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Welcome to A View on the New Technologies for Instrumentation and Measurements

On behalf of the organizing committee, we cordially welcome you to the 2006 IEEE Instrumentation and Measurement Technology Conference (IMTC).

This IMTC edition will be held for the first time South of Italy - Sorrento. The IMTC venue, Hilton hotel, with its modern yet inviting facilities, stands on a hill overlooking the town of Sorrento and offering to its guests a unique and spectacular view, beautifully framed by the jagged outline of the Gulf of Naples on the horizon, the unmistakable silhouette of Mount Vesuvius, while just round the corner unfolds the breathtaking Amalfi Coast. The same encounter of sky, land and sea that has inspired so many poets and writers since the old Roman times.

IMTC/2006 continues a series of successful scientific and technical annual events with this 23rd edition. The conference covers all aspects of the theory and practice of instrumentation, measurement and control technologies, and related applications. This year the conference is focused on *A View on the New Technologies for Instrumentation and Measurements*. The impetuous escalation of the technology requires, as a consequence, a continuous view on its impact on instrumentation and measurement field both from research, industry, and daily life.

We are sure that the universally recognized beauty of Sorrento will be a perfect frame for this prestigious conference. It is, in fact, a further occasion, not only to meet old friends and new people from all over the world, but, moreover, to engage with them a continuous comparison directed to make wider the views on the technological progress of Instrumentation and Measurement.

The IMTC/2006 organization was a complex task due to the large and increasing interest of our research and application areas. Effort from many people was required to shape the technical program, arrange accommodation, manage the administrative aspects, and set up the social functions. We like to take this opportunity to thank all and each of them. We like also to thank the public and private organizations that supported the meeting in different ways.

For the first time a complete automatic web based abstract selection was introduced, the final electronic version of the manuscripts was formatted by using an adequate software developed for this aim.

The IMTC/2005 Technical Program consists of 86 oral and poster sessions scheduled over three days. With the wide range of technical sessions covering the whole range of the Instrumentation and Measurement field we are happy to welcome you to the variety of technical presentations that await you this year. Thanks to all of the Technical Program Committee members and the reviewers who have contributed to make this outstanding program possible.

The technical program was particularly difficult to be arranged since we received, for the first time 644 abstracts from all over the world. Due to the time limits of the conference only 460 papers have been selected after a painstaking activity of the program committee and additional reviewers. We like to thank all people who contributed to this process with opinions, comments, and suggestions to choose the best papers and even improve their quality.

The technical program encompasses several events and activities. The keynote speech will be held by FERRARI experts in the field of electrical and electronic measurements, we tried to show a one the well recognized world wide Italian technology.

Several parallel sessions will accommodate the contributed papers: to avoid overlapping of sessions on related topics, papers are distributed in separate thematic tracks. A special one, the 2nd ADC Forum, was devoted to ADCs, DACs and DAQ. Some sessions are designated as special since they have been solicited and organized and will be chaired by well-known experts from the international industrial and academic communities. Panels have also been organized to allow a wider and in-depth discussion of some hot topics related to education and measurement system modernization.

Tutorial sessions have been included to offer attendees hands-on, practical information.

Several Awards offered by International Institution and Companies will be assigned, in particular to young researchers.

The Conference is about to begin. You are now in a position to enjoy the fellowship of colleagues and experts and to pass free time in natural and artistic beauties. It is up to you to appreciate the Conference worth! Be critical! We, metrologists, colleagues, and friends, we know that this is the best way to improve quality, and to achieve lasting excellences.

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A Proposal and Empirical Validation of Metrics to Evaluate the Maintainability of Software Process Models

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Abstract *–Software measurement is essential for understanding, defining, managing and controlling the software development and maintenance processes and it is not possible to characterize the various aspects of development in a quantitative way without having a deep understanding of software development activities and their relationships The current competitive marketplace calls for the continuous improvement of processes and as consequence companies have to change their processes in order to adapt to these new emerging needs. It implies the continuous change of their software process models and therefore, it is fundamental to facilitate the evolution of these models by evaluating its easiness of maintenance (maintainability). In this paper we introduce a set of metrics for software process models and discuss how these can be used as maintainability indicators. In particular, we report the results of a family of experiments that assess relationships between the structural properties, as measured by the metrics, of the process models and their maintainability. As a result a set of useful metrics to evaluate the software process models maintainability, have been obtained.*

Keywords *– Software Process Models, Metrics, Maintainability.*

I. INTRODUCTION

Software processes have turned into a very important factor to consider for the success of software organizations nowadays. They have to change their processes in order to keep high competitiveness in the market. Causes of such frequent and relevant modifications could be [1] [2] [3]: Introduction of new technologies; Improvement of maturity according to models as CMM (Capability Maturity Model) [4], CMMI (Capability Maturity Model Integration) [5] and ISO 15504 [6]; Innovative production methods: software components based [7], software product lines [8], development based on open-source software [9], agile methodologies [10].

This process improvement culture in organizations has made the management of software processes to be largely recognized as a key factor for improving both the productivity of an organization and the quality of the software delivered [11]. In software process management, the process modelling is a key activity to consider and it is the starting point for analysing, improving, and enacting processes [12].

A software process model (SPM) is an abstraction of a real-world software process expressed in a suitable process modelling language (PML). SPMs applications range from comprehension to enactment; Curtis et al. identify five main applications of process modeling [13]:

- To facilitate human understanding and communication.
- To support process improvement.
- To support process management.
- To automate guidance in performing process.
- To automate execution support.

SPMs can be grouped into two main categories: descriptive models and active models [13] [14]. Descriptive models are aimed at describing processes and organizational behavior in terms of entities—activities, roles, tools, and artifacts- and the relationships among them. Active models are intended for building executable systems that support the enactment of processes. Descriptive SPMs, which are the focus of this paper, have proven useful for guiding process execution and as basis for measurement in the context of software process improvement [15]. As a matter of fact, they are prerequisite for active modelling.

Taking into account the main uses of SPMs it is necessary to maintain effectively the process models with the aim to facilitate [13]: the communication of process modifications, the understanding of new responsibilities and procedures and the automation of guidance in performing new activities. As a consequence, process models must be continuously maintained based on gained experience, new requirements and changed policies [16]. This suggests the need for descriptive software process models with high maintainability. In particular, means are needed to evaluate the maintainability of software processes in the early stages of their development, primarily during process modelling. This would provide organizations with a basis for choosing, among semantically equivalent SPMs, the model which can be more easily maintained and adapted to new and emerging needs.

According to the issues previously identified, our main research goal consists of providing a set of objective indicators in order to evaluate the maintainability of descriptive SPMs. To reach this goal we have quantified descriptive SPMs by means of the definition of a set of suitable metrics and we have carried out a family of experiments to find the metrics that can be used as maintainability indicators.

This paper is organized as follows. Section 2 introduces the metrics for SPMs and presents an example of computation. Section 3 provides an overview of the family of experiments carried out in order to empirically validate the metrics and finally the conclusions and future works are outlined.

II. A PROPOSAL OF METRICS FOR SOFTWARE PROCESS MODELS

A representative set of metrics for software process models has been defined in order to evaluate SPMs maintainability (Table 1).

Table I. Model Scope Metrics.

Metric	Definition
NA	Number of **Activities** of the software process model
NWP	Number of **Work Products** of the software process model
NPR	Number of **Roles** which participate in the process
NDWPIn	Number of input dependences of the **Work Products** with the **Activities** in the process
NDWPOut	Number of output dependences of the **Work Products** with the **Activities** in the process
NDWP	Number of dependences between **Work Products** and **Activities** $NDWP(PM) = NDWPIn(MP) + NDWPOut(MP)$
NDA	Number of precedence dependences between **Activities**
NCA	Activity Coupling in the process model. $NCA(PM) = \frac{NA(PM)}{NDA(PM)}$
RDWPIn	Ratio between **input dependences** of Work Products with Activities and **total number of dependences** of Work Products with Activities $RDWPIn(PM) = \frac{NDWPIn(PM)}{NDWP(PM)}$
RDWPOut	Ratio between **output dependences** of Work Products with Activities and **total number of dependences** of Work Products with Activities $RDWPOut(PM) = \frac{NDWPOut(PM)}{NDWP(PM)}$
RWPA	Ratio of **Work Products** and **Activities**. Average of the work products and the activities of the process model. $RWPA(PM) = \frac{NWP(PM)}{NA(PM)}$
RRPA	Ratio of **Process Roles** and **Activities** $RRPA(PM) = \frac{NPR(PM)}{NA(PM)}$

The metrics have been defined following the SPEM terminology [17] by examining its key software process constructors, but they can be directly applied to other PMLs. The defined metrics are Model Scope (see Table 1), because they measure the structural complexity of the overall software process model. The metrics have been theoretically validated by using the DISTANCE framework [18] and they belong to the ratio scale.

In Figure 1 an exemplar software process model represented with SPEM is shown, for which the Activity Diagram UML notation and the stereotypes which represent the SPEM constructors can be used. The metrics values are also shown.

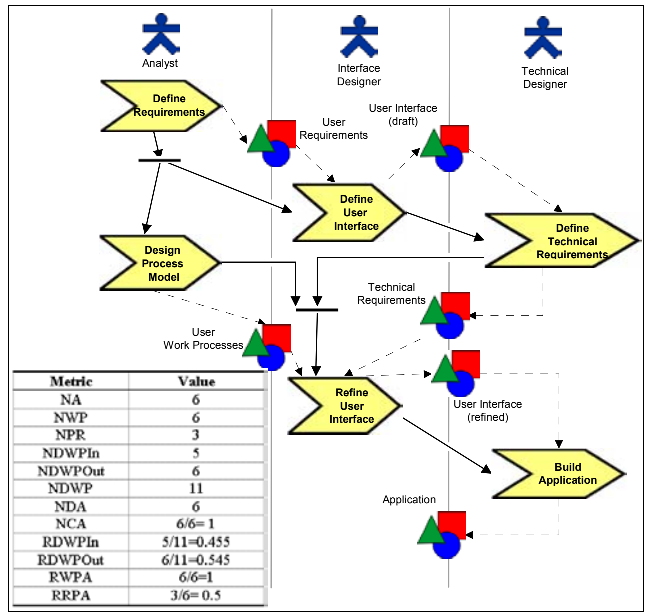

Fig. 1. Software Process Example and Metric Values

III. EMPIRICAL VALIDATION OF THE PROPOSED METRICS

With the aim to establish which metrics are useful SPMs maintainability indicators, a family of experiments was carried out [19]. A five steps process was exploited based on Ciolkowski et al. proposal [20]:

1. **Experiment Preparation**. The general goal of the experiments was to demonstrate the suitability of the selected SPM metrics as maintainability indicators. By using the GQM template [21] the experiment goal can be defined as follows::
   - **Analyse** SPMs Metrics
   - **With the purpose of** Evaluating
   - **With respect to** their capability of being used as maintainability indicators
   - **From the point of view of** Researchers
   - **In the context of** Computer Science Undergraduate Students and Professionals of Information Systems.

2. **Context Definition**. In order to ease the generalization of the results the following groups of subjects were identified to establish the context of each individual experiment:
   - ***Professionals***. They are the ideal subjects to generalize the results, and for this reason we have to use this kind of subjects whenever it is possible.
   - ***Students***. They play a very important role in software engineering experimentation, because in general before performing studies in industrial environments, which requires resources, and time, researchers carry out pilot studies with students in academic environments [22]. In addition, students are the next generation of professionals [23] and under some conditions, there is not a great difference between students and professionals.

3. **Material**. The material prepared for the family of experiments was composed of eighteen SPMs with different metric profiles. The models were based on different methodologies and SPMs found in literature, as for example PMBOK, Rational Unified Process, etc. Additional material was prepared for the individual experiments based on the types of tasks to be performed on the models and the data to be gathered.

4. **Conduct Individual Experiments**. According to the general plan of the family we carried out five individual experiments which were grouped under two main categories depending on the kind of tasks to be performed by the subjects:
   - **Subjective Rating**. In this group (1st and 2nd), the maintainability sub-characteristics were rated in a subjective way according to the opinion of the subjects.
   - **Objective Rating**. In the objective experiments (3rd, 4th and the two replicas) the subjects had to perform a set of tasks on the models related to their maintainability (understandability and modifiability). In these experiments the dependent variables were measured in an objective way by calculating the time spent by the subjects in performing these tasks.

   To carry out each individual experiment we took into account the general plan established in the context of the experiment family and the feedback obtained as a result of performing each experiment of the family.

5. **Family Data Analysis**. Table 2 provides a general summary of the results obtained in the individual experiments is provided. Five experiments grouped in two subjective and three objective ones were performed in which 224 subjects participated, belonging to the following groups: students, researchers, assistant professors and professionals.

Table II. Summary of the results of the Experiments Family.

Experiments	Subjects		Nº Subjects	Nº Mod	Dependent Variables	Measurement of Dependent Variables	Empirically Validated Measures
1st	Professors, Researchers, Students		20	18	Understandability (U) Analysability (A) Modifiability (M)	Subjective Rating of Subjects (U, A, M)	**U, A, M:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA
						Understandability Time (UT)	**UT:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA
2nd (replica of the 1st)	Professors, Researchers, Students		25	18	Understandability (U) Analysability (A) Modifiability (M)	Subjective Rating of Subjects (U, A, M)	**E, A, M:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA, RRPA (only A)
						Understandability Time (UT)	**UT:** NA, NWP, NDWPIn, NDWPOut, NDWP
3rd	Professionals		29	18	Understandability (U) Modifiability (M)	Understandability Time (UT)	**UT:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA
						Modifiability Time (MT)	**MT:** –
4th	Students		86	10	Understandability (U) Modifiability (M)	Understandability Time (UT)	**UT:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA, NCA
						Modifiability Time (MT)	**MT:** NWP, NDWPIn, NDWPOut, NDWP
5th (replica of the 4th)	R1	Students	26	10	Understandability (U) Modifiability (M)	Understandability Time (UT)	**UT:** NWP, NDWPIn, NDWPOut, NDWP
						Modifiability Time (MT)	**MT:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA
	R2	Students	38	10	Understandability (U) Modifiability (M)	Understandability Time (UT)	**UT:** NA, NWP, NDWPIn, NDWPOut, NDWP, NDA, NCA
						Modifiability Time (MT)	**MT:** NWP, NDWPIn, NDWPOut, NDWP

According to the results the following general conclusions were obtained:

- The metrics NA, NWP, NDWPIn, NDWPOut, NDWP and NDA are valid metrics which can be used as SPMs maintainability indicators. This significant group of metrics were correlated in all the experiments with the dependent variables studied.
- The metric NCA was not validated as a result of the subjective experiments, but it is correlated with the understanding time in the fourth experiment and in the second replica in the fifth experiment. As a result, it seems that NCA could be also a useful understandability indicator, but it is necessary to confirm it with new empirical studies focused on this metric.
- Also it could be necessary to consider in future studies the metric RRPA because although it has been only correlated with the analysability in the 2nd experiment, its values of correlation in the majority of the experiments of the family were relatively near of the cut-off.
- The metric NPR does not seem to be correlated with maintainability. It suggests that the process roles do not have influence on the SPM view on which the metrics were defined. The results show that in this view the activities, work products and their dependences are the most influent elements in maintainability. Anyway, this metric should be significant in other views of the SPMs, as for instance, the view in which are defined the roles and their responsibilities on the work products. This issue could be considered in future studies.
- The metrics RDWPIn, RDWPOut y RPTA are not correlated with maintainability. In future studies these metrics could also be taken into account to demonstrate if they really have an influence or discard them definitely.

In the group of objective experiments (3^{rd}, 4^{th} and 5^{th}) additionally to the time measure, other collected measures to evaluate the dependent variables (understandability and modifiability) were the subjective rating that subjects made about the understandability and modifiability of the SPMs (in a scale of five possible values from extremely difficult to extremely easy to understand or modify). The correlation data obtained confirmed the results of the time measure because the significant group of validated metrics was also correlated with the subjective ratings. Other significant measure to evaluate the understandability was the efficiency for which the formula used was:

$$Efficiency = \frac{Number\_of\_correct\_answers}{Time}$$

Table III summarizes the Spearman correlation results of the efficiency with respect to the proposed metrics:

Table II. Spearman Correlation Coefficients for Efficiency

	Efficiency			
Metrics	**Exp 3**	**Exp 4**	**Exp 5 (R1)**	**Exp 5 (R2)**
NA	**-0,616 p= 0,007**	**-0,890 p=0,001**	-0,543 p=0,105	
NWP	**-0,554 p=0,017**	**-0,736 p=0,015**	**-0,863 p=0,01**	
NPR	-0,212 p=0,398	-0,130 p=0,721	-0,253 p=0,480	
NDWPIn	**-0,552 p=0,017**	**-0,695 p=0,026**	**-0,854 p=0,002**	
NDWPOut	**-0,685 p=0,002**	**-0,853 p=0,002**	**-0,632 p=0,050**	
NDWP	**-0,627 p=0,005**	**-0,829 p=0,003**	**-0,817 p=0,004**	
NDA	**-0,613 p=0,007**	**-0,887 p=0,001**	-0,526 p=0,118	
NCA	0,409 p=0,092	**0,820 p=0,004**	0,422 p=0,224	
RWPTIn	0,023 p=0,929	0,042 p=0,907	-0,467 p=0,174	
RWPTOut	-0,023 p=0,929	-0,042 p=0,907	0,467 p=0,174	
RWPA	-0,030 p=0,906	0,248 p=0,489	-0,248 p=0,489	
RRPA	0,332 p=0,178	0,558 p=0,093	0,129 p=0,723	

Regarding the results shown in Table III, the obtained conclusions were: In the third and forth experiments the activities and their precedence relationships (evaluated with the metrics NA, NPDA and NCA) had influence on the correctness of answers. However these results were not confirmed by the replicas, due to in the first replica were no correlation at all between the metrics and correctness and in the second one the only metrics correlated were RWPTIn and RWPTOut, which indicated in this case that the work products dependences had influence on the correctness. These differences can be due to the possible differences between the educative programs in software engineering courses in Spain and Italy. Therefore, more empirical studies should be conducted in order to confirm if some of the proposed metrics can predict the understandability of the models by means of its answers correctness.

IV. CONCLUSIONS

In this paper we have proposed and empirically validated a set of representative metrics to evaluate the maintainability of descriptive SPMs. These metrics are based on the main elements included in a SPM and can be used to ease SPMs evolution. In order to empirically validate the metrics proposed we carried out a family of experiments from which we obtained significant conclusions. As a result of this study, we can conclude that the metrics NA, NWP, NDWPIn, NDWPOut, NDWP and NDA are good maintainability indicators.

The metrics provide companies with objective information about the maintainability of their SPMs. More maintainable SPMs can benefit the management of the software processes by providing: a better understanding and communication of the processes which eases its later active modelling and enactment; more easiness to reflect the changes between the models and their enacted projects which contributes to preserving their accuracy and a reduction of the necessary effort and cost to change the models.

The results obtained with the overall family of experiments are encouraging and have allowed us to select a set of useful maintainability indicators. However, it is necessary to develop new empirical studies to confirm the usefulness of the empirically validated metrics and obtain insight enough to discard the metrics that do not have influence on the maintainability of SPMs. As a result, the lines to consider in future works are:

- To design new experiments in order to evaluate:
    - Some metrics we consider relevant (NPR, NCA) and that according to the family experiment results seem not to be clearly correlated with the maintainability of SPMs.
    - New measures of the dependent variables understandability and modifiability. It is necessary to confirm with new experiments if some of the proposed metrics can predict the answer correctness of the subjects due to the current family of experiment do not provide insight enough to select valid metrics. The correctness also should be considered as measure of the modifiability variable.
- Building of prediction models of the maintainability of the models by researching the concrete influence of each validated metric in the easiness of maintenance of the SPMs.
- Performing case studies using real software process models.

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