Field Study: Influence of Different Specification Formats on the Use Case Point Method

Stephan Frohnhoff, Thomas Engeroff

Capgemini sd&m AG, Berliner Str. 76, 63065 Offenbach, Germany
frohnhoff@sdm.de, thomas.engeroff@sdm.de

Abstract. The Use Case Point method (UCP method) allows early, easy estimation of the anticipated effort during a software development project. The basis for such estimation in real industrial projects is commonly a number of rough specifications in different formats and of differing granularity. The success of the UCP method and comparability of the results depend above all on whether and how good use cases can be identified and weighted from the specifications. Within a field study, a total number of more than 200 UCP estimations based on eight different specification formats have been performed. The estimations have been compared quantitatively and qualitatively with regard to the reproducibility of effort estimation and with regard to expert valuations. With the help of statistical methods a mean variance (variation coefficient) between 13 % and 48 % was found depending on the specification format. Thus, a valuation of specification formats for improving estimation accuracy could be derived with the help of variance analysis.

Keywords: project effort estimation, top-down estimation, use case points, UCP, specification, estimation reproducibility, field study

1 Introduction

The Use Case Point method (UCP method) has already been described in detail in [1]. It is a top-down estimation method that classifies the functional requirements of the specification into countable units (use cases), to which points are assigned (use case points) according to their estimated complexity. The estimated project effort is then proportional to these use case points.

An important point of criticism about this method is that use cases can be described in different granularity, which could directly influence the UCP estimation result [2, 3, 4]. To reduce the influence of different formats a user guide to handle the different formats has been developed in the past [5].

To obtain an empirical evaluation of the reproducibility using the UCP method, a field study has been set up and executed [6]. The goal was to find out how big the intrinsic error of the UCP method is and how much the UCP method depends on the format of the specification the estimation is based on. Students at eight universities in Germany applied the UCP method on specifications provided in different formats. Thus, it was possible to analyze more than 200 UCP estimations with statistical methods. In addition, the results have been compared with estimations performed by experienced software engineers.

The context for this article and the field study are software development projects for business information systems delivered by the software house Capgemini sd&m as service provider for clients from different industries. The effort estimations are based on different rough specifications provided by clients or developed with clients and they follow no uniform format. The formats of the specifications vary from UML-like descriptions to purely text specifications.

2 Use Case Point method

The UCP method has been described in detail in [1]. The original UCP method [7] reveals an insufficient standard deviation for industrial usage and an enhanced version has been developed [8]. The following analysis is based on this enhanced version called UCP 2.0 [6] which is described in the following. Figure 1 provides a schematic summary. The total effort of a software development project is defined by the effort caused by the functional requirements (A-Factor) times the technological factor (T-Factor), the management factor (M-Factor) and the productivity factor (PF).

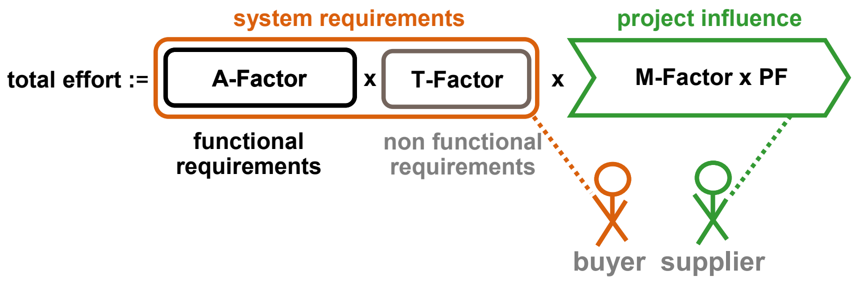

Fig. 1. : Project effort estimation in the enhanced UCP method

Furthermore, figure 1 visualizes the separation of functional requirements, non functional requirements and project influence. As a consequence, this helps to distinguish between influences on project effort caused by the requirements definition and those caused by the way of project delivery. The interpretation of the UCP terms characterizing the different types of efforts is defined as follows.

2.1 A-Factor

Use cases define the functional requirements related to the scope of the project. In business information systems these requirements are implemented in form of application software (A-Software) [9]. The effort for implementation is proportional to the use case points; it is called A-Factor. To ensure standardized levels of complexity, each use case is rated by the number of its main scenarios, steps and dialogs within the course of a use case.

A **scenario** is defined by its faultless courses achieving the main business goal or alternative goals of the use case. Fault scenarios are only counted if they contain business logic.

A **step** is defined by a self-contained business part of the use case being clearly separated by the adjacent steps, e.g. by change of the actor, by intermediate results or by splitting into scenarios.

A **dialog** is understood as any kind of interface of human interaction and includes e.g. print output. In addition, we also count the usage of interfaces to external systems as dialogs.

A detailed description is provided in the extensive and detailed user guide [5]. We define the following levels of complexity:

- Simple: at most 3 main scenarios, steps and dialogs => 5 points
- Medium: at most 7 main scenarios, steps and dialogs => 10 points
- Complex: 8 or more main scenarios, steps and dialogs => 15 points

The point values {5, 10, 15} are chosen according to the original UCP method [7]. The metric for steps and dialogs is based on large (unpublished) statistical data of the Capgemini group in the field of use cases. We count actors with an increased weight A_j = {5, 10, 15} in analogy to the use cases and in contrast to the original UCP method. If n is the number of use cases, m the number of actors and U_i the point values of the use cases, we define the *A-Factor* in the following way:

$$A - Factor := \sum_{i=1}^{n} U_i + \sum_{j=1}^{m} A_j \quad \textbf{(1)}$$

2.2 T-Factor

It corresponds to the Technical Complexity Factor (TCF) in the original UCP method and covers the non-functional requirements which have influence on effort. In UCP 2.0 the influencing variables of the T-Factor from the original UCP method are still used but the values of complexity of these variables (0 to 5 points) have been standardized by the definition of examples and analogies. The influencing variables of the T-Factor are presented in table 1.

The standardized descriptions of the T-Factors are not presented in this paper (cf. [6, 8]). Column 3 defines the corresponding weights g_i according to the original method [7]. The T-Factor ranges from 0.58 to 1.28 and is calculated by multiplying the influencing variables T_i with the weights g_i and by summarizing all weighted values:

$$T - Factor := 0.58 + \sum_{i=1}^{13} (T_i \cdot g_i \cdot 0.01) \quad \textbf{(2)}$$

Table 1. T-Factor of UCP 2.0

T-Factor ("Technical Factor")		
T_i	**influencing factor**	**weight g_i**
T1	Distributed System	2.0
T2	Performance and load requirements	1.0
T3	Efficiency of the user interface	1.0
T4	Complexity of business rules and calculations	1.0
T5	Reusability	1.0
T6	Easy to install	0.5
T7	Easy to use	0.5
T8	Portability	2.0
T9	Easy to change	1.0
T10	System availability	1.0
T11	Special security features	1.0
T12	Direct access for third parties	1.0
T13	Special user training facilities	1.0

2.3 M-Factor

The management (M-) factor defines the complexity caused by project organization and has been derived from the „Environmental Factor“ (EF) of the original UCP method. The EF has been enhanced to a new advanced M-Factor.

In analogy to the T-Factor, each influencing variable of the M-Factor has been standardized with regard to the level of complexity by definition of examples and analogies. The values again range from 0 to 5 points and the standardizing examples and analogies are not presented in this paper (cf. [6, 8]). Table 2 shows the influencing variables M_i of the M-Factor and their corresponding weights g_i.

Table 2. M-Factor of UCP 2.0

M-Factor ("Environmental Factor")		
M_i	**influencing factor**	**weight g_i**
M1	lead analyst capability	1.4
M2	collaboration (team player)	0.0
M3	personal continuity	0.3
M4	quality of rough specification and T-architecture (architecture/risk resolution)	0.5
M5	process model (process maturity)	1.5
M6	required development schedule	0.0
M7	stable requirements	1.8
M8	number of decision makers	0.0
M9	integration dependency	0.7

The M-Factor ranges from 0.23 to 4.81 and has been standardized to 1.0 (i.e. all factors rated with 3 points). The following formula is used to calculate the M-Factor:

$$M - Factor := \prod_{i=1}^{9} \left[1 + 0{,}1 \cdot g_i \cdot (3 - M_i) \right] \tag{3}$$

2.4 Productivity Factor (PF)

The productivity factor (PF) is constant and provides the delivery efficiency rate of the software house. In literature values between 20 and 40 are stated. Due to the higher actor weights, we computed a slightly lower PF of 17.3 h/UCP for our company by calibration with the help of an estimation database containing completed projects.

Both, the M-Factor and the PF are mainly determined by the supplier. The product of all these terms gives the total project effort.

3 Field study

As described in the introduction the goal of the case study was to find out how big the intrinsic error of the UCP method is and how much the UCP method depends on the format of the specification the estimation is based on. In the following a brief introduction to experiments in the area of software engineering is given followed by the description of the setup of the field study.

3.1 Experimental Setup

The experimental setup in general has to ensure that in a given situation the change X to variable x results in a change Y to variable y [10]. This requires that a change Y being observed is causal determined by X which is the case, if during the experimental setup only X changes.

In the case of effort estimation on different specification formats, it is difficult to ensure that only the specification format changes without changes in the estimation process since the estimator is a human being with learning curves and other influencing factors. This has to be minimized with the means of a controlled experiment setup.

Field study versus laboratory study: In a laboratory study each of the n examined specification formats has to address the same business requirements. In estimation praxis, this is unavailable. Therefore, we focus on a field study with a different project context for each specification format. The most important variables to control for this experiment are:

1. ***Instrumentation:*** Repetition of effort estimations by the same estimator may result in learning curves and therefore interference of the experiment. Therefore, each person creates estimations for (only) two different projects. Furthermore, the same

detailed slides and handouts are used for the lectures and exercises at each university.

2. ***Individual differences*** of estimators have been managed by a large scale of estimators and carefully analysis of the experience and the background of these. Each participant (student) attends to a lecture about effort estimation in general and UCP to prepare the exercise (UCP-estimation); mainly information technology students of different universities participated who have the necessary background knowledge on specification of use cases.
3. ***Maturation:*** Effects caused by learning effects during the exercise of this experiment have little to no influence on the results because the participants can easily adjust their results.
4. ***Mortality:*** This means that participants cancel their participation during the field study. For this field study no significant mortality occurred since the estimation was performed in a short period of time (less than 60 minutes) and the participants were highly motivated because of being eager to learn.
5. ***Expectancy and Requirements characteristics:*** Different motivation or attitude to work of the estimators may interfere the field study. To ensure equal task settings for the estimators all instructions were provided literally in the same way.
6. ***Sequence effects*** were controlled by changing the estimation order randomly.
7. ***Sophistication:*** The estimator (reagent) might be influenced by getting a notion of what results are expected by the field study. Therefore, intermediate results have been kept secret during the field study.

Further information can be found in [6].

The first step to set up the field study was to find out which types/formats of specifications are used in real industrial projects. Several projects delivered by Capgemini sd&m have been analyzed. Eight formats have been identified (cf. table 3) to be the most common and therefore the most important ones: three of them consist of UML diagrams, four represent textual formats and one uses dialogs/screenshots to describe the functional requirements of the specified system.

Table 3. Identified specification formats *(most common for Capgemini sd&m projects)*

no.	specification formats	description of format
1	activity diagrams	Unified Modeling Language (UML)
2	sequence diagram	Unified Modeling Language (UML)
3	state charts	Unified Modeling Language (UML)
4	rough textual description	textual description
5	tabular description	textual description
6	functional description	textual description
7	business process description	textual description
8	dialog description	uses dialogs/screenshots complemented with textual description

The specifications used in the field study were taken from these real projects and have only been shortened to fit into students exercises time slots and anonymised to satisfy nondisclosure agreements. It was attempted to use each specification format isolated in exactly one specification. In real projects different specification formats are usually mixed up to specify the system functionality. This had to be avoided for the field study to be able to compare the influence of the different formats.

The **next step** was planning and organizing the field study which was executed as a semi controlled experiment. An experiment design was developed: eight specification formats were chosen (cf. table 3); greater 20 results per format have to be gathered; students from eight universities in Germany participated. In [6] it is shown that a minimum of 20 results per format is a valid and practical sample size to be able to perform a variance analysis using the statistical methods described in chapter 4.1.

3.2 Raw results of the field study conducted

The following table 4 provides raw results of the field study performed with additional values for mean, median, standard deviation and coefficient of variation for each format.

Table 4. Characteristics of the UCP-distributions, sorted by increasing coefficient of variation *(3. column: „N“ = sample size without outliners; 4. column: #UC = number of Use Cases)*

no.	specification format	N	mean #UC	mean [UCP]	median [UCP]	standard-deviation [UCP]	coefficient of variation
4	rough textual description	21	12,9	108,4	106,5	14,9	**0,14**
3	state charts	24	5,3	42,6	43,0	9,4	**0,22**
7	business process description	23	11,5	47,1	45,0	11,3	**0,24**
2	sequence diagram	21	5,3	51,7	50,0	13,2	**0,25**
5	tabular description	29	6,5	70,1	65,0	18,8	**0,27**
8	dialog description	25	8,7	45,7	45,0	12,9	**0,28**
1	activity diagrams	29	13,0	54,7	50,0	15,9	**0,29**
6	functional description	10	6,7	74,6	75,3	23,8	**0,32**

Due to the different mean UCP values the standard deviation cannot be used to compare the different samples (cf. chapter 4.1). Therefore, the coefficient of variation is provided and will later be used to compare these formats. The average dispersion of the UCP values for the different formats (samples) is between 14 % and 32 %. The distributions of the samples and their corresponding formats are visualized using box plots in the following figure 2.

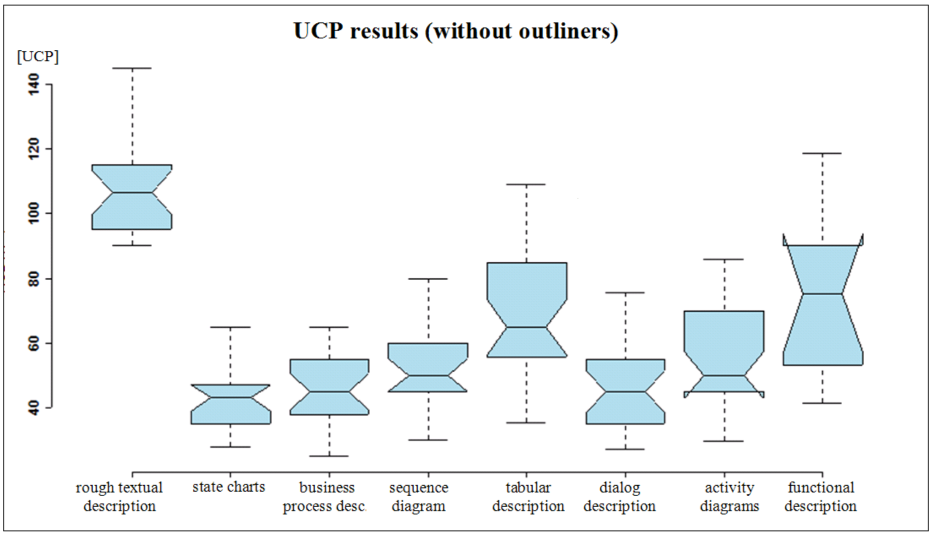

Fig. 2. UCP results visualized using box plots *(results by students, without outliners)*

As an additional characteristic to analyze how much the UCP method depends on the format of the specification the number of use cases identified could be used. During the analysis of this field study it was decided that the validity of this characteristic is weak because the variability of the number of use cases is even much higher for most formats than the variability of the UCP results. This is due to the fact that the estimator can e.g. split a medium sized use case in two simple uses cases which does not make a difference for the UCP result but for the number of use cases.

4 Evaluation of the field study

In a next step the statistical evaluation of the experiment outcome has been prepared. We performed a variance analysis to compare the variances of the estimation results corresponding to the different specification formats. Levene´s Test (cf. chapter 4.1.2) was chosen to compare these variances and to cluster formats with similar variance. In the following subchapters the statistical evaluation of the field study is described followed by a comparison of these student results with additionally collected expert results for the same specifications.

4.1 Statistical methods used

In the following short paragraphs the statistical methods used to analyse and interpret the data of the field study are described briefly. This should give the reader, who is not familiar with statistics, the required statistical background. Subsequently the transformation of the UCP values and the variance analysis performed are explained.

4.1.1 Coefficient of variation

Pearson introduced the coefficient of variation V which is a normalized measure of dispersion of a probability distribution [11]. It is defined as the ratio of the standard deviation σ to the mean μ:

$$V = \frac{\sigma}{\mu} \tag{4}$$

The coefficient of variation can therefore be used to compare the variability of samples with different mean values. V is a relative, dimensionless measure of dispersion with the mean of the corresponding sample as its unit. To simplify interpretation of V conversion to a percent-value (multiply by 100) is often used. This describes the variation from the mean value in percent.

4.1.2 Levene´s test

In statistics, Levene´s test [11] is an inferential statistic used to assess the equality of variance in different samples. It can be used to compare two or more samples at once and is more robust against deviation from normal distribution then the widespread F-Test [11].

Graphically homogeneity of variance can be deduced from the box plots. The boxes and whisker of the samples need to have the same length. Levene´s test is therefore an additional tool to analyze and confirm homogeneity of variances. For two sided problems the pair of hypotheses is as follows:

$$H_0 = \sigma_1 = \sigma_2 = \ldots = \sigma_n \tag{5}$$

$$H_1 = \sigma_i \neq \sigma_j \quad \textit{for at least one i, j with } i \neq j$$

Assuming the 5% level of significance the null hypotheses can be rejected for a p-value < 0.05. In that case the alternative hypothesis, which means heterogeneity of variance, has to be accepted. The other way around this procedure cannot be applied because homogeneity of variance does not follow automatically if the p-value is greater than 0.05. For a p-value close to the value 1.0 together with the observation of the box plots homogeneity of variance can be deduced.

4.1.3 Transformation of UCP values in relation to number of Use Cases

As explained above the coefficient of variation is used to compare the different samples due to the different mean values. Still there is another problem when trying to compare these coefficients of variation. For specifications containing only very few use cases (about less than six), a misjudgment of a single (or a few) use cases will already lead to a quite high deviation from its original total UCP value. From this it follows that the UCP values of the different specifications have to be transformed relative to their mean number of use cases.

For this experiment this means that dispersions of specifications with very few use cases need to be compressed and dispersions of specifications with many use cases need to be stretched out according to the overall mean number of use cases.

Transformation is done by multiplying the UCP value with a constant factor b for each sample. The transformation factor b is calculated to:

$$b = \frac{\overline{ucCount}}{ucCountMean} \qquad (6)$$

where $\overline{ucCount}$ is the mean number of use cases for a specific format and $ucCountMean$ is the overall mean number of use cases. The values of the transformation factor b for the samples of this experiment are in-between 0.6 (state diagram) and 1.5 (functional specification). These transformed UCP values [tUCP] allow the comparison of their coefficients of variation V and therefore allow comparing the variation of the UCP results for the different specification formats.

Figure 3 shows the box plots of the tUCP values ordered by ascending coefficient of variation.

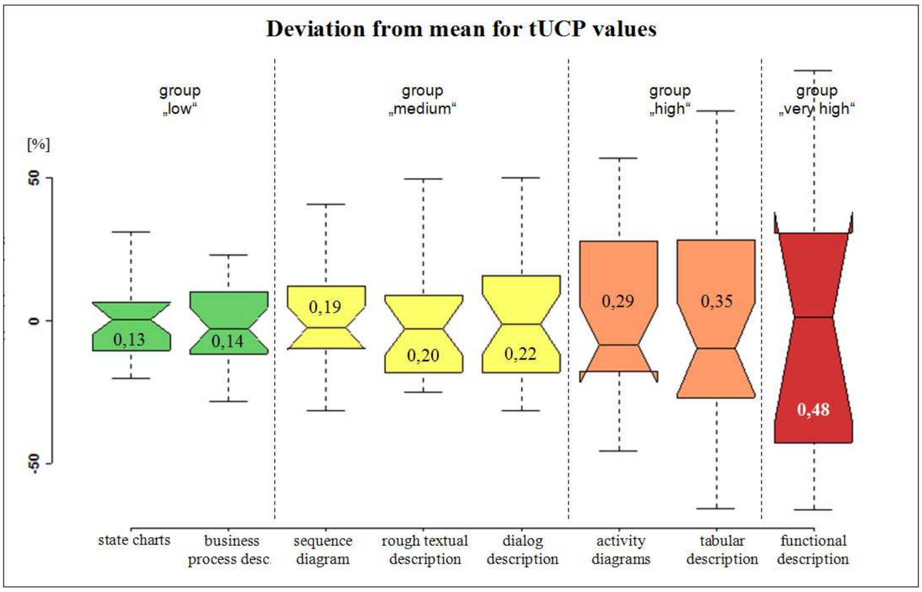

Fig. 3. Deviation from mean for tUCP values in percent *(The explanation of the colors and the group names follows in chapter 4.1.4. The coefficient of variation value for each format is plotted in the middle of each box plot)*

The order of the coefficient of variance values [tUCP] and their corresponding formats do not match with the order of the coefficient of variation values [UCP] (cf. table 4). For example the rough textual description now is only the fourth best format, whereas before the transformation it was the best format. The average number of use cases for this specification is higher than that for most other specifications and therefore the transformation constant b is greater than 1. Through normalizing to a comparable number of use cases by the transformation described above the variance of this format was thereby increased.

4.1.4 Variance analysis performed

To derive a valuation of the specification formats based on its variability a variance analysis has been performed. For all tests performed the following assumptions are fulfilled:

- Independence of cases - this is a requirement of the design
- The distributions in each of the groups are roughly normally distributed

As shown in table 5 Levene´s test has been applied to several groups of formats. The goal was to identify groups of formats which have approximately the same variability, if UCP estimations are performed by more than one estimator based on the same specification.

Table 5. Groups of specification formats by coefficient of variation *(Groups have been gathered by variation coefficient and proven by Levene´s test: Within one group no variance homogeneity is given whereas between the groups variance homogeneity is given.)*

<table>
<tr><th>variability of estimation results</th><th>specification format</th><th>coefficient of variation</th><th>Levene´s test (p-value)</th><th>Levene´s test (p-value)</th></tr>
<tr><td rowspan="2">low (13 – 14 %)</td><td>state charts</td><td>0,13</td><td rowspan="8">6.536e-06</td><td rowspan="2">0,5004</td></tr>
<tr><td>business process descript.</td><td>0,14</td></tr>
<tr><td rowspan="3">medium (19 – 22 %)</td><td>sequence diagram</td><td>0,19</td><td rowspan="3">0,6592</td></tr>
<tr><td>rough textual description</td><td>0,20</td></tr>
<tr><td>dialog description</td><td>0,22</td></tr>
<tr><td rowspan="2">high (29 – 35 %)</td><td>activity diagrams</td><td>0,29</td><td rowspan="2">0,3628</td></tr>
<tr><td>tabular description</td><td>0,35</td></tr>
<tr><td>very high (48 %)</td><td>functional description</td><td>0,48</td><td>-</td></tr>
</table>

The result of Levene´s test applied to all formats (p = 6.536e^{-06}) is highly significant and proofs that variances cannot be equal. Additional intra- and inter-group tests have been performed to find a grouping of the formats. The test results for the intra-group tests are not significant ($p > 0.05$) and therefore the assumption of homogeneity of variances cannot be rejected for the formats of these groups.

The test results for the inter-group tests which are not shown in the table are all significant ($p < 0.05$). Therefore, the assumption of homogeneity of variances between these groups has to be rejected. The variances of these groups differ.

4.2 Comparison with expert results

In addition to the field study with students, four experts at Capgemini sd&m were instructed to perform UCP estimations for each specification format based on the same specifications used by the students. The reason was to compare these expert results with the student results of this field study. By this, a rating of the influence of experience could be derived. A comparison with efforts of real projects was not possible due to shortening of the specifications and because of additional project information was withheld. In figure 4 the box plots showing the deviation between expert and student results in percent are visualized.

The formats are sorted by increasing mean deviation. To support the understanding of the diagram the box plot for the format dialog description is chosen to be explained: The box plot shows that 50% of the students achieved UCP results which differ from the experts´ mean UCP value only between -25% and +30%. The median of the students´ results is very close to the experts´ mean value. Therefore, the influence of experience is very low for this format. Even inexperienced estimators can achieve reliable UCP results if estimation is based on that format.

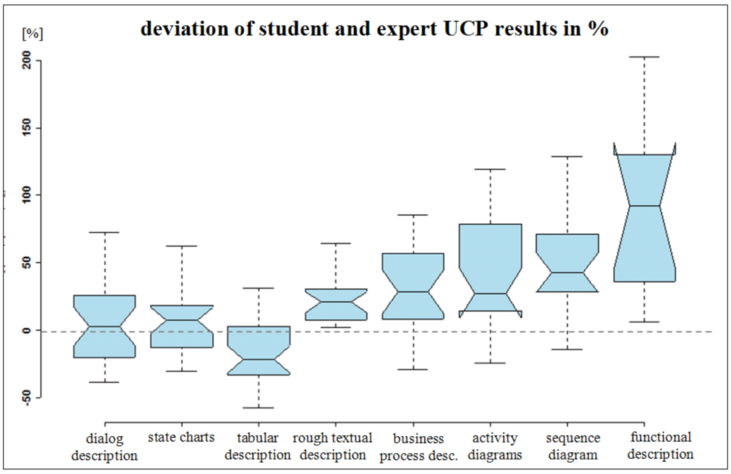

Fig. 4. Deviation of students´ and experts´ UCP results (mean values) in percent

5 Conclusion and Outlook

Within the field study at least 20 estimations by students per format were collected and therefore a valuable statistical evaluation was possible. The mean variance (variation coefficient) of the formats was between 13 and 48% which could be approximately approved by UCP estimations by experts mentioned above.

This field study has proven that the estimation accuracy significantly depends on the underlying specification format. As result, we derived four clusters of the specification formats by variability of the estimation results and we derived a rating of the influence of experience (cf. table 6). A low variability indicates high reproducibility of the UCP estimates. For example, state charts and business process description are very well suited for the UCP method whereas activity diagrams and tabular description result in much less reproducibility.

The clustering by variability of the estimation results was proved with help of Levene´s Test [11]. With the clustering, expert valuation as published in a previous study [5] could now be empirically evaluated and partly confirmed. The rating of the influence of experience was measured by comparing the average use case points from student with results of the four experts. The bigger the distance between average student and expert results, the more influence experience seems to have for the underlying format.

For example, state charts, dialog and tabular descriptions require only low experience by the estimator. On the other hand, the specification with activity diagrams reached a high variability with medium influence of estimators´ experience. This does not correspond to the previous study [5] by experts, who intuitively rated the suitability of the activity diagrams for UCP very good. The reason for this is that steps to be counted for UCP can not always easily be mapped to activities in activity diagrams.

Table 6. Results of field study [6] compared to expert ratings of formats [5]

	expert rating on how good specification format is suitable for UCP-estimates		result field study on suitability of format	
specification format	**expert rating**	**explanatory note to expert rating**	**variability of estimation results**	**influence of experience**
state charts	**average**	-	**low (13 – 14 %)**	low
business process description	**average**	depends on degree of detailing		medium
sequence diagram	**good**	if all use-cases are described	**medium (19 – 22 %)**	high
rough textual description	**good**	-		medium
dialog description	**good**	-		low
activity diagrams	**very good**	-	**high (29 – 35 %)**	medium
tabular description	**very good**	-		low
functional description	**good**	depends on comprehension	**very high (48 %)**	high

Another finding is that the intrinsic error of the UCP method decreases with increasing number of use cases. The method should therefore not be used for small projects with less than 50 use cases. Moreover we found, that for some specification formats the UCP method is suited to be applied without extended knowledge. Furthermore, the execution time for performing the UCP estimate does not reveal an impact on the estimation results.

For further investigations it would be necessary to compare the occurred project efforts with the UCP estimations by taking the different specification formats into account. The UCP database at Capgemini sd&m has been extended with the declaration of the specification format to provide more insights in future.

Within this field study eight different projects, based on disparate types of specifications, have been estimated. Thus, only one specification document per specification format type has been analyzed. This might be the source of a systematical error even if much care has been spent on avoiding interfering experimental effects. In further investigations it might be worth while to have different specification formats for identical business requirements (i.e. laboratory study) to approve the presented results.

References

1. Frohnhoff, S.; Jung, V.; Engels, G.: "Use Case Points in der industriellen Praxis" In "Applied Software Measurement - Proceedings of the International Workshop on Software Metrics and DASMA Software Metrik Kongress", Abran, A. et al. Eds., Shaker Verlag, 2006, pp. 511-526.
2. Habela, P. et al.: "Adapting Use Case Model for COSMIC-FFP Based Measurement Proceedings of the 15th International Workshop on Software Measurement", Montreal, Canada 2005. Shaker Verlag 2005.
3. Ouwerkerk, J.; Abran, A.; "An Evaluation of the Design of Use Case Points (UCP)". Mensura2006 (International on Software Processand Product Measurement), Cadiz, Spain 2006.
4. Cockburn, A.: "Structuring Use Cases with Goals". http://alistair.cockburn.us/crystal/articles/sucwg/structuringucswithgoals.htm, 15. Januar 2007
5. Frohnhoff, S.; Kehler, K., Dumke, R.: "Leitfaden zum Finden von Anwendungsfällen für die Use Case Points Methode", Preprint, Fakultät für Informatik, Universität Magdeburg, 2007
6. Engeroff, T.: „Analyse der Use-Case-Points-Methode hinsichtlich der zugrunde liegenden Spezifikationsformate", Diplomarbeit, Fachbereich Elektrotechnik und Informationstechnik, Technische Universität Darmstadt, April 2008
7. Karner, K: Metrics for Objectory. Diploma thesis, University of Linköping, Sweden, No. LiTHIDA-Ex-9344, 1993
8. Frohnhoff, S; Engels, G.: "Revised Use Case Point Method - Effort Estimation in Development Projects for Business Applications" in "Proceedings of the CONQUEST 2008 - 11th International Conference on Quality Engineering in Software Technology", Potsdam, dpunkt.verlag, 2008
9. Siedersleben, J.: „Moderne Software-Architektur", dpunkt.verlag, 2004.
10. Prechelt, L. „Kontrollierte Experimente in der Softwaretechnik: Potenzial und Methode", Springer, Berlin, 2001
11. Sachs, L.; Hedderich J.: „Angewandte Statistik – Methodensammlung mit R". Springer, Kiel, 12. Auflage, 2006