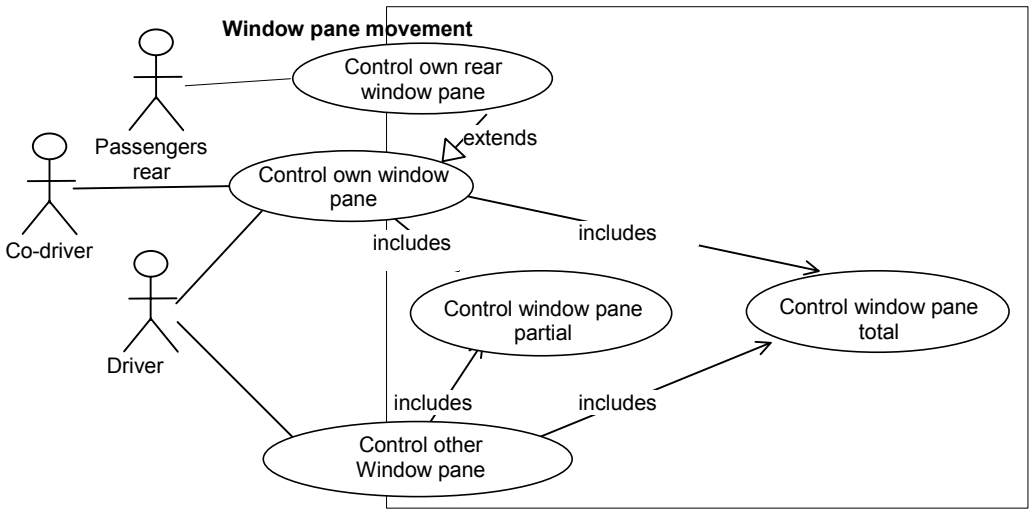

Figure 6: refined UC diagram for "window positioning"

Figure 6 shows a refined UC diagram for the function block "window positioning". The UC "Control own rear window pane" extends the UC "Control own window pane", because the former behaves like the latter but in addition deals with "Child security".

- Package similar monitored or controlled variables, if they trigger or exhibit similar behavior, respectively. (e.g. "moving up and down" is essentially the same behavior of a window, because the system mainly follows the user input and checks for limit positions. Thus, it is enough to use monitored variable "Windowpanepostion" instead of "Windowpaneposition_up" and "Windowpaneposition_down".)
- Adapt context diagram and UC diagram according to changes in the variables and UCs. Only use extends and includes relationships, if really necessary.
- Avoid too many UCs (there should not be more then 10 for each function block) [Li99]
- Do not forget the supporting UCs [BS03]. These UCs help to achieve certain preconditions for other UCs or tracking information relevant for other UCs.

For embedded systems very technical descriptions are typical. Thus, it is tempting to use the system viewpoint too early. E.g. for a temperature control system, it is tempting to just use different system modes (e.g. comfort, standby, off, non-heating) as different tasks. However, from the view of the user these modes have different significance: Standby and off should be treated as case distinctions, since system behavior only differs for some temperature parameters. Comfort, nonheating and standby/off differ significantly, because in the first and second case the system behaves independently of the user actions (it keeps temperature or it does not heat at all), and in the third case it reacts to the presence or absence of the user. Since nonheating does not really induce system behavior (it is non-behavior), the two tasks "start comfort modus" and "enter room" should be distinguished, where nonheating is treated as exceptions to both.

3.5 Step 5: Fill out UC template for each identified UC

The details of the combined behavior of the user and the system to achieve a task need to be collected in a template. This template supports completeness of the description as well as efficient access to specific aspects of the requirements.

As an example, Figure 7 shows the UC template for the UC "Set saved seat position according to internal identification input".

- The filled template should not be longer than 2 pages [Li99].
- Refine UC diagram and/or context diagram, if you discover new actors, inputs or outputs or subtasks during UC description.
- Take the name and the actor of the UC from the UC diagram. In the intent description give essential additional information that could not be reflected

in the name (in order to avoid names which are too long). So e.g. in Figure 7 the intent also makes explicit that "Driver seat" is to be moved (in contrast to e.g. the "Co-driver seat").

- In case that a UC only includes other UCs (e.g. the UC "Position seat" in Figure 5), then this UC should also be described in the template. Specify explicitly when the included UCs will be called in the event flow (see for example Figure 8).

UseCase	Set saved seat position according to internal identification
Actors	Driver
Intent	Actor sets saved seat position of the driver seat
Preconditions	None
Flow of events	1. Actor enters identification over internal identification input 2. System moves driver seat in the seat position saved under the entered identification [Exception: no seat position saved] [Exception: speed is too high] [Exception: actor activates identification input] [Exception: actor activates direct seat position input] [Exception: technical problem]
Exceptions	• No seat position saved: system doesn't react • Speed is too high: system doesn't react • Actor activates identification input: at internal identification input: → UC *„Set seat position according to internal identification input"*, at external identification input: → UC *„set seat position according to external identification input"* • Actor activates direct seat positioning: → UC *„Set seat position according to direct seat position input"* • Technical problem: system sets at least one movement direction not as wished
Rules	• Speed too high, if > 5 km/h • At set saved seat position: first the relaxing movements, then the opposed movements. Relaxing movements are increasing the distance between seat and steering-wheel, increasing the back angle, lowering the seat area, increasing of the casing size • At a particular time, the seat is only allowed to move in two directions. The order is: distance between seat and steering-wheel, back angle, casing size, seat area front, seat area back
Quality constraints	None
Monitored environmental variables	• Internal identification input • Actual speed • Saved seat position
Controlled environmental variables	• New seat position
Postconditions	Seat position changed

Figure 7: UC Description for "Set saved seat position according to internal identification input"

UseCase	Position seat
Actors	Driver
Intent	Actor positions his/her seat according to his/her
Preconditions	None
Flow of events	• Actor activates direct seat positioning input and no identification input (→ UC *„Set seat position according to the direct seat position input"*) Or 1a) Actor activates internal identification input (→ UC *„Set saved seat position according to internal identification input"*) Or 1b) Actor activates external identification input (→ UC "*Set saved seat position according to internal identification input*)
Exceptions	See included UCs
Rules	See included UCs
Quality constraints	See included UCs
Monitored environmental variables	See included UCs
Controlled environmental variables	See included UCs
Postconditions	Seat position changed

Figure 8: UC description for "Position seat"

3.5.1 Preconditon

Preconditions capture conditions needed for successful execution of the UC. They are typically established by other UC.

- Use present tense to formulate preconditions.
- Preconditions must describe system or environmental states visible to the actor.

3.5.2 Flow of events

The flow of events is the most important facet of the UC template. It captures how the actor together with the system achieves the actors' task (described in the intent). It is different from a system function description. The latter describes the output of the system in reaction to an actor input. The UC description describes the behavior of actor and system together. For an embedded systems often the flow of event is quite short consisting only of one actor action and one system reaction. For information systems UCs typically comprise several actor actions.

The flow of event description consists of actor input and major system reaction and exceptions. Note that exceptions are different from case distinctions.

- Refine the informal system description from step 4.

- Give numbers to actor and system actions. You can additionally label actor actions with "Act" and system actions with "Sys" [RB98]
- Use active and present tense to describe the actions [RB98,BS03].
- Use affirmative wording ("system validates that" instead of "system checks if". The former describes the positive case, the latter leaves the outcome open. [,Co01]
- If there are several possible paths to reach the goal, think of one typical scenario and complete it gradually with exceptions or case distinctions. [,RB98].
- Capture all exceptions with a name, e.g. "Exception: Speed is too high". List them *after* the typical system reaction (so they describe what could happen to prevent this system reaction).
- If the system action comprises computations or business rules, separate them into the rule facet.

3.5.3 Exceptions

In this facet the system behavior for the exceptions is described.

- Use other UC as much as possible to shorten description of the exceptional behavior. (e.g. reference to UC "Set saved seat position according to internal identification" for the exception "Actor activates internal identification")
- Preconditions must not be dealt with in the exceptions.
- Describe explicitly the postcondition of the exception treatment.
- Make clear, if the exception treatment leads back to a state in the normal scenario.
- If the UC includes other UC, refer to their exceptions and only list exceptions particular to the including UC. For an example see Figure 8.

3.5.4 Rules

Rules are used to describe the system reaction in detail. These details are separated from the flow of the events. Only the details that cause different steps in the flow should be described in the flow of events facet.

- Capture all rules governing system reaction in detail as rules. E.g. in Figure 7 one detail is the exact number when the speed is too high. Another detail is in which order the different seat parts are treated and how many movements are possible in parallel. Of course, these details are important for implementing the system behavior, but they do not need specific user actions nor do they substantially influence the expectations of the user on the system.

- Make clear when a rule is applied.
- In case a separate system specification is created (in German "Pflichtenheft"): Only describe rules that the user should know about. Further refinements are added in the system specification.
- If the UC includes other UC, refer to their rules and only list rules particular to the including UC. For an example see Figure 8.

3.5.5 Quality constraints

Quality constraints capture all quality requirements (e.g. wrt. performance, ressource usage, security) relevant for this particular UC.

- List quality constraints.
- If the UC includes other UC, refer to their constraints and only list constraints particular to the including UC. For an example see Figure 8.

3.5.6 Monitored and controlled Variables

These facets collect all variables relevant for the UC to allow easy cross checks (e.g. when a variable changes, it should be easy to identify which UCs might be affected).

- List all variables mentioned in the flow of events.
- All variables must be part of the context diagram
- If the UC includes other UC, refer to their variables and only list variables particular to the including UC. For an example see Figure 8.

3.5.7 Postcondition

The postcondition describes the effect of the major and successful system reaction (typically in terms of states reached by the controlled variables). Thus it refines the intent in terms of the system states achieved.

- Refine intent to postcondition.
- Make sure that for each precondition of any UC there is a UC that establishes this precondition as postcondition.

4 Evaluation of the Use-Cases Guidelines

The guidelines described in this report have been evaluated in a case study during the practical course "Software Engineering 1" at the university of Kaiserslautern. In this chapter we describe the context of this case study and the outcome of the qualitative evaluation of the UC guidelines. The chapter presents most of the results of the case study but the charts to some questions are not presented in this chapter for sake of clarity. The complete evaluation can be found in Appendix A.

Note that the described evaluation results are based on the version of the guidelines that was used in the case study. The guidelines described in this document are already improved, based on the results of this case study and further analysis.

4.1 The Aim of the Case Study

In recent years, several guidelines and templates were developed to support the requirement engineering phase of a software development projects Beside pure natural language, UCs are the most frequently used notation to describe the functional requirements of a system and thus, guidelines were proposed on how to create UCs and how to use them to describe the system requirements form a user point of view (e.g. [Co01]). Although a lot of guidelines are given, these guidelines are rarely evaluated with respect to their applicability and usefulness when applied in software development projects. The goal of this case study is to evaluate the recommended UCs creation guidelines in order to learn whether the guidelines are perceived as useful and valuable or whether they produce only overhead and useless requirements documents.

4.2 The Context of the Case Study

In order to evaluate the UC-guidelines we performed a case study at the university of Kaiserslautern. The guidelines were used in summer 2003 in the practical course "Software Engineering 1" at the university of Kaiserslautern. During this course the subjects had to develop a building automation system that regulates the temperature and the light in rooms and floors of a university building. In the working description of the practical course the system was separated into three sub-systems, namely, the "Temperature Control" (Temp), "Light Control" (Ligh) and "User Interface" (UI).

The students had to develop the whole system following the V-Model, starting from a general problem description of the system and ending with the acceptance testing of the complete system. Within this development process the students had to develop UCs based on the problem description of the system. As an additional input detailed user requirements for each of the three subsystems were given to the students. After the subjects got acquainted with the problem description, 2 weeks were scheduled for the UC creation and the creation of scenarios for each UC.

12 subjects were involved in the case study and a group of 4 people was responsible for one sub-system. The overall time effort for each subject was scheduled with 10 hours a week for the duration of 11 weeks (for the complete project).

4.2.1 The Empirical Approach in the Case Study

Within the case study the students used the UC guidelines within the first process step; that is, to create the UCs from the problem description and the user requirements for the different sub systems. To evaluate the usefulness of the UC guidelines we used two questionnaires that were given to the subjects before they actively used the UC guidelines and after they used the guidelines to create UCs.

The goal of the first questionnaire ("Pre-Questionnaire") is to capture the experiences of the subjects regarding requirements engineering and UC creation. This questionnaire was filled in by the students after they received the UC guidelines and had read the guidelines once. Thus, a second aim of the pre-questionnaire is to evaluate the first impression of the subjects regarding the usefulness of the guidelines.

The subjects filled in the second questionnaire after they had used the guidelines to create the UCs and the scenarios of the UCs in the practical course. This questionnaire aims at the concrete perception of the subjects regarding the usefulness of the guidelines to support their process of UC creation. The subject's perception of the guidelines after using them can then be compared to their perception before they used them.

In order to evaluated the overall usefulness of the guidelines each of the questionnaires was designed following the model recommended by Davis [Dav89] that evaluates the general usefulness of a certain technique by means of three basic elements:

1. **Perceived usefulness** "the degree to which a person believes that using a particular technique would enhance his or her job performance"

2. **Perceived ease of use (applicability)** "the degree to which a person believes that using a particular technique would be free of effort"
3. **Self-predicted future use** "the degree to which a person would use a particular technique again in the future"

The original definitions of these elements are focused on the use of tools. Note that the above stated definitions are adapted to be used to evaluate general software engineering techniques. According to [LD98] it is also possible to use the model to evaluate the usefulness of software engineering techniques.

The basic idea of the model is that beside other factors, people are one of the most important factors when talking about the use of tools or certain software engineering techniques such as the UC guidelines. The people tend to use a certain technique when they perceive it as helpful to perform their task. But according to [LD98] this factor might be out-weight if the people perceive the technique as too difficult to use; that is, they think that the application of the technique costs to much effort. Thus, it is important to consider the perceived ease of use (applicability) of the technique in combination with the usefulness. The model is complete by the subject's self-predicted future use. This gives hints whether or not the subjects will use a certain technique in a similar situation in the future. This element also indicates on the perceived usefulness and applicability.

As there are no objective measures for the usefulness and the applicability of a technique subjective measures have to be used. In the questionnaire performed after the subjects used the guidelines, the subject's are asked to respond to certain statements in terms of their degree of agreement or disagreement to the statement. In this evaluation the subjects had to select one of six statements (extremely likely, likely, rather likely, rather unlikely, unlikely, extremely unlikely) expressing their agreement or disagreement to a certain statement. In the pre-questionnaire the subject's first impression was also measured subjectively. Of course it is not possible to ask for the self-predicted future use in the pre-questionnaire, thus this aspect was not considered.

In addition to the aspects recommended in the model of Davis we asked the subject's to evaluate the understandability of the guidelines. We perceive this as an additional important aspect when talking about the general understandability of a certain techniques.

4.2.2 The Subject's Qualification

All of the subjects participating in the case study are enrolled at the university of Kaiserslautern in computer science, applied computer science, or industrial engineering with computer science as their major subject. The distribution over the different subjects is shown in Figure 9.

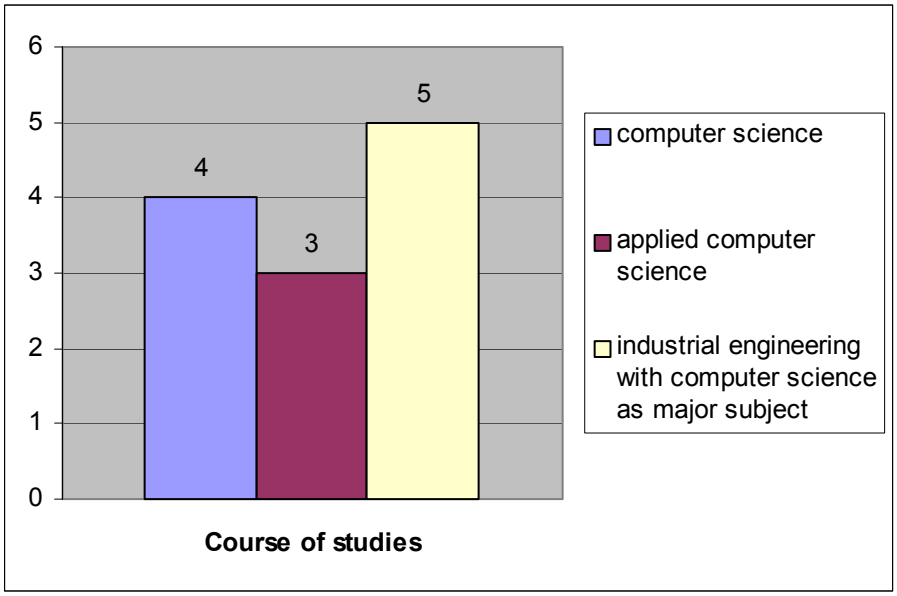

Figure 9: University programs of the subjects

Each of the subjects has passed the "Vordiplom" exams (comparable to bachelor degree) and is in the "Hauptstudium", thus studying at least for 4 semesters. The time the students are already studying is shown in Figure 10. Each student at the university of Kaiserslautern has to perform two practical courses before he or she is allowed to apply for the master's exams. Thus, the motivation of the subjects regarding the practical course (and thus implicitly in creating the UCs) was rather good.

Beside their studies most of the subjects have no additional experiences in the fields of software engineering or computer science. Some subjects have experiences in database development or developing web-applications. Most of the experiences were gained in internships at companies which lasted for several weeks. Only one subject has over 4 years experience in developing database systems.

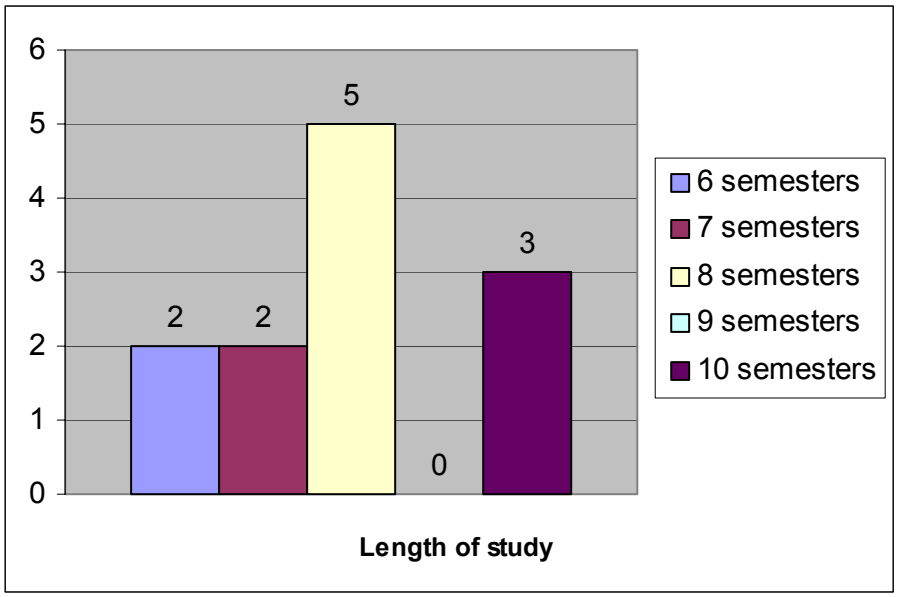

Figure 10: Number of semesters

The case study is situated in the embedded system domain and there in the sub-domain of building automation systems. Thus, it is important to analyze the subjects experience regarding this domain.

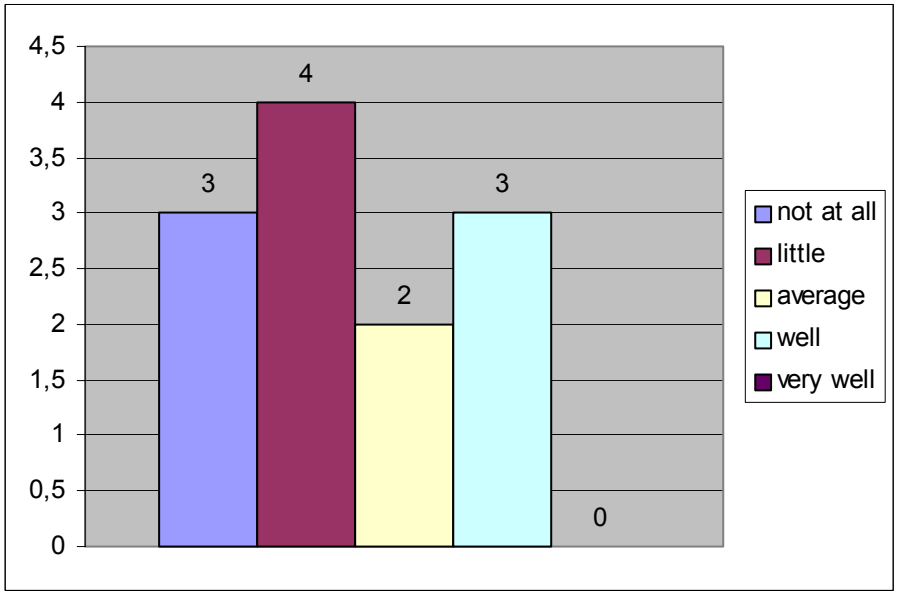

Figure 11: Experiences in the embedded systems domain

The figures Figure 11 and Figure 12 show that most of the subjects (7 out of 12) have only few or none experiences in the domain of embedded system.

Only 3 subjects know the domain quite good. Almost all subjects have only few experiences with building automation systems (10 out of 12). Thus, most of the subjects in case study are rather inexperienced in the domain of embedded systems and almost none of the subjects is familiar with the domain of automation systems.

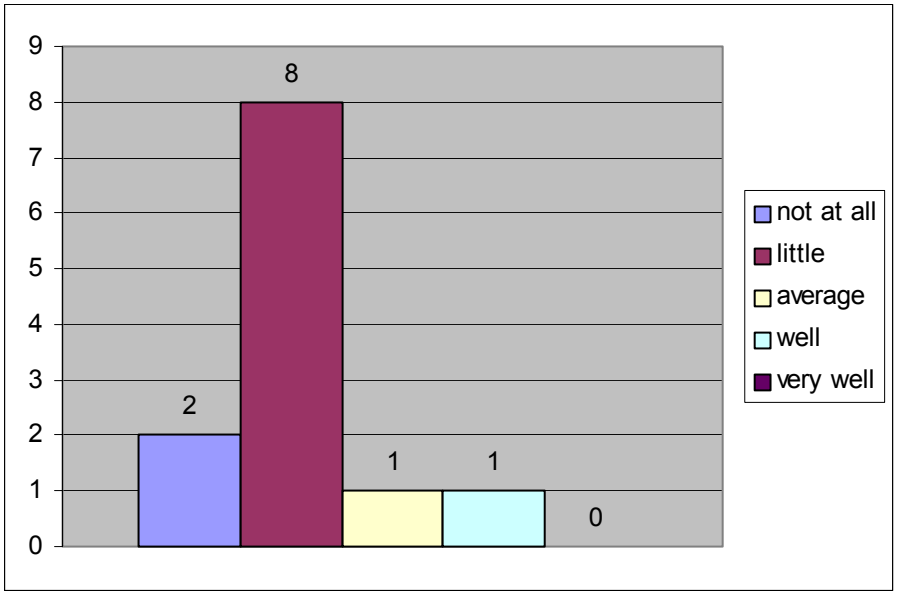

Figure 12: Experiences in the domain of building automation systems

4.2.3 The subject's experiences in the field of Requirements Engineering

As the focus of the evaluation is the applicability of the UC guidelines it is necessary to evaluate the subject's experiences in the fields of requirements engineering, especially the experiences with requirements documents and UCs. Thus, we evaluated the subject's experience in reading and creating requirements documents in general. The same questions were evaluated for UCs. In the following figures (Figure 13 - Figure 16) the distribution regarding these questions are shown.

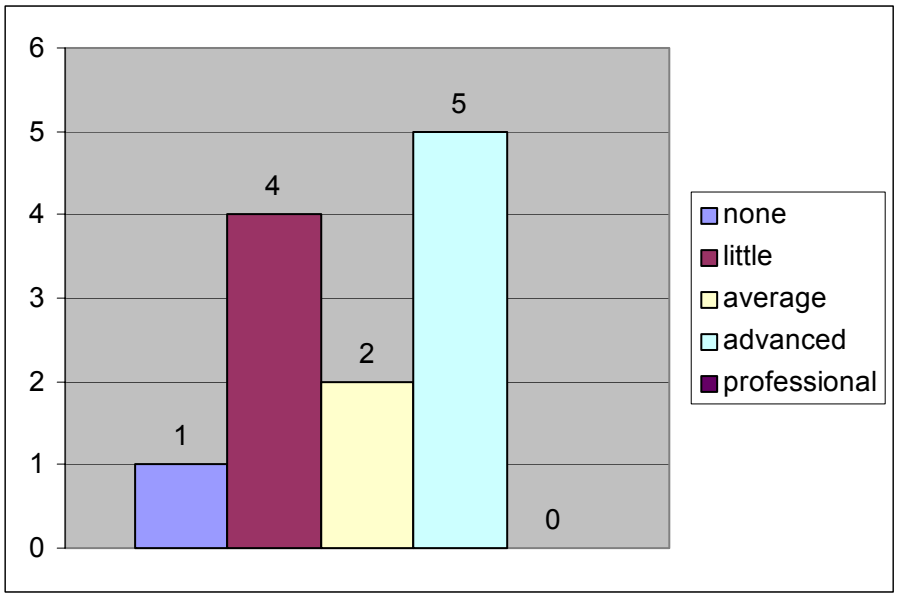

Figure 13: Experiences in the creation of requirements documents

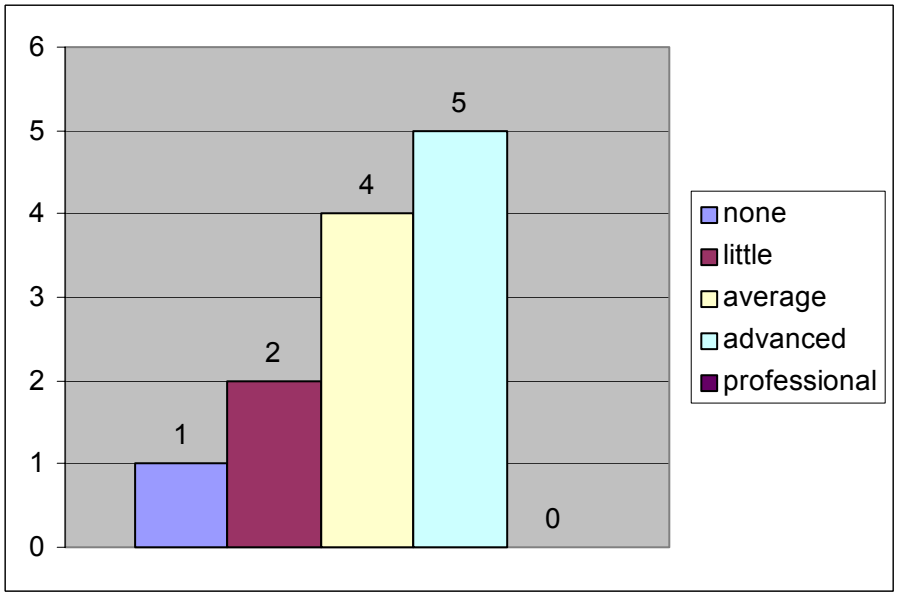

Figure 14: Experiences in reading requirements documents

It gets obvious that the major part of the subjects has advanced or at least medium experiences in reading requirements documents (9 out of 12) only 1 subject has no experience in reading requirements documents. The subject's experience regarding the creation of requirements is not that high. 7 out of 12 subjects have advanced or medium experiences in the creation of requirements documents and 5 out of 12 have none or only few experiences.

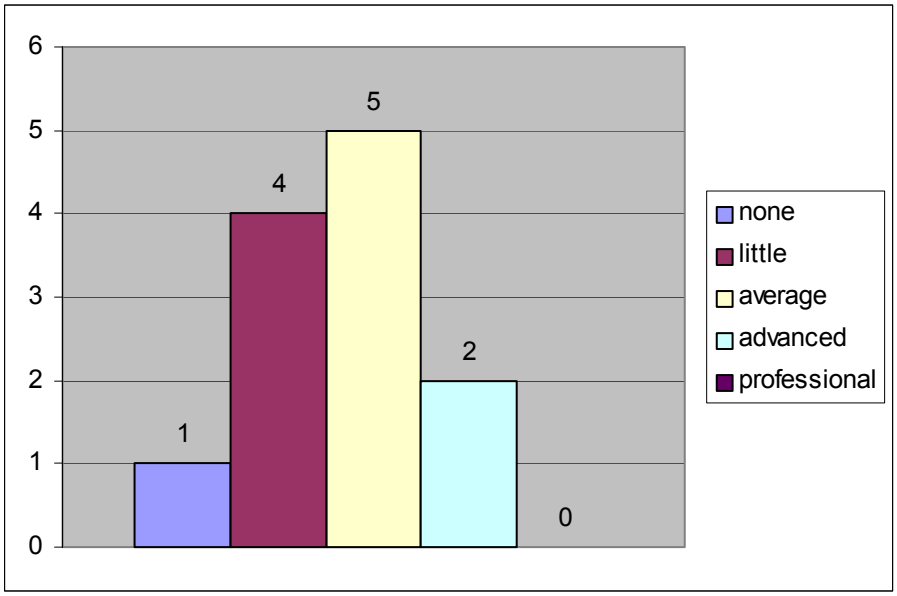

Figure 15: Experiences in creating UCs

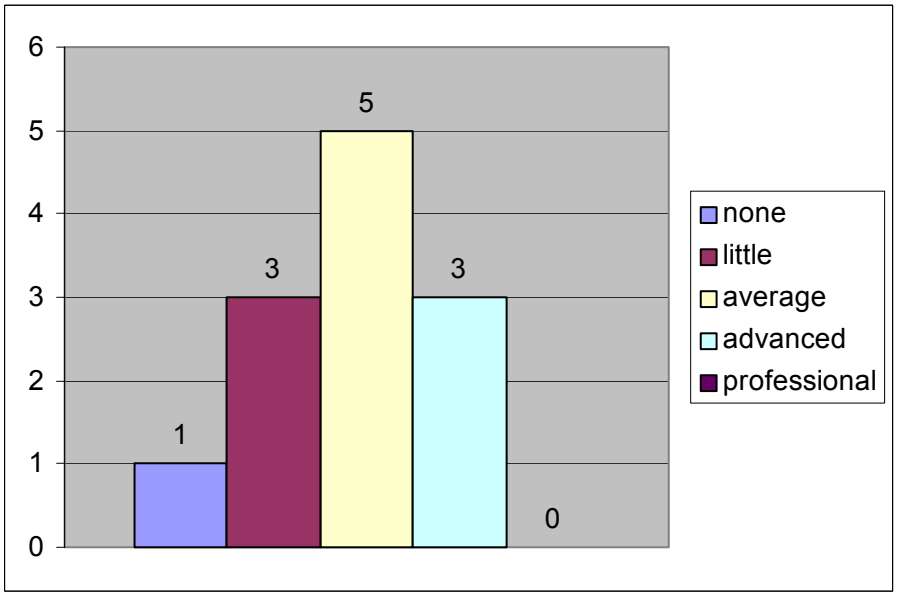

Figure 16: Experiences in reading UCs

Even though the subjects have some experience with requirements documents in general a few subjects have advanced knowledge of creating or reading UCs. (2 out of 12 and 3 out of 12 respectively). 5 subjects state that they have none or only little knowledge about creating UCs and 4 subjects have none or few experience in reading UCs. However, the differences between the experiences with requirements engineering in general and UCs are not very big.

Taking into account the subject that stated to have average knowledge in requirements engineering and with UCs the evaluation of these questions shows that the subjects are rather experienced in the fields of requirements engineering.

4.3 The “Pre-Questionnaire”

Before the subjects started working with the UC guidelines, they were asked to read the guidelines and estimate how they perceive the understandability, applicability and the usefulness of the guidelines without having them used.

In order to evaluate the subject’s first impression the time to read the guidelines was measured as well as the subject’s impression of the understandability of the guidelines. Moreover, the subjects had to estimate whether they perceive the guidelines as helpful, easy to use and helpful for their task (creating UCs and scenarios for their sub-system).

The result of the evaluation of these questions is shown in the following figures (Figure 17 - Figure 21).

In Figure 17 the different times to read the guidelines are summarized. On average the subjects needed 29,9 minutes to read the document. The overall time span is between 22 and 35 minutes. This indicates that the guidelines are not too complex and easy to read as the whole document that was used in the practical course is14 pages long written in English language.

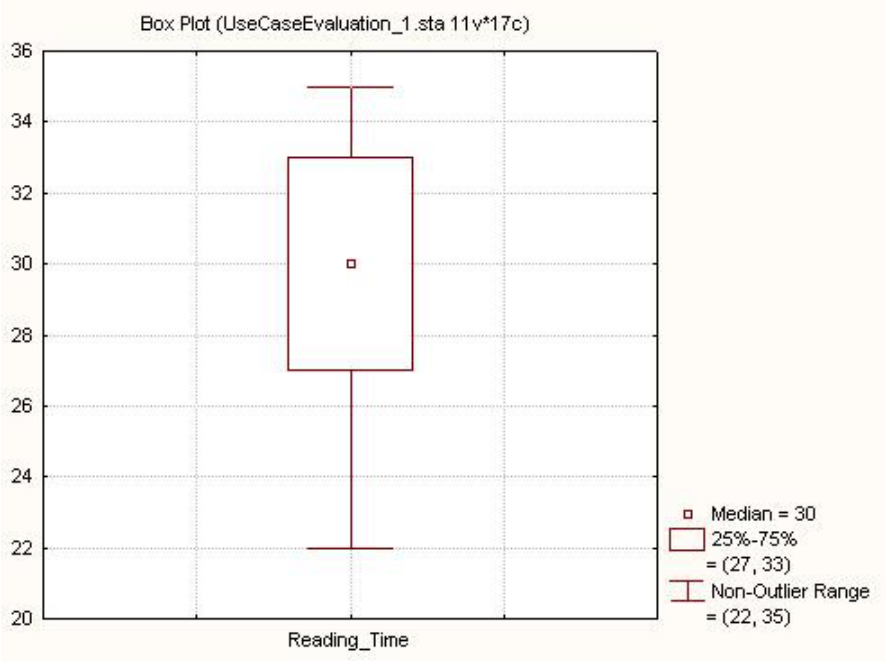

Figure 17: Time needed to read the guideline document

The first impression that the guidelines are not too complex is supported by Figure 18 that shows the perceived understandability of the guidelines.

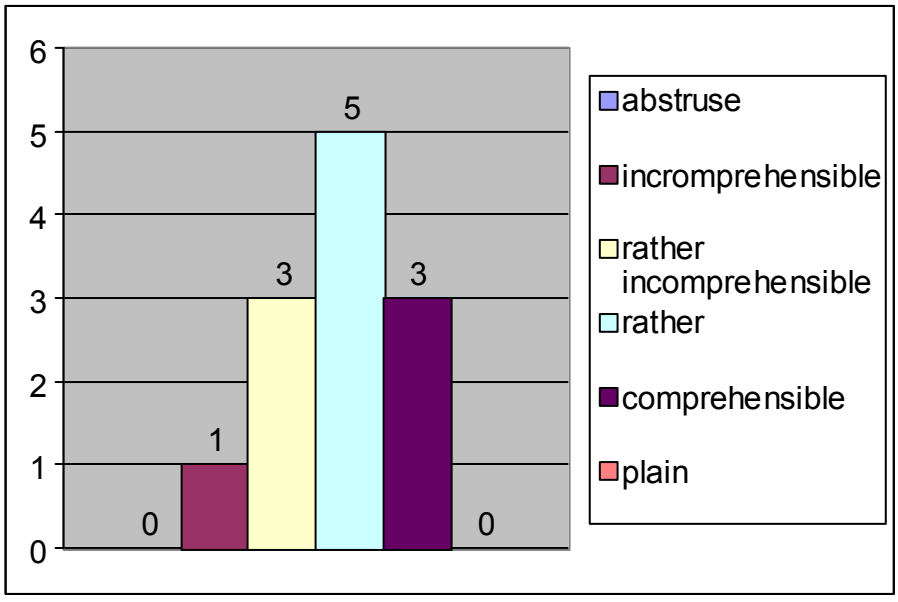

Figure 18: How did the subjects perceive the understandability of the guidelines

The major part of the subjects perceives the guidelines as easy to understand. In 8 out of 12 answers the guidelines are perceived as rather understandable and understandable. Only 1out of 12 answers states that the guidelines are not understandable.

The applicability of the guidelines is an important aspect as in many cases guidelines might be very good and reasonable but not applicable to perform a certain task. Figure 19 shows the result of the subject's first impression of the applicability of the guidelines.

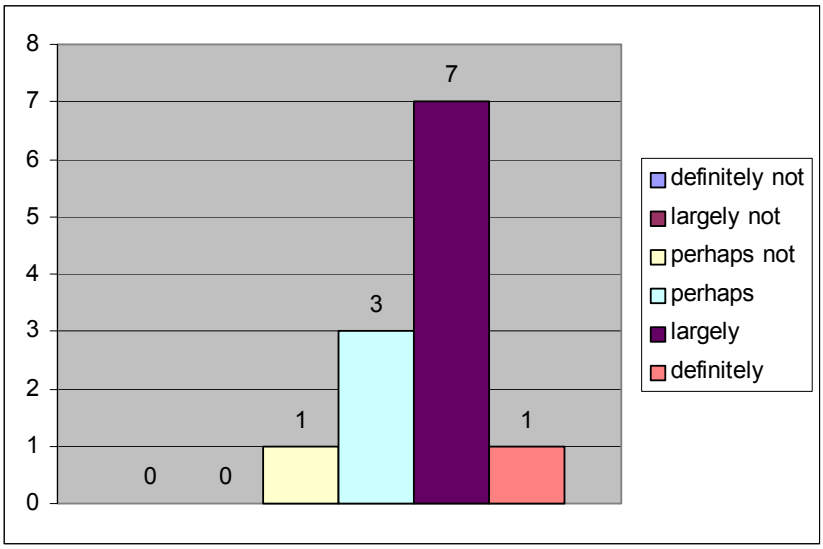

Figure 19: How did the subjects perceive the applicability of the guidelines

The subjects are very positive in their first impression of the applicability. 11 answers indicate that the guidelines are rather applicable or applicable only 1 answer out of 12 indicates that the guidelines are perhaps not applicable in the current situation.

In Figure 20 and Figure 21 the subject's impression on whether the guidelines can support their task of creating UCs by giving valuable information on how to perform the tasks are summarized.

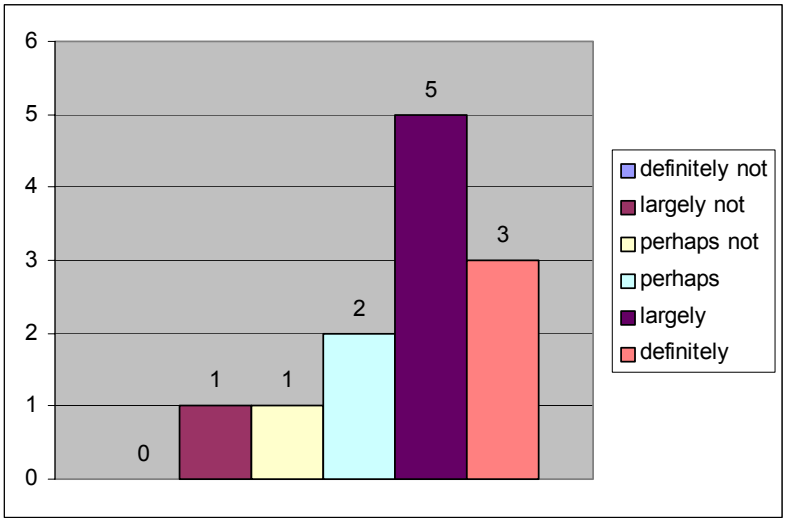

Figure 20: Will the guidelines be helpful to support the subjects in performing their task in the practical course

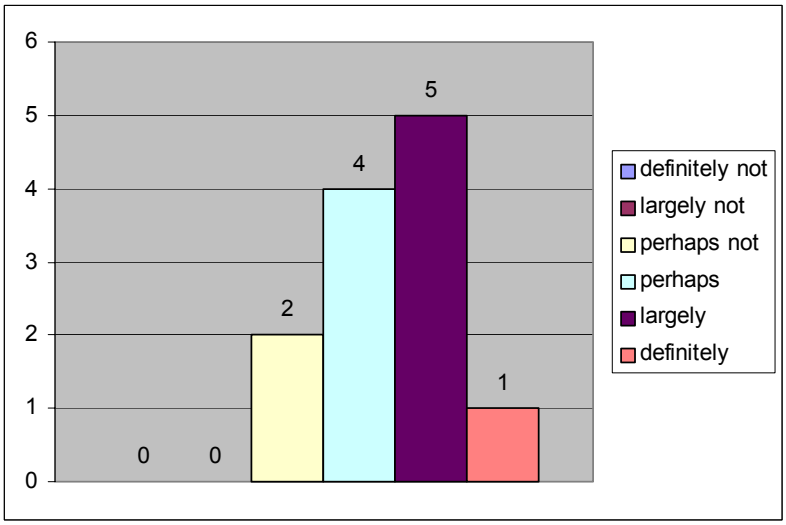

Figure 21: Will the guidelines ease the subject's task in the practical course

Regarding this questions the subjects impression of the guidelines is extremely positive. 9 out of 12 subjects perceive the guidelines as a rather valuable up to a very valuable support for their work. 10 out of 12 subjects think that the guidelines will ease their task of creating UCs out of the problem description.

In summary the subject's first impression of the guidelines is very positive. The major part of the subjects perceives the guidelines as easy to understand, applicable and a valuable means to support their work in the practical course. This first impression of the guidelines will be compared to the impression after the subject's used the guidelines in the practical course.

4.4 Evaluation of the UC Guidelines

In this section the detailed evaluation of the UC guidelines is presented. In order to evaluated the guidelines we followed the model recommended by Davis [Dav89] as described in Section 4.2.1. In the following sections this model will be used to evaluate the UCs guidelines. In Section 4.4.1 some general remarks of the subjects regarding the performed task are evaluated. Section 4.4.2 is related to the perceived understandability of the guidelines which can be compared to the results of the pre-questionnaire. In section 4.4.3 the guidelines are evaluated with respect to the described model of ease of use, usefulness and self-predicted future use.

4.4.1 General information regarding the task

In order to get a better understanding of how the subjects performed the task "creating UCs" in the practical course some general questions regarding this task were asked.

First, it is important to see whether the subject's understood the task, that is whether or not the subjects knew what they were requested to do. In the case that the task is specified not clearly the results of the evaluation of the guidelines might be biased. Figure 22 shows that all of the subjects understood the task they had to perform. None of the subjects stated that he or she did not know what to do or did only know somehow what to do.

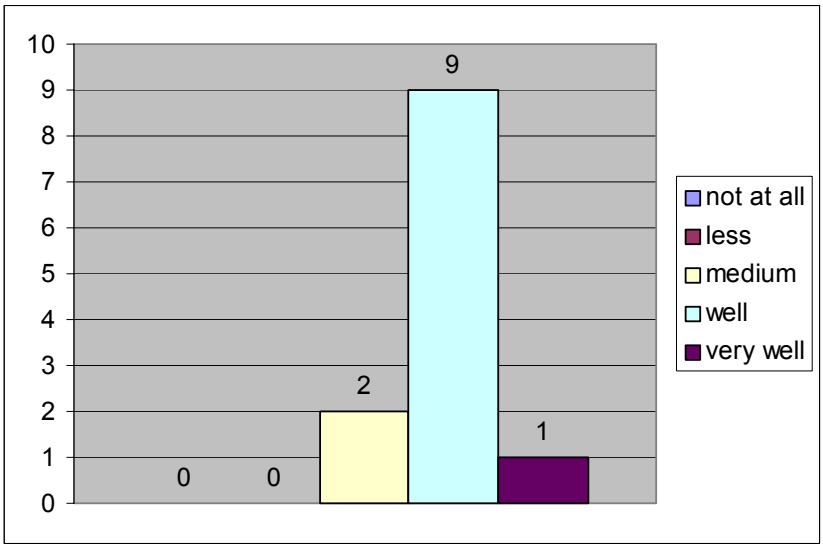

Figure 22: Perceived understanding of the task

All of the subjects estimated the quality of their work product (i.e. the created UCs) as good or very good which is shown in Figure 23. In order to evaluate the perceived quality with respect to the real quality of the created UCs several expert analyzed the UCs with respect to their quality (are they written according to the guidelines, are the complete, consistent, etc.) Thus, the subjective perception of the subject's can be compared to the objective perception of the expert. The result of this comparison is that the objective expert perception contradicts the subjective impression of the subjects as the quality of the UC of two sub systems was poor and the quality of the other sub system was on an average level. Often the subjects obviously did not follow the guidelines as for example UC template elements were not specified or certain steps seem to have been omitted at all.

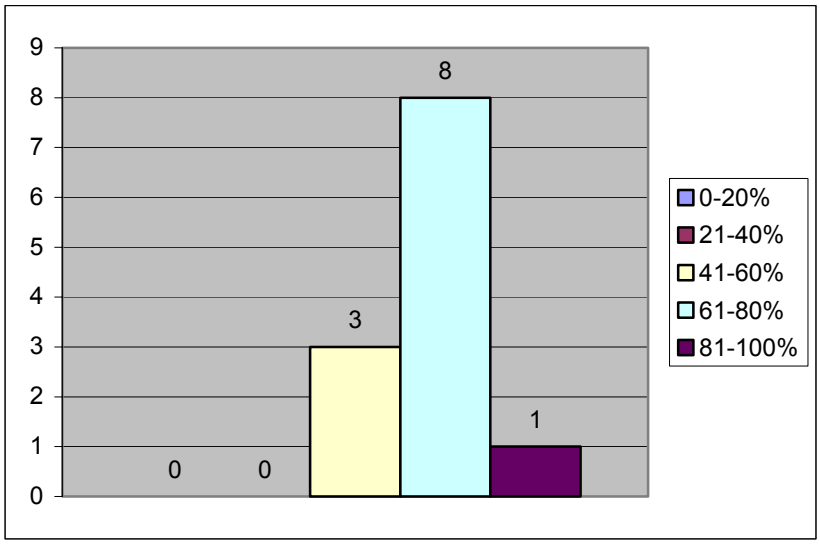

Figure 23 Perceived Quality of the created UCs

Another interesting aspect regarding the general performance of the subjects during the task is how long they needed to create the UCs; that is, how much time did the subject's spent to perform the task. The scheduled time for the creation of the UCs was 10 hours (one week of the practical course). As shown in Figure 24 all subjects needed less time for the creation of the UCs. The average time that was spent on the UC creation is 4.8 hours. The interval of the time is between 3 hours and 6.5 hours and most of the subjects spent between 4 and 5.5 hours to perform the UC creation process.

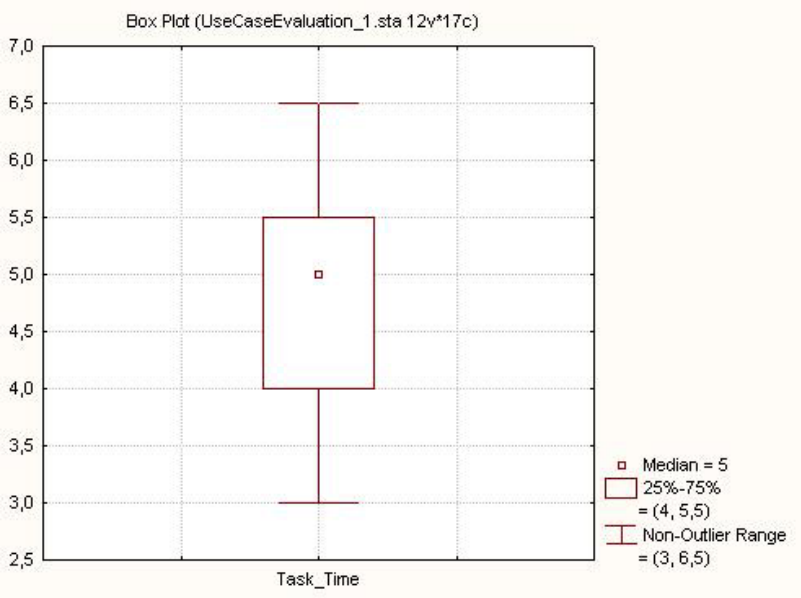

Figure 24: Time spent (in hours) for creating the UCs

4.4.2 Understandability of the UC guidelines

In order to see a shift of the subject's perception of the understandability of the guidelines they were asked to evaluate the understandability of the guidelines after using them to perform their task.

Thus, two questions where asked. The first one focuses on the degree of detail of the guidelines. Figure 25 depicts that the subjects perceive the guidelines very differently. 6 subjects state that the degree of detail is good as it is, 4 subjects perceive the guidelines as not detailed enough and 2 subjects perceive them as too detailed. So there is no conclusive direction of the subject answers.

The second question focuses on the understandability of the guidelines. In Figure 26 the subject's perceptions regarding the understandability are summarized. Again the perceptions are not conclusive. 6 subject's perceive the guidelines rather understandable and 6 subject's perceive them rather not understandable. However, comparing the numbers in Figure 26 to the subject's perception before using the guidelines (see Figure 18), there is a slight shift (2 subjects) from rather understandable to rather not understandable. A more detailed analysis of the subject's perception presented in Figure 27 shows that 6 subjects perceived the understandability of the guidelines after using them worse than before using them. 4 subjects did not change their perception of the guidelines and 2 subjects perceived the understandability of the guidelines after using them better then before. This detailed analysis of the shift in the

understandability shows improvement potential of the guidelines regarding their understandability. In a second version of the guidelines the wording and the example of the guidelines was improved to gain a higher understandability.

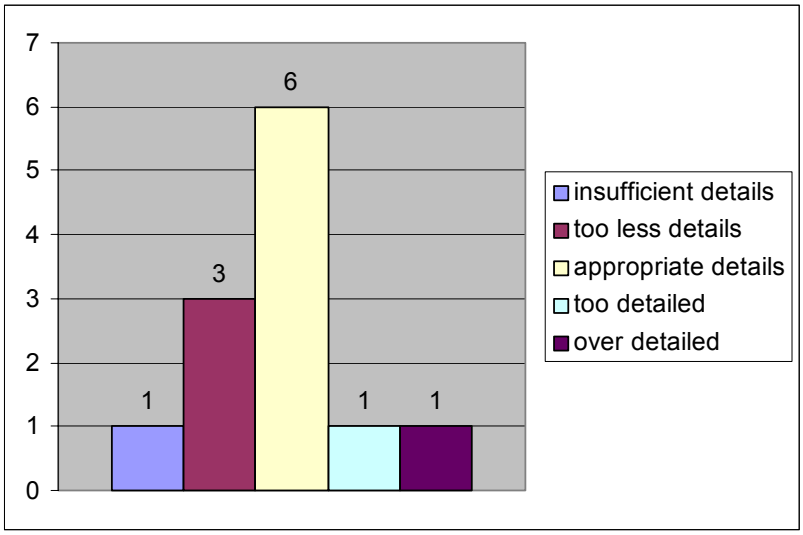

Figure 25: Perception of the degree of detail of the UC guidelines

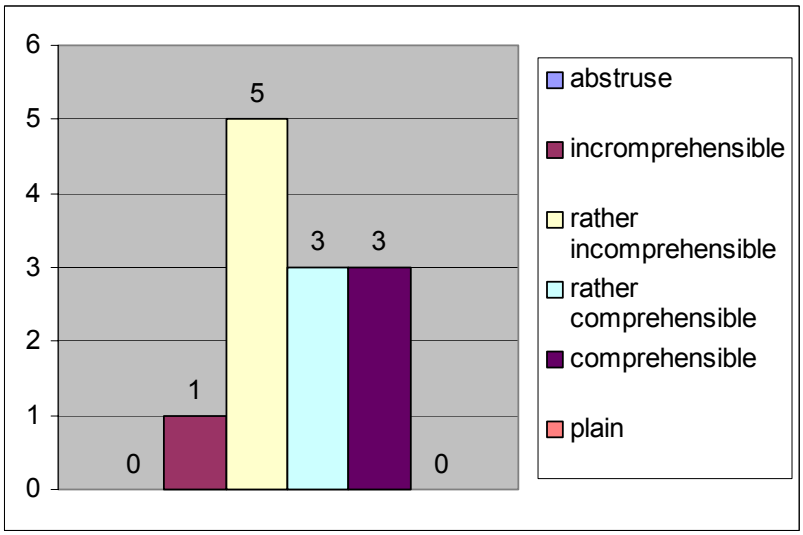

Figure 26: Perceived understandability of the UC guidelines after having them used

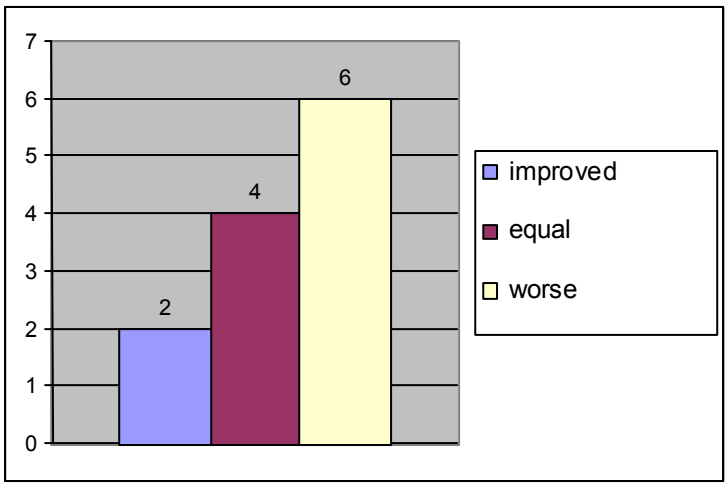

Figure 27: Shift in the perception of the understandability

4.4.3 Evaluation following the model of Davis

In this section the UC guidelines are evaluated against the three-element model of Davis as described in Section 4.2.1. Before the questions that are part of the model are evaluated we first asked the subject's to estimate to which degree they used the guidelines to fulfill their task in the practical course. Thus, the subjects had to choose a range of percentage values that indicate the degree of use. In Figure 28 the results are shown. 5 out of 12 subject's estimated to have followed the guidelines quite thoroughly; that is they estimate to have used 61% up to 80% of the guidelines to fulfill their task. The same number of subjects has followed the guidelines to an average degree (between 41% and 60% of the guidelines were used). Only 2 subjects estimated to have not followed the guidelines in detail (21% - 40% of the guidelines were used). As a usage of up to 80% is a very good value (not all guidelines can be applied in all situations) the subjects followed the guidelines quite thoroughly. However, again the estimated and subjective values of the subjects contradict to the objective expert's opinion. As mentioned earlier, the created UCs were not of a good quality and template elements for the textual description were not specified at all which indicates that some guidelines were not adhered to.

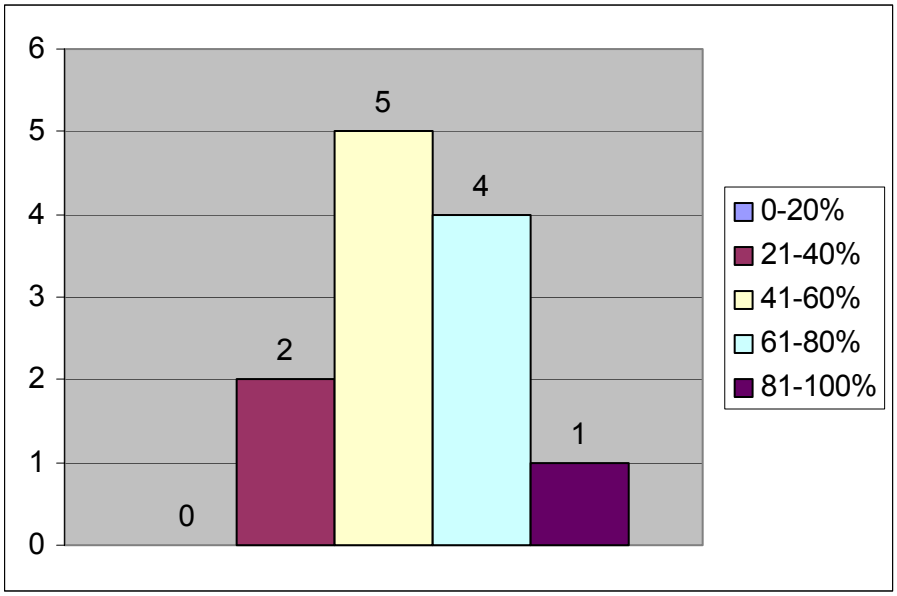

Figure 28: Degree of usage of the guidelines to fulfill the task

Applicability

In the following paragraph the applicability of the UC guidelines is evaluated. In order to evaluate the applicability the subjects had to state there degree of agreement or disagreement to the following three questions:

1. The UC guidelines are easy to learn
2. The single steps of the guidelines are easy to remember
3. The application of the guidelines is easy

In Figure 29 the answer to the first question are summarized. Most of the subject's (9 out of 12) would rather agree or agree that the guidelines were easy to learn during their application. Only 3 out of 12 subject's would rather disagree to this statement. This result indicates that the subjects perceive the guidelines as rather easy to learn.

The responses to the second question are shown in Figure 30. The aim of this question is to evaluate how the subject's perceive the structure of the guidelines and how the single steps described in the guidelines fit together. The result to this question is not conclusive. 7 subject's would agree that the single steps of the guidelines are easy to remember while 5 subjects would rather disagree to this statement.

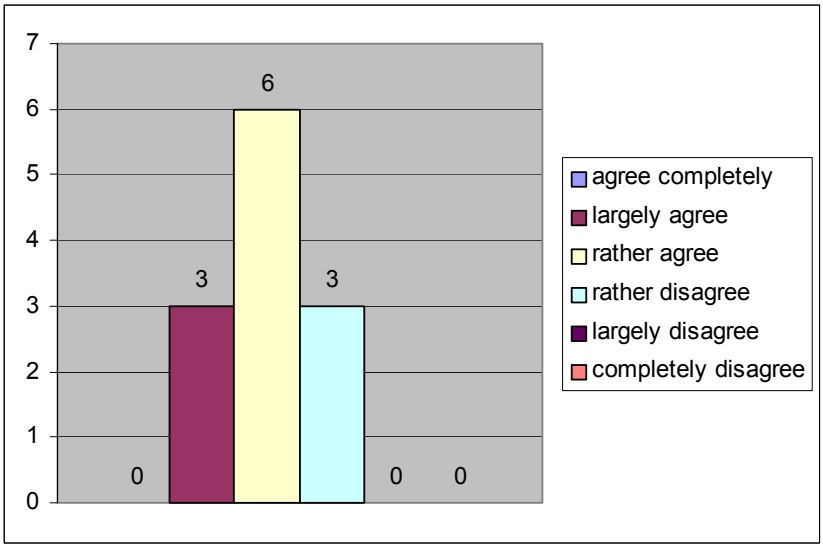

Figure 29: Degree of agreement to the statement "The guidelines are easy to learn"

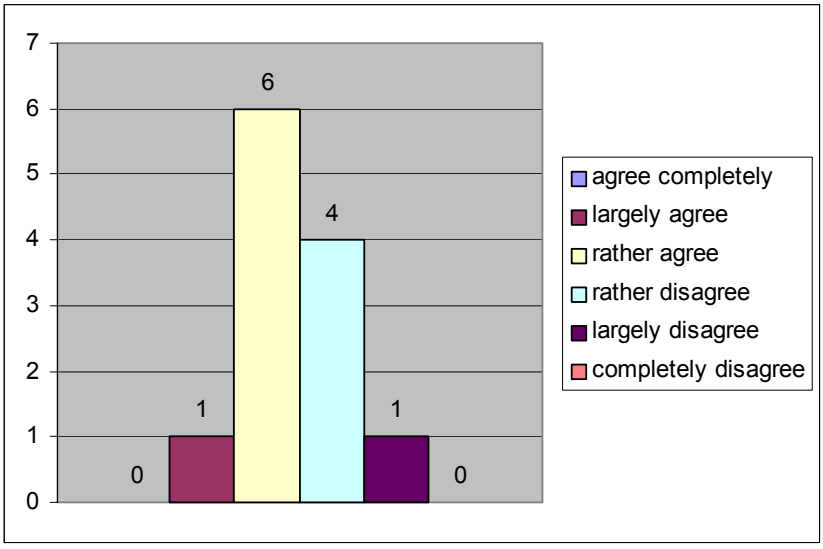

Figure 30: Degree of agreement to the statement "The single steps of the guidelines are easy to remember"

The third question of this question-block directly asks the subjects how they perceive the applicability of the UC guidelines. The results are shown in Figure 31. Again most of the subjects would rather agree that the UC guidelines are easy to apply to fulfill their task (9 out of 12 subjects rather agree or agree to the statement). Only three subjects would rather disagree or disagree to this statement.

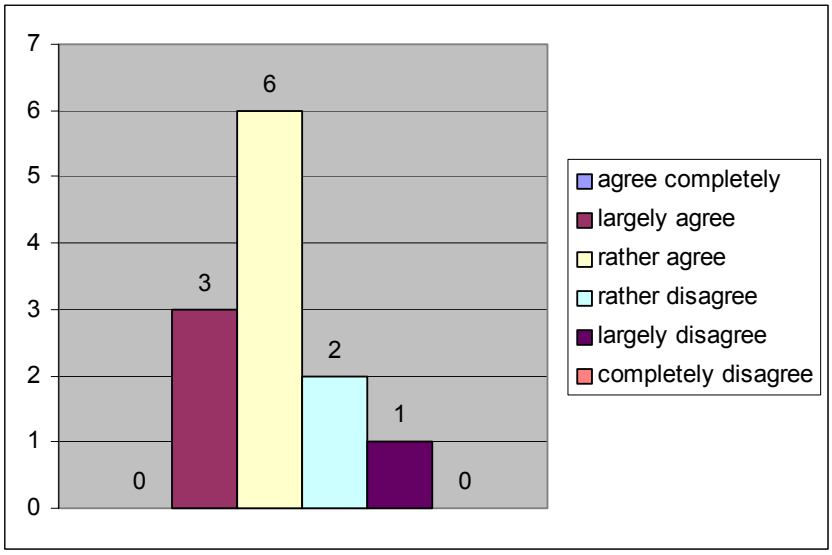

Figure 31: Degree of agreement to the statement "The application of the guidelines is easy"

In order to evaluate the applicability of the UC guidelines the results of the three questions are now summarized. Assuming that each question has the same impact on the perceived applicability we can give a general evaluation of the applicability of the guidelines. The results of the summarization are shown in Figure 32.

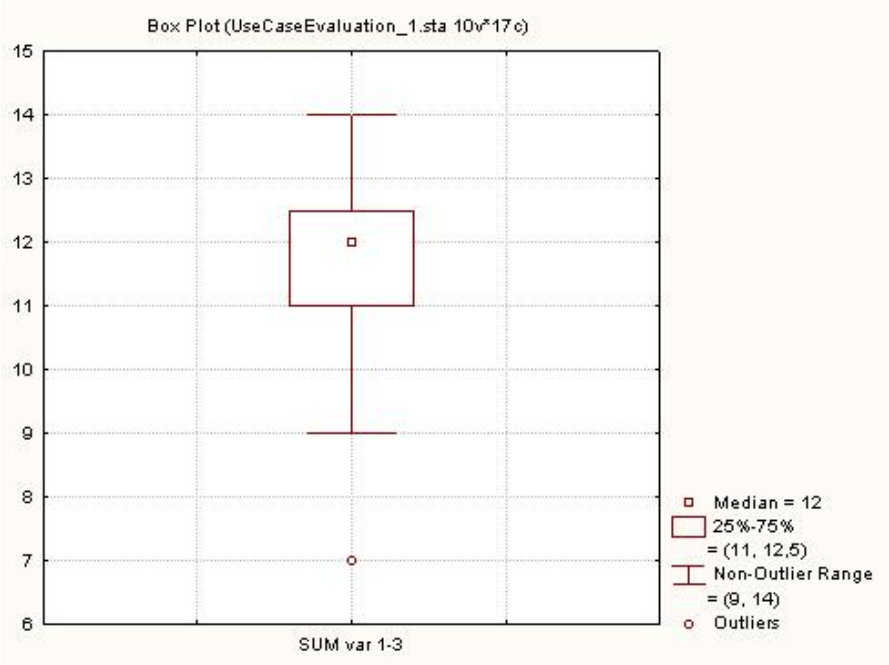

Figure 32: Summarized results for the perceived applicability

We can see that the median is 12. This indicates an overall rather positive perception of the applicability of the UC guidelines. The maximum value is 18 so the evaluation shows that there is still improvement potential with respect to the guidelines applicability. The evaluation shows also that the subjects perceive the applicability in very different ways as the interval of the summarized values of the responses vary from 7 to 14. The reasons for this variance have not been further analyzed but should be part of further research approaches that try to investigate the influencing factors of the perception of a certain technique. (e.g. experience of the respondents)

Again we compared the subject's perception of the applicability before and after using them. This analysis shows (see Figure 33) that there is a big shift towards a negative perception of the applicability of the guidelines. 8 subject's stated that they perceived the applicability of the guidelines better before using them compared to their perception after using them. Only 2 subjects' perception improved and 2 subjects' perception did not change.

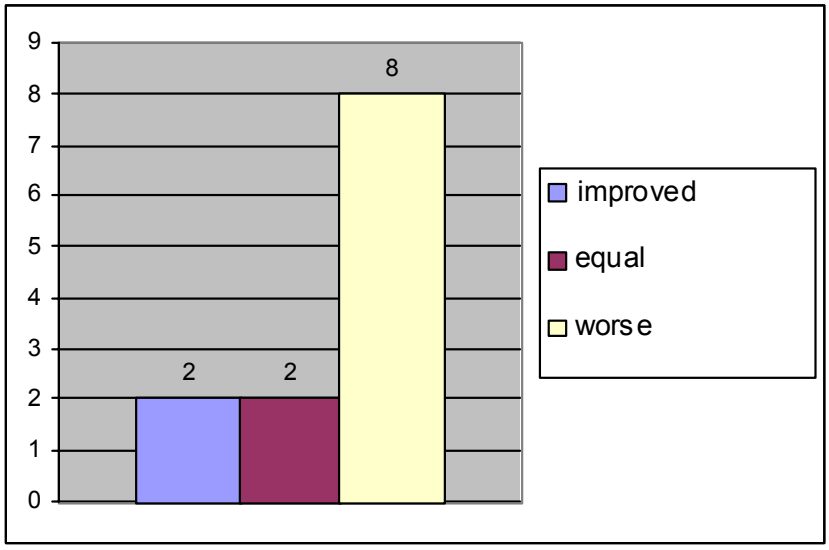

Figure 33: Shift in the perceived applicability of the guidelines

However, at all the analysis of the applicability shows that the guidelines can be regarded as rather applicable in the context of the case study but that there is still improvement potential regarding their applicability.

Usefulness

The second element of the evaluation model is the perceived usefulness of the guidelines. Within this category the subjects had to state their agreement or disagreement to five statements that are correlated to the perceived usefulness of the guidelines:

1. The guidelines accelerate the UC creation

2. The guidelines improve the effectiveness of the UC creation
3. The guidelines improve the productivity of the UC creation (that is, effort and results are in a positive relationship, it is worth spending the effort)
4. The guidelines facilitate the UC creation process
5. The guidelines in general were useful to fulfill the task

In the following paragraph the subject's degree of agreement or disagreement is analyzed. In order to get a general impression of the subjects attitude towards the usefulness of the guidelines we added one question to the five model statement. The subjects had to estimate the degree to which they perceive the guidelines as helpful in performing the UC creation.

In Figure 34 the results to this question are shown. Half of the subjects perceive the help of the guidelines on an average degree and 5 out of 12 subjects state that the guidelines are helpful to support the UC creation. Only one subject stated that the guidelines are not helpful to support the UC creation. This indicates a positive trend, i.e. the subjects perceive the guidelines rather helpful. In order to get the complete picture we need to consider these results in combination with the results of the evaluation of the five model statements.

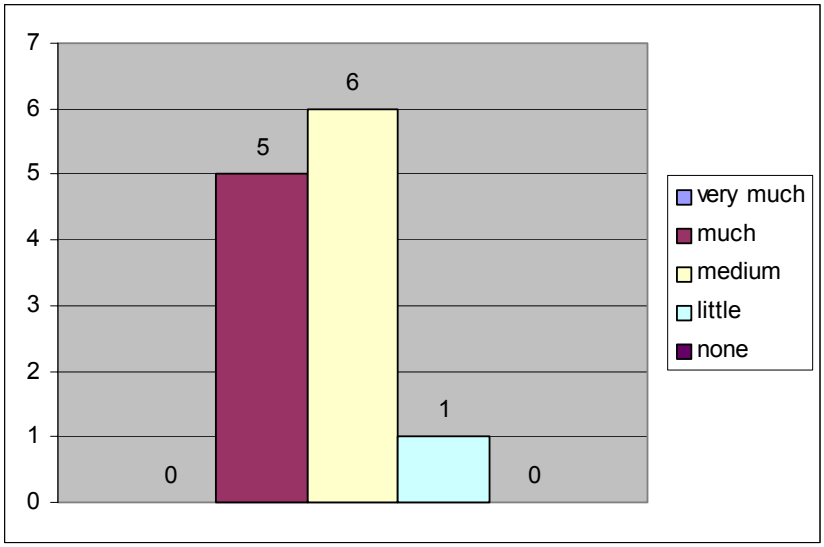

Figure 34: General estimation to which degree the guidelines were helpful

The first statement to evaluate the usefulness of the UC guidelines is that the guidelines accelerate the UC creation process. The subject's degree of agreement is shown in Figure 35. Most of the subjects (8 out of 12) rather agree (5 subjects) or agree (3 subjects) that the guidelines accelerate up the UC creation process. 4 subjects rather disagree or disagree to this statement. Thus, the per-

ception of the subject's towards the guidelines potential to improve accelerate up the case creation process is rather positive.

The second statement regarding the usefulness of the guidelines is that the guidelines improve the effectiveness of the UC creation process; that is, that the guidelines help to create UCs of good quality. The subject's degree of agreement is shown in Figure 36.

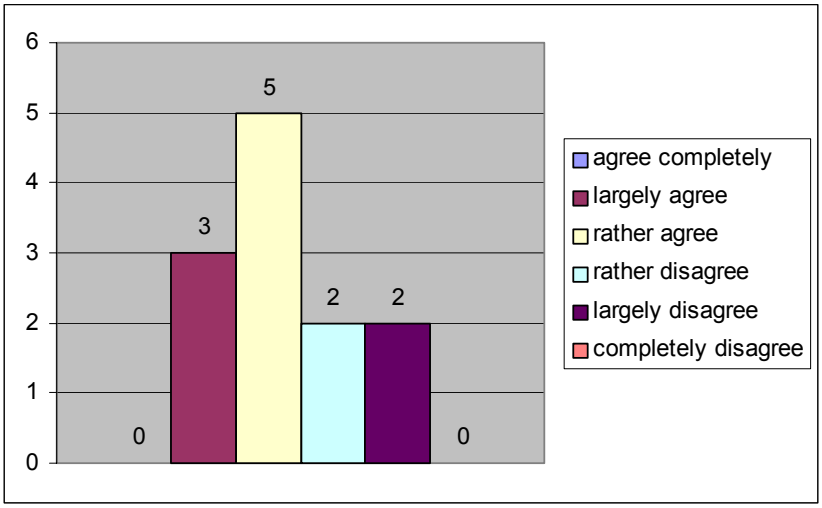

Figure 35: Degree of agreement to the statement "The guidelines accelerate the creation of the UCs"

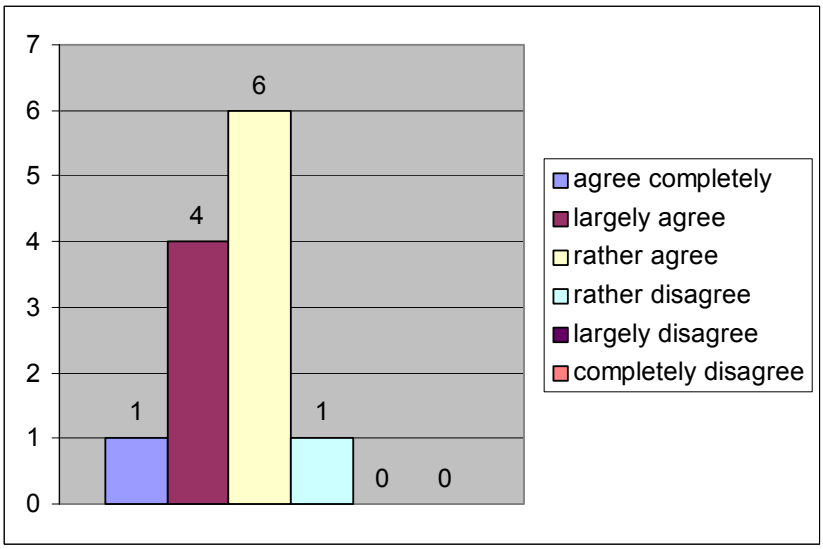

Figure 36: Degree of agreement to the statement "The guidelines improve the effectiveness of the UC creation"

Figure 36 indicates that the subjects perceive the guidelines as a means to improve the effectiveness of the UC creation process. One subject totally agrees

to the statement and 10 out of 12 subjects agree (4 subjects) or rather agree (6 subjects) to the statement and only one subject rather disagrees. This shows that the subjects perception of the guidelines regarding their potential to improve the effectiveness of the UC creation is very positive. This result has of course a positive impact on the overall usefulness of the guidelines.

In the third statement of the evaluation model aims at the relationship between the effectiveness of the guidelines and the time needed to be more effective. The subjects had to state their degree of agreement to the statement that the guidelines improve the productivity of their work; that is, with the guidelines it is possible to create high quality UCs with an appropriate effort (time).

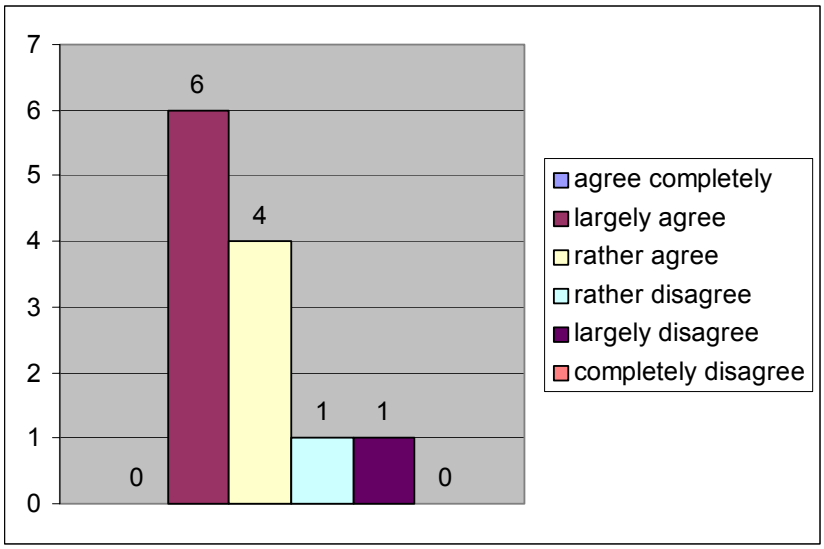

Figure 37: Degree of agreement to the statement "The guidelines improve the productivity of the UC creation"

Figure 37 shows the distribution of the subject's answers to this statement. Even though the subject's would only rather agree that the guidelines accelerate the UC creation process, they perceive the guidelines as very helpful to improve the productivity of the UC creation.

6 out of 12 subjects agree to an improved productivity and 4 rather agree to the statements. Thus, the majority of the subjects has a positive attitude towards this aspect of the guidelines. Only 2 of the 12 subjects don't agree to the statement. Again these results indicate a positive perception of the guidelines in general.

The fourth statement aims at the subject's perception whether the UC creation process is easier to manage with the use of the guidelines. Thus, the subjects had to state their degree of agreement towards the statement that the guidelines facilitate the UC creation process.

In Figure 38 the results are shown. Again the overall perception of the guidelines is very positive. 7 out of 12 subjects agree and 3 of the subjects rather agree that the guidelines facilitate the UC creation process. Only two subjects rather disagree to the statement.

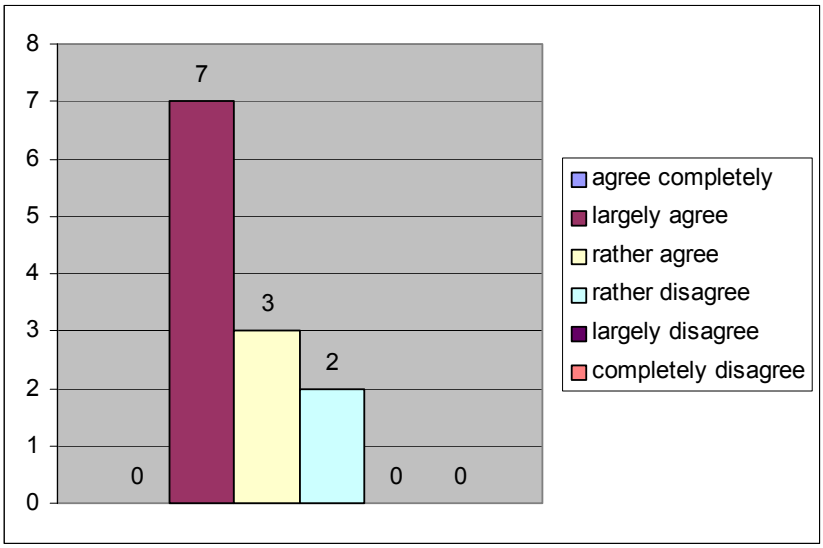

Figure 38: Degree of agreement to the statement "The guidelines facilitate the creation of the UCs"

The last element of the evaluation model is again the general statement that the guidelines are helpful to perform the UC creation task. The results are summarized in Figure 39.

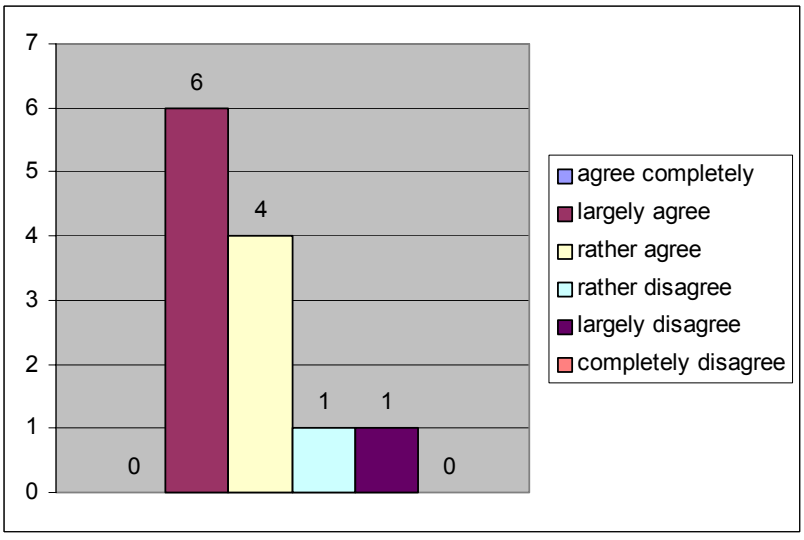

Figure 39: Degree of agreement to the statement "The application of the guidelines is helpful"

The subjects perceive the general support of the guidelines to fulfill their task as very positive. Again half of the subjects agree that the guidelines are helpful and 4 subjects rather agree to the statement. Thus, the majority of the subjects perceives the guidelines as very helpful and thus increasing the positive general perception of the guidelines.

In order to evaluate the overall usefulness of the guidelines the results of answers to the five statements correlated to this factor are summarized in

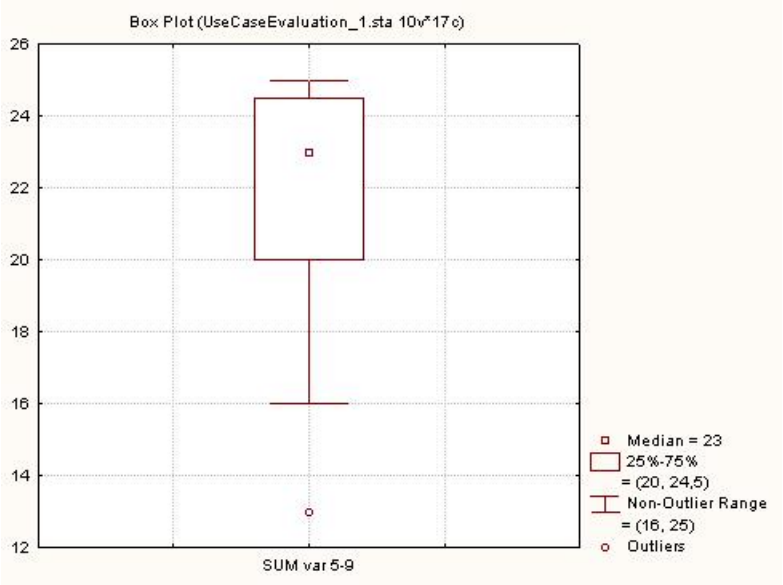

Figure 40: Summarized results for usefulness

The summarized results show again a positive general perception of the usefulness of the guidelines. The median is 23 (maximum: 30) and thus, the subjects of the case study agree that the guidelines are useful to perform their task. Again the evaluation indicates that there is a high variance between the answers of the different subjects (13 – 25). However, the evaluation shows that the guidelines are perceived as useful.

Also the subjects' perception of the usefulness improved while using the guidelines. A detailed analysis (see Figure 41) shows that in 4 cases the perceived usefulness improved and in 5 cases the perceived usefulness did not change. However, three subject's indicated that the perceived usefulness before using the guidelines was better then after using them.

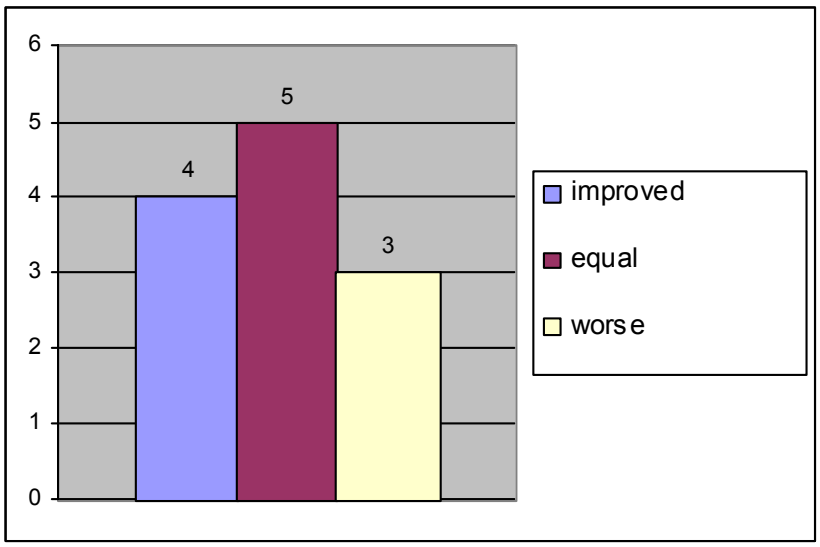

Figure 41: Shift in the perceived usefulness of the guidelines

Self-predicted future use

The third part of our evaluation model is the self-predicted future use of the guidelines. In order to estimate this influencing factor the subjects had to answer whether or not they would use the guidelines again in a future project where during the requirements engineering phase (in particular to create UCs). In Figure 42 the subject's responses are summarized. Regarding the future use the majority of the subjects agree that they would use the guidelines in a future project. 8 subjects agree and 2 subjects rather agree to use the guidelines again. Only 2 subjects would not use the guidelines in a future project.

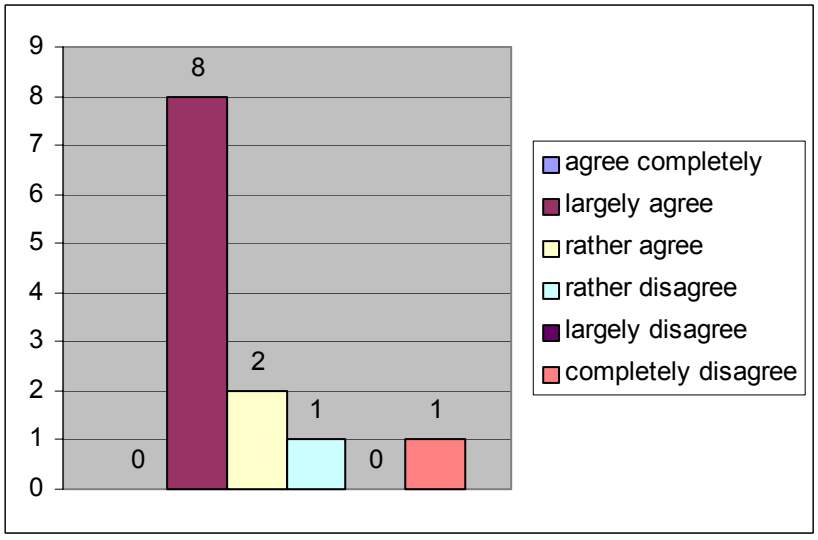

Figure 42: Future use of the UC guidelines

This strong agreement of the subjects regarding the future use indicates an overall positive perception of the subjects regarding the usefulness of the UC guidelines in general.

To summarize all the results the overall impression of the guidelines is rather positive. The evaluation indicates that the guidelines are useful to create the UCs in the requirements engineering phase. Moreover, most of the subjects would definitely use the guidelines again in a future project. Furthermore, the evaluation shows that the applicability of the guidelines is only rather positive; that is, the subject's do not perceive the guidelines as easy to apply. In each category of the evaluation model there is improvement potential of the guidelines as the maximum values are not reached.

As there is a huge variance of the answers of the subjects to different questions, we analyzed the influence of the experience of the subject's, that is we analyzed whether more experienced subjects perceive the guidelines different from less experienced subjects. A detailed analysis shows that 2 subjects are inexperienced in the fields of requirements engineering and use case creation; that is, both have none or only a few experiences with reading and the creation of requirements documents and use case documents. One subject perceives the guidelines as rather not useful and the second subject perceives the guidelines as not useful.

We compared these answers to the answers of those subjects that stated that they have more experiences with reading and creating requirements documents and use case documents in particular. The comparison shows that those subjects that are more experienced in the fields of requirements perceived the guidelines as more useful. The reason for this result could be the fact that inexperienced subject's have more difficulties with the application of the guidelines as they need more effort to understand the different steps described in the guidelines. The evaluation shows that the subjects had several problems with certain steps of the guidelines, as these steps were described not detailed enough or are hard to understand. Our hypothesis is, that more experienced subject's are able to cope with such problems in the guidelines while rather inexperienced subjects do not know how to apply the guidelines in the case of problems. However, this hypothesis needs to be further investigated in future evaluations.

4.4.4 Group Evaluation

In order to evaluate the perception of the guidelines in the different groups of the case study ("Temperature Control", "Light Control", "User Interface") the questionnaire was evaluated regarding the answers of the different group members. Table 1 shows the result of the group evaluation.

Question	Temp	Light	GUI
Perception of the degree of detail of the UC guidelines [1-insufficient...5 – over detailed]	2,5	3	3
Perceived understandability of the guidelines ? [1 – abstruse...6 – plain]	4,25	3,5	3,25
Degree of usage of the guidelines to fulfill the task (in percent) [0-20],[21-40],[41-60],[61-80],[81-100]	4	3	3
Degree of agreement to the statement "The guidelines are easy to learn" [1-completly agree...6 – completely disagree]	3	3	3
Degree of agreement to the statement "The single steps of the guidelines are easy to remember" [1-completly agree...6 – completely disagree]	3,25	3,5	3,5
Degree of agreement to the statement "The guidelines are easy to use" [1-completly agree...6 – completely disagree]	2,5	3,5	3,25
General estimation to which degree the guidelines were helpful [1-very much...5-not at all]	2,5	2,5	3
Degree of agreement to the statement "The guidelines accelerate the creation of the UCs" [1-completly agree...6 – completely disagree]	2,5	4,25	3
Degree of agreement to the statement "The guidelines improve the effectivness of the UC creation" [1-completly agree...6 – completely disagree]	2	3	2,75
Degree of agreement to the statement "The guidelines improve the productivity of the UC creation" [1-completly agree...6 – completely disagree]	2,25	3	3

Degree of agreement to the statement "The guidelines facilitate the creation of the UCs" [1-completly agree...6 – completely disagree]	2,5	2,5	2,625
Degree of agreement to the statement "The application of the guidelines is helpful" [1-completly agree...6 – completely disagree]	2,25	3,25	2,625
Future use of the UC guidelines [1-completly agree...6 – completely disagree]	2,25	3,25	2,5

Table 1: Evaluation of the questionnaire regarding the different groups

The analysis of the questionnaire within the different groups shows that the group "Temperature Control (Temp)" perceived the guidelines in all categories in a more positive way than the two other groups. The "Light Control (Light)" perceived the guidelines in all categories worse than the other groups.

The differences in the perception of the guidelines between the different groups might result from different complexities of the different sub-systems. The "Light Control" sub-system has had only a small number of use cases and a few user- system interactions. This could be one reason for the negative perception of the guidelines in this group, as the guidelines could not be used in their full strength.

4.5 Limitations of the Case Study

There are several limitations of the results described in the last section. As the results were gained in a case study the results are tied to the context of the case study (see Section 4.2.). One important aspect within this context is that the UC creation process was based on a very detailed problem description that already stated the requirements on the system on a lower level of abstraction. This is not typical in all industrial settings as there the problem description is often on a very high level. However, this situation is quite similar in the embedded system domain where often detailed technical descriptions are available right from the start.

The evaluation of the usefulness and applicability of the guidelines are based on subjective measures but due to the absence of objective measures for these elements there are no other opportunities. Also the comparison between the perception of the guidelines before and after using the guidelines was based on an ad-hoc comparison of the answers.

Finally, the subjects of the case study were students. In such cases the internal validity of the results is often very high but the external validity is low. This limits our possibility to generalize the results of the case study. However, due to the fact that we performed a case study and not a controlled experiment the external validity is increased while the internal validity is decreased.

4.6 Conclusion and Lessons Learned

The evaluation of the case study shows that the guidelines in general are useful to support the UC creation process. Beside the positive results of the analysis of the guidelines general statements of the subjects support the positive impression.

The subjects stated that especially the stepwise approach of the guidelines was very helpful. The different steps showed clearly how the UCs are build and gives a concrete structure of the creation process. Furthermore, the steps support the workflow and improve team work during the fulfillment of the task. Also the subjects perceived the template for the textual description as very helpful as it defines a standardized description for each UC. Furthermore, the template improves the reuse of UCs. Beside the UC template the subjects state that the context diagrams are helpful to get an overview of the system and its relationship to the environment. The description of the input and output variables with by means of the context diagram is especially an advantage of the context diagram.

However, beside the positive general impression of the guidelines also negative aspects must be mentioned. The degree of agreement to the different aspects of the evaluation model is in most cases not at its maximum. Thus, there is still improvement potential for the guidelines. In order to better understand where the subjects had problems with the guidelines and where they see improvement potential, they had to answer three open questions.

The evaluation of these questions shows that the subjects had the most problems with step 4 and step 5 of the guidelines. These steps deal with the refinement of the UC and the subjects state that they had difficulties to perform these steps as the guidelines were to vague and on a high level of abstraction regarding the refinement steps.

One reason for this might be that the examples of the guidelines that were used in the case study were given in German while the guidelines themselves where written in English. The subjects mentioned this as a negative aspect of the guidelines that reduces the understandability. Another negative aspect of the example is that it is not an ongoing and self-consistent example. However, the example was not intended to be ongoing throughout the whole guideline text. There is always a trade-off between an ongoing example and the space

limitations in the guidelines. The guideline document was intended to enable the subjects to use the guidelines with as low effort as possible. Thus, only excerpts of the ongoing example were given to clarify the most essential steps of the guidelines. Related to this critique is the statement that the subjects perceive the example as too high level.

Based on the evaluation the guidelines were improved in several ways. First of all, the examples were translated to English in order to avoid switching between different languages. This should improve the readability and understandability of the guidelines.

The biggest change of the guidelines was made within the steps 4 and 5. These steps where rephrased in a way that makes them easier to understand and thus easier to apply. In particular we used the problems we detected in the use case descriptions of the students to give hints to avoid them.

Altogether, the current state of the guidelines is now a good starting point for application in teaching and industry. In each case they should be evolved based on the experiences made.

Acknowledgement

These guidelines have been developed in the context of the QUASAR project and the Forpics project. They have profited very much from the discussions with all project members.

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Appendix

Formblatt 0 - Dokumente und Ablauf

Teilnehmer-Nummer:

Allgemeines

Anforderungsdokumente müssen für eine Vielzahl von Interessensgruppen verständlich sein: z.B. die Kunden, Entwickler, Projektmanager, Tester. Je nach Kontext unterstützen unterschiedliche Beschreibungsformen die Verständlichkeit von Anforderungen. Ziel dieser Befragung ist die Nützlichkeit von Richtlinien zur Erstellung von Anforderungsdokumenten in Form von Use Cases zu evaluieren. Ihre Mitarbeit an dieser Umfrage ist für diese Evaluation sehr wichtig. Wir bedanken uns für Ihre Unterstützung.

Material

Bitte überprüfen Sie, ob Sie die folgenden Dokumente erhalten haben:

- Formblatt 1 mit allgemeinen Fragen zu Vorbildung und Motivation
- Eine Problembeschreibung des Systems
- Die Richtlinien zur Erstellung der Use Cases

Ablauf der Befragung

Lesen Sie die einzelnen Schritte sorgfältig durch. Stellen Sie Fragen, wenn etwas unklar ist. Es ist sehr wichtig, daß Sie die Schritte in der angegebenen Reihenfolge bearbeiten.

1. Bitte beantworten Sie die allgemeinen Fragen auf Formblatt 1.
2. Bitte lesen Sie die Richtlinien zur Erstellung von Use Cases und notieren Sie die Zeit, die Sie dazu benötigen.

   Start (Lesen des Dokumentes):

   Ende (Lesen des Dokumentes):gh

Lesezeit (Minuten):

Bis zu welcher Seite des Richtliniendokumentes sind Sie gekommen?

3. Bitte beantworten Sie die folgenden Fragen bzgl. Ihrer Wahrnehmung der Richtlinien ohne diese konkret verwendet zu haben (bitte ankreuzen):

   (a) Bitte geben Sie an, wie verständlich die Richtlinien beim ersten Lesen erscheinen (1 - völlig unverständlich; 6 - sehr leicht verständlich) (Bitte ankreuzen)

1	2	3	4	5	6

   (b) Denken Sie, dass Sie die Richtlinien anwenden können (1 - auf keinen Fall; 6 - ja bestimmt) (Bitte ankreuzen)

1	2	3	4	5	6

   (c) Denken Sie, dass Ihnen die Richtlinien wertvolle Informationen zur Erstellung von Use Cases geben (1 - auf keinen Fall; 6 - ja bestimmt) (Bitte ankreuzen)

1	2	3	4	5	6

   (d) Denken Sie, dass Ihnen die Richtlinien die gestellte Aufgabe erleichtern werden (1 - auf keinen Fall; 6 - ja bestimmt) (Bitte ankreuzen)

1	2	3	4	5	6

4. Bitte verwenden Sie die Richtlinien in den nächsten Tagen, um die Use Cases für die Gebäudeautomation zu erstellen. Erfassen Sie bitte die Zeit (in Stunden), die sie benötigen, um die Use Cases aus der Problembeschreibung abzuleiten.
5. Am Ende Ihrer Aufgabe (nach dem Sie die Use Cases erstellt haben) findet eine detailliertere Befragung bzgl. der Nützlichkeit und Anwendbarkeit der Richtlinien statt.

Alle von Ihnen bereitgestellten Informationen werden vertraulich behandelt. Wir bedanken uns noch einmal für Ihre Unterstützung.

Formblatt 1 - Seite 1 - Allgemeine Fragen

Teilnehmer-Nummer:

Bemerkung

Ziel dieser Befragung ist die Nützlichkeit von Richtlinien zur Erstellung von Anforderungsdokumenten in Form von Use Cases zu evaluieren. Die Informationen, die Sie uns in diesem Fragebogen liefern, sind für uns sehr wertvoll. Bitte beantworten Sie diese Fragen möglichst genau. Alle Informationen werden streng vertraulich behandelt. Vielen Dank.

Qualifikation

Qualifikation (Studienrichtung und Semester, ggfs. bereits erzielter Studienabschluss):

Welche Erfahrung im Bereich Software-Entwicklung haben Sie bereits außerhalb des Studiums (z.B. Firmenpraktika) gemacht? Erläutern Sie bitte kurz diese Erfahrung:

Erfahrung

Bitte beantworten Sie die folgenden Fragen entsprechend der folgenden Erfahrungsskala:

Keine	Wenig	Mittel	Fortgeschritten	Professionell
bisher noch keinen Kontakt gehabt	über Konzepte gehört	darüber selbst gelesen	selbst schon mal angewendet/erstellt	regelmäßig angewendet/erstellt
1	2	3	4	5

1. Wieviel Erfahrung haben Sie generell mit der Erstellung von Anforderungsdokumenten? (Bitte ankreuzen)

1 2 3 4 5

2. Wieviel Erfahrung haben Sie generell mit dem Lesen von Anforderungsdokumenten? (Bitte ankreuzen)

1 2 3 4 5

Formblatt 1 - Seite 2 - Allgemeine Fragen

Teilnehmer-Nummer:

3. Wieviel Erfahrung haben Sie speziell mit der Erstellung von Use Cases? (Bitte ankreuzen)

1 2 3 4 5

4. Wieviel Erfahrung haben Sie speziell mit dem Lesen von Use Cases? (Bitte ankreuzen)

1 2 3 4 5

Kenntnis der Domäne

Bitte beantworten Sie die folgenden Fragen entsprechend der folgenden Verständnisskala:

Gar nicht	Kaum	Mittel	Gut	Sehr gut
1	2	3	4	5

1. Wie gut kennen Sie die Domäne "eingebettete Systeme"?
   (Bitte ankreuzen)

1 2 3 4 5

2. Wie gut kennen Sie die Domäne "Gebäudeautomation"?
   (Bitte ankreuzen)

1 2 3 4 5

Motivation

1. Schätzen Sie, wie motiviert Sie heute zur Erstellung der Use Case sind. Bitte beantworten Sie diese Frage so ehrlich wie möglich, die Information werden nicht weitergegeben. (Bitte ankreuzen).

Gar nicht	Wenig	Mittel	Gut	Sehr
1	2	3	4	5

Bitte erläutern Sie Ihre Antwort:

Formblatt 2 - Seite 1 - Fragen zu den Richtlinien

Teilnehmer-Nummer:

Bemerkung

Ziel dieser Befragung ist die Nützlichkeit von Richtlinien zur Erstellung von Anforderungsdokumenten in Form von Use Cases zu evaluieren. Die Informationen, die Sie uns in diesem Fragebogen liefern, sind für uns sehr wertvoll. Bitte beantworten Sie diese Fragen möglichst genau. Alle Informationen werden streng vertraulich behandelt. Vielen Dank.

Allgemeine Fragen zur Aufgabe

1. Bitte schätzen sie, wie gut Sie die Ihnen gestellte Aufgabe verstanden haben. (Bitte ankreuzen)

Gar nicht	Kaum	Mittel	Gut	Sehr gut
1	2	3	4	5

2. Bitte schätzen Sie die Qualität der erstellten Use Cases (in %) ein. (Bitte ankreuzen)

0-20	21-40	41-60	61-80	81-100

3. Bitte geben Sie die Zeit in Stunden an, die Sie zur Erstellung der Use Cases benötigt haben:

Beurteilung der Verständlichkeit der Richtlinien

1. Wie beurteilen Sie den Detailgrad der angegebenen Richtlinien zur Erstellung von Use Cases? (Bitte ankreuzen)

zu wenig detalliert	wenig detailliert	Genau Richtig	zu detalliert	übermässig detalliert
1	2	3	4	5

2. Bitte beurteilen Sie die Verständlichkeit der gegebenen Richtlinien zur Erstellung von Use Cases auf einer Verständlichkeitsskala von 1-6.

   (1 - völlig unverständlich; 6 - leicht verständlich) (Bitte ankreuzen)

   1 2 3 4 5 6

3. Welche Punkte der Richtlinien haben Sie am wenigsten verstanden und warum?

Formblatt 2 - Seite 2 - Fragen zu den Richtlinien

Teilnehmer-Nummer:

4. Was erschwert Ihrer Meinung nach die Verständlichkeit der Richtlinien am meisten? (Bitte nur eine Alternative ankreuzen)

   (a) Nichts besonderes.

   (b) Der Aufbau der Richtlinien in die verschiedenen Teilschritte (z.B. Aktoren identifizieren, Ausnahmefälle identifizieren,....)

   (c) Der Detailgrad der Richtlinien.
   Bitte beschreiben Sie in wie fern der Detailgrad ein Problem ist?:

   (d) Andere Aspekte, und zwar:

Wahrgenommene Anwendbarkeit der Richtlinien

1. Bitte schätzen Sie wie viel der Richtlinien (in %) Sie während Ihrer Arbeit benutzt haben. (Bitte ankreuzen)

   0-20 **21-40** **41-60** **61-80** **81-100**

2. Bitte geben Sie an in welcher Weise Sie den untenstehenden Aussagen zustimmen. Verwenden Sie dazu bitte folgende Skala:

Stimme voll zu	Stimme zu	Stimme eher zu	Stimme eher nicht zu	Stimme nicht zu	Stimme überhaupt nicht zu
1	2	3	4	5	6

   (a) Die Richtlinien waren einfach zu erlernen.

   1 **2** **3** **4** **5** **6**

Formblatt 2 - Seite 3 - Fragen zu den Richtlinien

Teilnehmer-Nummer:

(b)Die einzelnen Schritte der Richtlinien sind sehr einprägsam.

1	2	3	4	5	6

(c)Ich finde die Anwendung der Richtlinien einfach.

1	2	3	4	5	6

Wahrgenommene Nützlichkeit der Richtlinien

1. Bitte schätzen Sie wie sehr Ihnen die Richtlinien bei der Erstellung der Use Cases geholfen haben (Bitte ankreuzen)

sehr viel	viel	mittel	wenig	gar nicht
1	2	3	4	5

2. Bitte geben Sie an in welcher Weise Sie den untenstehenden Aussagen zustimmen. Verwenden Sie dazu bitte folgende Skala:

Stimme voll zu	Stimme zu	Stimme eher zu	Stimme eher nicht zu	Stimme nicht zu	Stimme überhaupt nicht zu
1	2	3	4	5	6

(a) Die Anwendung der Richtlinien beschleunigt meine Arbeit.

1	2	3	4	5	6

(b) Die Anwendung der Richtlinien verbessert die Effektivität der Use Case Erstellung, d.h. die erstellten Use Cases sind von hoher Qualität.

1	2	3	4	5	6

(c) Die Anwendung der Richtlinien verbessert die Produktivität (d.h. die aufgewendete Zeit steht in einem ausgewogenen Verhältnis zur Qualität der Use Cases).

1	2	3	4	5	6

(d) Die Anwendung der Richtlinien macht die Erstellung von Use Cases einfacher.

1	2	3	4	5	6

(e) Ich finde die Richtlinien nützlich..

1	2	3	4	5	6

Formblatt 2 - Seite 4 - Fragen zu den Richtlinien

Teilnehmer-Nummer:

3. Welche Aspekte der bereitgestellten Richtlinien erachten Sie für besonders sinnvoll? Bitte begründen Sie Ihre Antwort:

4. Welche Aspekte der bereitgestellten Richtlinien erachten Sie am wenigsten für sinnvoll? Bitte begründen Sie Ihre Antwort:

Benutzung in der Zukunft

1. Bitte geben Sie an in welcher Weise Sie der untenstehenden Aussage zustimmen.

   Angenommen ich müsste erneut Use Cases erstellen, dann würde ich die Richtlinien erneut verwenden.

Stimme voll zu	Stimme zu	Stimme eher zu	Stimme eher nicht zu	Stimme nicht zu	Stimme überhaupt nicht zu
1	2	3	4	5	6

Document Information

Title:	Guidelines - Creating Use Cases for Embedded Systems
Date:	September 17, 2003
Report:	IESE-078.03/E
Status:	Final
Distribution:	Public