Graphical Technique to Support the Teaching/Learning Process of Software Process Reference Models

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Abstract. In this paper, we propose a set of diagrams to visualize software process reference models (PRM). The diagrams, called dimods, are the combination of some visual and process modeling techniques such as rich pictures, mind maps, IDEF and RAD diagrams. We show the use of this technique by designing a set of dimods for the Mexican Software Industry Process Model (MoProSoft). Additionally, we perform an evaluation of the usefulness of dimods. The result of the evaluation shows that dimods may be a support tool that facilitates the understanding, memorization, and learning of software PRMs in both, software development organizations and universities. The results also show that dimods may have advantages over the traditional description methods for these types of models.

Keywords: Software reference model, teaching, learning, dimods, MoProSoft.

1 Introduction

The software process improvement has become the primary approach for software organizations to increase the productivity and the quality of its products and to reduce the time and the cost of the development process [1]. To improve their processes, many companies make changes to meet the specifications of the process reference model (PRM) that they want to implement. Recently, a number of PRMs have been proposed to guide and promote software process improvement (SPI) initiatives. Some of the most well known models are ISO 9001:2000, CMMI, ISO/IEC 15504:2004, ISO/IEC 12207:2004. Additionally, many researchers have proposed several simplified PRMs specific for the small and medium-sized enterprises (SMEs), since traditional PRMs do not consider the particular characteristics of SMEs (for example, their severe restriction and limitation of resources and employees). The implementation of these simplified models in the SMEs is easier and cheaper than comprehensive PRMs. An example of a simplified PRM is MoProSoft (that we describe later in this section).

In general, the implementation of a PRM in a software development organization is a very complex and expensive process and it takes a long time (especially in the context of SMEs). The literature mentions a number of factors that hinder the implementation of these models in software development organizations [2-6]. One of

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the first steps in a SPI initiative is to train the employees about the PRM. During this stage, the people involved (engineers, technicians, and managers) learn or teach the PRM structure and the four perspectives of its processes: functional perspective (what), behavioral perspective (when and how), organizational perspective (where and who) and the perspective of information (data). However, the following problems sometimes limit this teaching/learning process:

- *Lack of technical knowledge*. Many of the people involved in the SPI initiative are not software engineers (managers, technicians, etc.). It is desirable that any employee without specialized technical knowledge or training can understand the PRM and the structure of its processes [7-9]. Additionally, some PRMs also include UML (Unified Modeling Language) diagrams; however, in general the managers and technicians do not know UML diagrams and their symbols.
- *The use of narrative in PRMs.* Narrative sometimes can be unsatisfactory because it can suffer from ambiguities inherent in the language; sometimes narrative can be semantically confused since to penetrate into an explanation, it increases the size of the description [10]. In addition, time is wasted since very often the reader is forced to read unnecessary information. According to Buzan [11], narrative excludes from the brain its capacity to catch color, dimension, synthesis, rhythm, and image. Another problem is that narrative impedes brain from establishing associations, which restricts the memorization ability and creativity.

There are also some characteristics of the SMEs that hinder the teaching/learning process: their employees are usually overworked and have little time to learn the PRM [2, 12-14]; in general, the SMEs have large budgets constraints [2, 15, 16]; SMEs train only a small number of employees because of the high training costs [12]. In general, the PRM for the software industry are complex and we believe that the problems mentioned above worsen this situation.

In Mexico, where 90% of the organizations that develop software are SMEs, the Mexican government [17] introduced the simplified Software Industry Process Model, MoProSoft [18], and its evaluation method EvalProSoft [19]. MoProSoft is based on other widely implemented models such as ISO 9001:2000, CMMI and ISO/IEC 12207. MoProSoft (available online[1]) has nine processes, and unlike other reference process models, it includes administrative processes such as business management, resource management and project management. MoProSoft mainly uses narrative to describe its processes and it includes a few UML diagrams. MoProSoft is now the Mexican standard for software development and until April 2010, 145 companies were certified in some level of MoProSoft. Additionally, MoProSoft is the model that is intended to be the standard for ibero-american countries through COMPETISOFT project [20]. MoProSoft is also the base for the standard ISO/IEC 29110 [21].

The idea for this research came after attending a seminar of the MoProSoft model. The motivation for the research was to understand how we could improve the description of the PRM to facilitate its teaching/learning process. Therefore, the objective of the present paper is twofold; first, it aims to answer the following question.

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1 http://www.comunidadmoprosoft.org.mx/COMUNIDAD_MOPROSOFTADM/Documentos/V_1.3.2_MoProSoft_English.pdf

– *How can we improve the description of the process improvement model to facilitate its teaching-learning process?*

Second, by using the information we gathered after answering this question, to design a mechanism or tool that could facilitate its teaching/learning process. The resulting tool is a special type of diagrams, that we call "dimods". Our research shows that dimods has some advantages over the traditional way to describe MoProSoft.

This paper is organized as follows. Section 2 describes the related work. Section 3 describes our methodology. Section 4 describes the identification of areas of improvement. Section 5 describes the development of dimods. Section 6 describes the dimods. Section 7 explains the evaluation procedure for these diagrams and presents its results. Finally, in Section 8 we present our conclusions and provide some research directions for future work.

2 Related Work

To facilitate the use of PRMs, researchers have developed a set of techniques and tools. Kellner *et al.* [22] developed an EPG, which is an online electronic system that contains all the information regarding the PRM (that originally is in printed format) and additional information such as tables, diagrams, examples and templates to get a better understanding of the PRM. EPGs also allow flexible navigation through the information they provide. Other researchers also developed EPGs [23, 24] and tested their adoption [25, 26]. Hauck *et al.* [27] developed the Process Reference Guide, which is an electronic tool that maps requirements of PRMs to a broad variety of processes, techniques and/or tools to satisfy the requirements. Shin *et al.* [28] developed Jasmine, which is a PSP (personal software process) supporting tool that includes an EPG and an ER (Experience Repository) to allow developers to store important experiences during their daily activities. The above proposals focus on facilitating the management and flow control of information of processes, but none of them focus on facilitating the teaching/learning process for stakeholders.

3 Methodology

We divided the study into three stages; in stage one, we identified the problems that arise in the teaching/learning process of MoProSoft and identified the features that are necessary for a tool that supports this process. Later in stage two, we developed the tool based on the information gathered in stage one. Finally, in stage three we made the evaluation of the proposed tool. We collected and analyzed data using a combination of qualitative and quantitative methods. We conducted semi-structured interviews; the information obtained was analyzed with the techniques of open codification and axial codification of the grounded theory technique [29]. Additionally, one of the authors of this paper attended the MoProSoft seminar and used the participant observation technique to enrich the information collected with the semi-structure interviews. Finally, we developed and implemented a questionnaire survey to obtain quantitative data to help verify the data obtained in the semi-structured interviews.

4 Identification of Areas for Improvement

In order to address the research question, we interviewed thirty people. The target population in this research was people with knowledge and experience in the teaching/learning process of MoProSoft (from hereafter, we refer to the MoProSoft user manual as the *norm*). Ten of them are faculty members, eight are software engineers, five are software entrepreneurs, and seven are undergraduate engineering students. We wanted to identify their perceptions and experiences regarding the teaching/learning process of the norm. We transcribed the entire semi-structured interviews and got some commentaries such as the following:

- *"...it is necessary another way of representing the information to help me to understand more easily the process, their relations, and dependences…"*
- *"... for me is not very clear how, when, where and by whom the activities must be performed..."*
- *"...the norm is so confused that I do not know where to start the implementation, and I do not know how to convey the information that I am learning to my coworkers."*

We analyzed the information collected in the semi-structured interviews with the grounded theory technique and found some problems. We divided these problems in four categories.

1. *Description and presentation*. Problems related to the form in which the norm describes processes, the way it highlights the relevant information, and those problems related to the quality and quantity of its graphs.
2. *Organization of information*. Problems related to how the norm organizes the information, how it groups processes, highlights the maturity levels of the tasks and products and facilitates information search.
3. *Identification of elements and associations*. Problems related to the identification of activities, tasks, products and roles in the norm and their associations and dependences.
4. *Pedagogic feature*. The number of activities and effort required to perform the teaching/learning process of the norm.

From the analysis of the information gathered, we concluded that it is necessary to design a mechanism that integrates the following characteristics:

- It must be compact and simple to clearly visualize the diverse elements (activities, tasks, roles, artifacts and products) of the norm.
- It must clearly show the dependences and interactions among the diverse elements of the norm, and to indicate to which capability level each of them corresponds.
- It must clearly show the activities that each person has to perform and when this person has to perform them.
- It must include color and figures to facilitate the learning process and to increase retention of information and the level of memorization.

5 Basic Techniques That Support Dimods

The dimods are based on four techniques: Role Activity Diagrams (RAD), IDEF diagrams, mind maps, and the rich picture technique. We choose RADs and IDEF diagrams because they are probably the best and simplest techniques to understand and communicate processes [30]. Additionally, we included the mind maps and the rich picture technique because they emphasize the use of color, the association of ideas, and the relationship of elements. In spite UML can be used for process modeling, the above techniques are more suitable for this activity than UML; remember that UML is focused to the object-oriented paradigm, which is mainly used to model systems. We provide a basic description of the above techniques.

5.1 Mind Maps

Mind maps [11] are tools that help to organize and represent information with the intention of facilitating learning processes, administration and organizational planning as well as decision-making. Mind maps allow representing ideas by using the cognitive functions of the brain hemispheres [31]. Brain and mind maps operate by association of ideas. Mind maps start with a central idea (or keyword); from this idea, many branches ramify and connect to other related ideas. The connected ideas show different aspects of the same topic. A mind map can help to represent graphically all the activities tending to accomplish a specific goal. To improve its appearance, a mind map may also include colors, images, and codes.

5.2 Rich Pictures

Peter Checkland developed rich pictures as part of his Soft Systems Methodology [32]. He describes rich pictures as a methodology to represent an idea, a problem or a concept. Rich pictures do not have rules, except that they must contain four principal elements: actors, activities, artifacts and products. Rich pictures provide a general view of a topic. They also show relations and interdependences among the elements, clearly identify the main activities and the actors of the activities.

5.3 Role Activity Diagram (RAD)

The *Role Activity Diagrams* (RADs) is a visual notation for business process modeling. They concentrate on modeling individual or group *roles* within a process, their component activities, and their interactions, together with external events and the logic that determines what activities are carried out and when [33]. RADs differ from most other process diagrammatic notations in that they adopt the *role*, as opposed to the *activity*, as the primary unit of analysis in the process model. Due to this focus, they are suitable mostly for organizational contexts, in which the human element is the critical organizational resource addressed by that process change. However, they cannot accommodate the explicit depiction of an experimentation with other organizational perspectives (for example, *functional* or *informational*), restricting their role to being mostly complementary in the context of business engineering [30].

5.4 IDEF family

The development of the IDEF family [34] of modeling techniques started in the 1970s as a set of notational formalisms for representing and modeling process and data structures in an integrated fashion. The IDEF family consists of a number of independent techniques, the most well known modeling languages are IDEF0 (function modeling), IDEF1x (data modeling), and IDEF3 (process description capture). The IDEF0 language models the actions, decisions, and activities of an organization or any other system. The IDEF1x language is useful to analyze, understand, represent, and communicate data resources in an organization. The IDEF3 language was developed to overcome some of the limitations of the IDEF0 language. IDEF3 describes processes as ordered sequences of events or activities. This language supports the description of all the elements involved in a process such as roles, activities, relations, etc. It can represent a process from several points of view [30].

6 Dimods

The diagrams to visualize PRM, called dimods, are a graphical technique with the aim of facilitating and supporting the teaching/learning process of PRMs. Dimods inherit the properties of mind maps, since mind maps constitute the fundamental structure for dimods. Thus, dimods facilitate concentration, capacity of retention and the comprehension of the model, because to read a dimod (as well as mind maps) the brain uses its both cerebral hemispheres. Dimods use color to relate activities to their process and sub-process. Similarly, products are related to the levels of capability. Dimods as well as the rich picture technique emphasize the roles, products, tasks and artifacts, since these elements are represented by figures. Additionally, as well as the RAD diagram, the primary unit of analysis of dimods is the role. Finally, the dimods as well as the IDEF diagrams allow users to view the models from different levels of generality. We now describe the set of dimods that we designed to represent model MoProSoft. In order to imitate its structure, we designed the dimods in three hierarchical levels:

1. The dimods of the first level (see Figure 1) provides a global view of MoProSoft with its three process categories (Top management, Management, and Operations) each one has its own label (*e.g.* the process business management has label TM.1). Each category also shows its processes and sub-processes. We designed only one diagram for this level.

2. The dimods of the second level detail the components of each process or sub-process. It clearly specifies its goals, roles, activities, inputs and outputs. Figure 2 shows the basic information related to the process business management. This figure shows its three goals (labeled as G1, G2 and G3), its three activities (labeled as A1.G1, A2.G2 and A3.G3), its three roles that participate in this process (labeled as RBM, SC and MG), its six inputs, and its five outputs. We designed nine diagrams for this level.

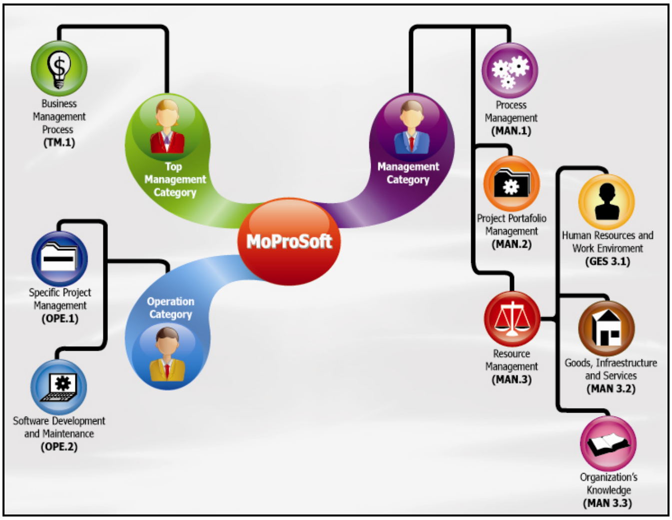

Fig. 1. Dimods of the first level

3. The dimods of the third level detail an activity. For each activity, dimods clearly specify its tasks, the role in charge of performing each task, the inputs and output products for each task, the dependences among tasks of the same activity and with tasks of other activities. Figure 3 shows the activity strategic planning. The central part of this diagram shows the name of the activity, its label (TM.1-A1.G1), and the roles that participate in this activity (each role has a number inside a black circle). The tasks of activities are represented by white boxes that surround the central figures. Each task has a name and a label for easy identification. Each task has one or more numbers associated to it; these numbers indicate the role or roles that are in charge of accomplishing the task. Each task also has input and output products. The products are represented by rectangles (in shape of documents) and are connected to tasks by arrows to indicate if they are inputs or outputs. The box legend provides an explanatory list of the symbols used in the diagram. The arrows of the products define a relation of precedence. We designed thirty-two diagrams for this level.

Dimods are only a technique that may facilitate the teaching/learning process of PRMs and have the following limitations:

- They are not a substitute of the information provided by the PRM.
- The dimods are neither a tool that manages the information nor a tool for controlling the information flow.
- They only consider explicit process preconditions when the tasks or activities require input products.

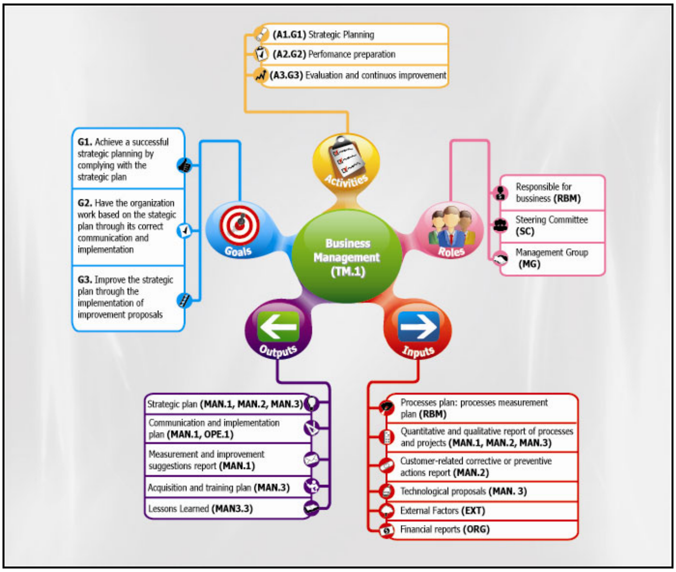

Fig. 2. Dimods of the second level

7 Evaluation of Dimods

We developed a two questionnaires survey to obtain quantitative data to evaluate the properties of dimods and the norm. Both questionnaires are based on the four previously identified categories (see Section 4). Both questionnaires contains 22 questions: four questions for category 1, five for category 2, eight for category 3, and five for category 4. Table 1 shows four sample questions from the dimods questionnaire (one for each category). Each question evaluates a specific feature. For the responses, we used a five-point Likert scale ranging from a very negative perception at 1, to a very positive perception at 5; number 3 indicates a neutral perception.

Table 1. Sample questions from the questionnaire survey to evaluate the norm

It is visually pleasing that the standard only uses the colors black and white	1	2	3	4	5
The standard is organized in a clear way	1	2	3	4	5
Identify the roles and activities in the norm is easy	1	2	3	4	5
The structure of the norm makes it easy to learn	1	2	3	4	5

Twenty-five people took part in the evaluation of norm (five are faculty members, six are software engineers, three are software entrepreneurs, and eleven undergraduate engineering students). Forty-two people took part in the evaluation of dimods (three are faculty members, eleven are software engineers, four are software entrepreneur and twenty-four undergraduate engineering students).

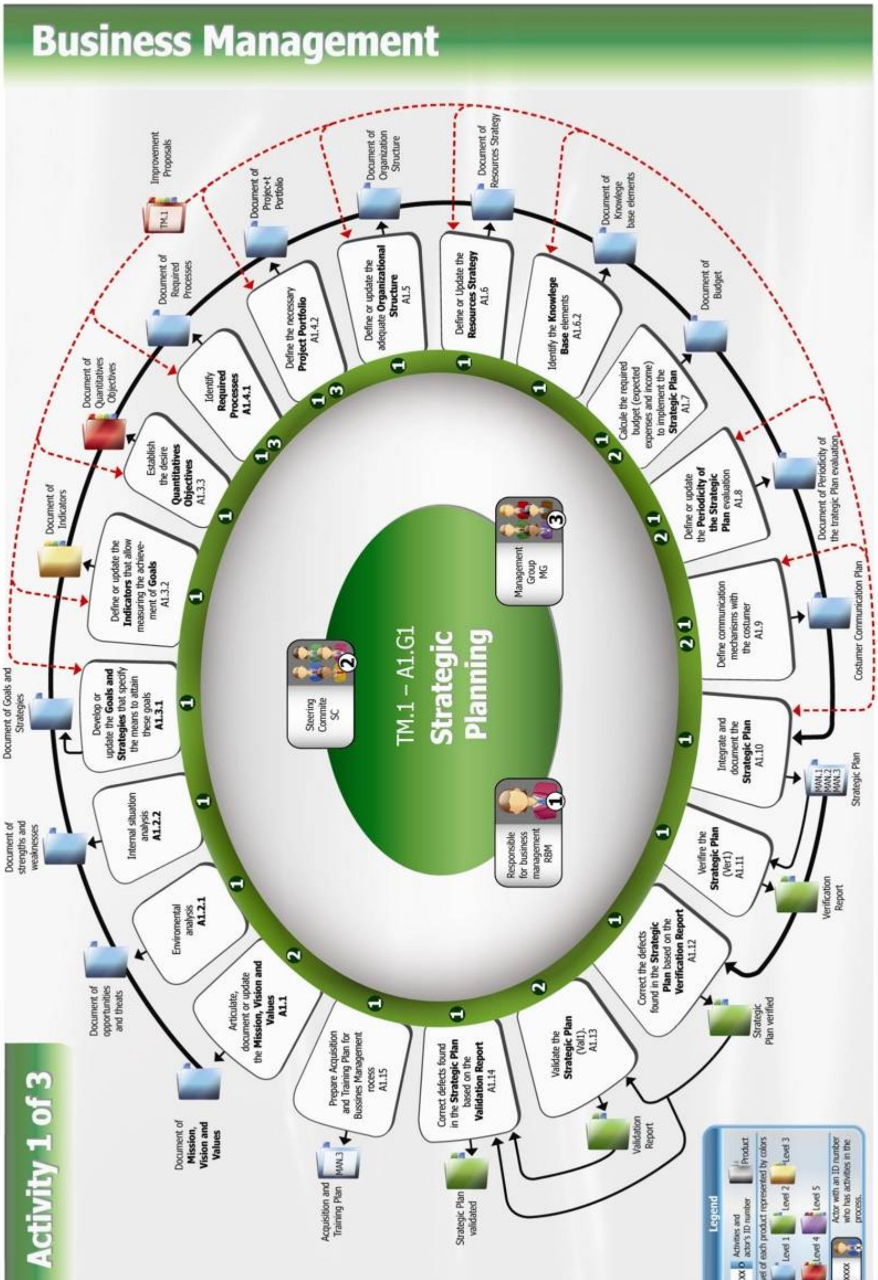

Fig. 3. Dimods of the third level

All the participants were familiar with the norm. Before the evaluation of dimods, we gave a thirty minutes presentation to explain their characteristics and how to use them. At the end of the presentation, they answered the questionnaire.

7.1 Results, Analysis and Discussion

Table 2 shows the results of the questionnaire survey of the norm (second column) and the questionnaire survey for the dimods (third column). Notice that the respondents have a slightly negative perception about the norm.

Table 2. Evaluation results for the norm, dimods and their differences

Category	Norm mean	Dimods mean	Increment	Improvement
1	2.7	4.52	+1.82	67.4%
2	3.0	4.08	+1.08	36.0%
3	2.6	4.03	+1.43	55.0%
4	2.4	4.24	+1.84	76.6%

We performed statistical analysis to determine if there is a significant difference between the means of the results of the dimods and those of the norm in each variable (category). For this purpose, we used the SPSS statistical software. Next, we explain the procedure we followed to perform the analysis:

1. *Determining if the variables have a normal distribution.* We perform the Shapiro-Wilk test and Kolmogorov-Smirnov test for each variable. The tests show that the data of all variables do not come from a population with a normal distribution; therefore we had to perform non-parametric analysis [35].
2. *Defining the hypothesis.* For each of the variables, we define a null hypothesis (H0) and an alternative hypothesis (HA). The null hypothesis establishes that there is no significant difference between the means of the results regarding the dimods and those regarding the norm. The alternate hypothesis establishes the opposite.
3. *Determining if there is a significant difference.* We perform *Mann–Whitney* U test (Similar to the T test in parametric analysis) for each of the variables using $\alpha = .05$ as the level of significance. All p-value of each variable obtained with *Mann–Whitney* U test (.000, .001, .000, .000, respectively for each category) were lower than the alpha level (0.05); therefore, we reject all null hypotheses (H0) and accept all alternative hypotheses (HA) [35].

From the analysis, we conclude that the results achieved with the norm differ significantly from those obtained with the dimods; additionally, the dimods show higher ratings than the norm in all categories (see column 6 on Table 2).

8 Conclusions and Future Work

This work proposes a visual technique called dimods. This technique may support the teaching/learning process of a PRM. Dimods can help software organizations to save resources in the training process when they are adopting a PRM. We compared the user manual of MoProSoft (the norm) and dimods in four categories. This comparison shows some advantages of dimods over the norm. The dimods describe MoProSoft in a clear, logical, practical and attractive form. It is simple to identify the elements of the model (roles, products, artifacts and tasks) and the relation that exists among them. Dimods is a general technique that can describe many types of processes. For future work, we are planning to design another type of dimods that shows the processes from the point of view of each role. Additionally, we are planning to design a set of dimods for other process reference models such as CMMI.

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