Product Focused Process Improvement: Experiences of Applying the PROFES Improvement Methodology at DRÄGER

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In this paper the principles and contents of a new product characteristics driven improvement methodology for embedded systems and product development (PROFES[5]) is introduced. The paper includes also experiences of application of the methodology in practice. The methodology was recently developed in an ESPRIT Project called PROFES (PROduct Focused improvement of Embedded Software processes). The methodology aims at helping organisations improve their product quality characteristics through improving just those characteristics of their software development processes that most effectively affect the product improvement. The methodology was developed through an experimental approach in three industrial organisations developing commercial products including embedded systems.

1. Introduction

The number of products based on embedded computer systems has rapidly increased. At the same time, complexity of product features controlled or supported by embedded systems has dramatically increased and the role of embedded software has become crucial. All these developments make it necessary to develop new approaches for software process improvement that are focused to improve specific product characteristics.

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[5]PROFES (PROduct Focused improvement of Embedded Software processes) is an ESPRIT Project (No 23239) lasting 1.1.1997 to 30.06.1999. The methodology providers in PROFES consortium are Etnoteam S.P.A from Italy, Fraunhofer IESE from Germany, University of Oulu, and VTT Electronics from Finland, and the application providers are LM Ericsson Finland, Dräger Medical Technology from the Netherlands, and Tokheim Retail Petroleum Systems from The Netherlands.

Software process assessment, process and product measurement, and process modelling are all important tools for software process improvement (SPI) professionals. On the other hand, there has also been discussion on their relative merits and interrelationships. Furthermore, the use of different methods has been fairly isolated, even in progressive organisations that use several approaches in their SPI activities. Such methods have often been seen as alternatives and even competitors.

The basic assumption in most SPI methods is that improved processes result in improved products. Most SPI professionals agree on this hypothesis. However, there have been some doubts concerning the unquestioned effectiveness of process improvement activities, with regard to improving product quality and even the process itself.

This led to the establishment of the PROFES project, whose main goal is to develop, validate and exploit a methodology for product quality driven software process improvement. The project combines and enhances well-known and widely used process assessment, improvement and goal-oriented measurement methodologies to form a new improvement methodology that identifies also product and process dependencies. This paper introduces the principles and contents of the PROFES improvement methodology and experiences of its application.

2. The PROFES Improvement Methodology

PROFES (PROduct Focused improvement of Embedded Software processes) software process improvement methodology for embedded systems was developed in an ESPRIT project (No. 23239) during the years 1997 –1999. The resulting methodology is briefly described here as an introduction to the application experience presented in the subsequent sections.

2.1 Industry Needs and PROFES Objectives

Several process improvement approaches like process assessment–based process improvement [11, 14,12,8,17], metrics-driven process improvement [1,19,18,5], and process modelling are well known among academy and practicioners. Process improvement approaches claim to help organisations achieve their business goals and particularly improve their productivity, time-to-market and product quality. Despite the fact that data become more and more available showing benefits of process improvement projects in real organisations, there is no methodology available which guides an organisation to improve those process characteristics that will result in a target product quality. For instance if an organisation aims at improving the reliability of its product, it would need to know which process changes will result in a measurable improvement of the final product reliability.

There is a clear need for such a guidance in the market: organisations developing software-based products face an increasing competitiveness, which result in a demand for higher and higher product quality, cost effectiveness and shorter and shorter time-to-market. This requires an improvement approach that helps focus improvement actions in the most effective way. The ESPRIT project PROFES has developed an improvement methodology that helps organisations in satisfying these demands. The objectives of the PROFES improvement methodology is to answer questions like:

- Which aspects of the development process should be improved to achieve a specified target product quality?
- How much is it going to costs?

2.2 Background Principles in Developing the Methodology

A fundamental principle of the PROFES project was to build a new methodology on existing approaches for software process improvement (SPI), including process assessment, goal-driven software measurement, process modelling, experience factory [1,2] and software product quality characteristics based on ISO/IEC 9126. A major goal of PROFES development was to integrate these existing approaches [3] to provide guidelines for product-driven process improvement.

The PROFES improvement methodology was developed using an experimental approach in three industrial case studies, namely at Ericsson Finland, Dräger MT, The Netherlands and Tokheim, The Netherlands. Two subsequent improvement cycles were applied in the three industrial sites:

- The first improvement cycle was devoted to establish the process assessment, process modelling and measurement methodologies in order to derive the basic PROFES framework from experience.
- The second improvement cycle focused on application of the enhanced PROFES framework and validation of the methodology.

2.3 Overview of the PROFES Improvement Methodology

Figure 1 provides an overview of the main elements of the PROFES improvement methodology [6].

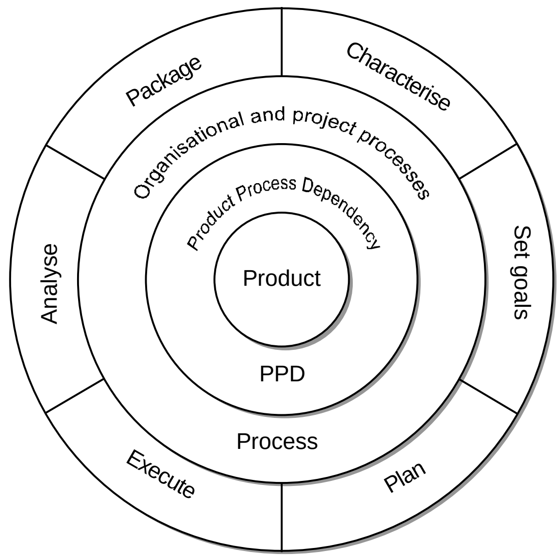

Figure 1: The PROFES Improvement Methodology

The main focus of the PROFES improvement methodology is the final product and its target quality characteristics. ISO 9126 is used as a basic reference to describe product quality characteristics. However, it is recognised that major product objectives are cost effectiveness and short time-to-market, which are considered additional product quality characteristics to the original ISO 9126 characteristics. Moreover it is recognised that organisations often need to provide quite specific description of their product quality that varies and depends on sector specific requirements.

The target product qualities are achieved through both organisational and project processes.

The main feature of the PROFES improvement methodology is to link product quality characteristics and process characteristics: the so-called Product-Process Dependency (PPD) [15,9, 10]. A PPD describes a cause-effect relationship between a product characteristic and a process characteristic in a defined context. An example of a PPD is that software inspections applied to software requirement analysis improve the final product reliability. This is true in a specified context, for example when the complexity of inspected documents is high, the size of inspected documents is in the average and the organisation has a good experience is conducting inspections. Of course there are several PPDs, which are collected in a PPD repository. PPDs can be generated in several ways, including elicitation of experience from expert engineers, literature survey and experiments. PPDs are used within the PROFES improvement methodology to assist an organisation selecting those process changes that will help in achieving the organisation target product quality.

Finally the PROFES improvement methodology provides a phase model consisting in six phases to guide organisations in performing product-driven process improvement. The six phases (characterise, set goals, plan, execute, analyse, and package) are synthetically described in the following[6].

Characterise

First step of the characterise phase is to commit the target organisation and involved projects to continuous product improvement. Then the product quality needs are defined based on customer surveys, market research, or from other sources. An assessment of the current product quality is performed that together with the product quality needs is the basis to define product improvement goals. If product related measurement is feasible, product quality characterisation can be done using the Goal/Question/Metric (GQM) method, or some other available method. The current process capability is evaluated by performing a process assessment or, if available, using already existing assessment results. A description of the current process may be needed if a process model is missing or if the model is not applied for any reason. Process improvement recommendations are identified through assessment and PPDs.

Set goals

Product improvement goals are set. Needed process changes are identified based on process assessment results and on evaluation of potential PPDs. If a PPD repository is available, product improvement goals drive the identification of suitable PPDs taking into account process assessment recommendations. If a PPD repository is not available, an analysis of project history, engineers' experience and literature sources allow to formulate hypothetical PPDs for the organisation. Hypothetical PPDs are then validated through experiments. Defined and validated PPDs provide suggestions for process changes that will support achievement of the specified target product qualities. Process changes resulting from PPD analysis are selected based on priorities, feasibility and other criteria.

Plan

Improvement actions are planned before their implementation in the project. In this phase needed process changes are selected, described and modelled. Improvement goal(s) are transformed into measurement goals. The measurement goals are refined into measures via questions according to the GQM method. Measurement data are used for monitoring process performance and achievement of

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[6] The PROFES improvement methodology is further specified in twelve steps. For a description of the steps refer to the PROFES User Manual.

target product improvements. A measurement plan is prepared, based on measures defined in the GQM plan. The measurement plan defines operational procedures to collect measurement data, including measurement frequency, responsibilities, information sources, tools and templates to be used and all additional information to completely measure the goals defined in the GQM plan.

Execute

The defined improvement actions are implemented in the product development process according to the prescriptive process model previously defined. Measurement data are collected and analysed according to the GQM and measurement plan. Measurement data are presented during feedback sessions where the engineers of the target organisation give their feedback and corrective actions are agreed.

Analyse

The purpose of the analysis phase is to check whether product quality has improved as expected according to changes made to the process. In the analysis phase, the released product data and process data and findings are analysed and interpreted as thoroughly as possible. Differences between planned improvements and actual achievements are analysed, and root causes of deviations are identified. Also the new process models adopted for use are evaluated. This may require a re-assessment of changed and new processes. In this phase emphasis is on gathering the lessons learned during implementation of improvement actions. Organisation-wide learning is assured by the organised reuse of the collected information.

Package

The purpose of the package phase is to store all experience gained in the project about product-process interdependency. This also includes rejection and modifications of PPD experience packages, according to results of the analysis phase. Packaging and storing experience is necessary for later reuse in forthcoming projects [7]. Project evaluation findings are documented in a reusable format. Project and organisation-specific terms are removed, and the contextual situation in which the PPD experience packages are supposed to be reused, is defined.

3. Application of Product-Driven SPI: the Dräger Experience

3.1 The Target Organisation

Dräger is a multinational company operating primarily in the fields of medical technology and safety technology, with limited operations in aerospace technology. One of the main divisions of Dräger is Dräger Medical Technology (Dräger MT). The target organisation is Dräger MT-M (the monitoring sub-division of Dräger MT) which is developing a complete new line of patient monitoring devices. This family of devices should create a BSW (BedSide Workstation) around each bed location in a department in a hospital. The BSW's ensure ventilation and monitoring of patients during surgery and treatment in intensive care departments. Monitoring is required to inform hospital personnel about important changes in the patient status and for deciding actions to be taken to treat the patient. The system incorporates a PC based "Central Work Place", which displays relevant patient data and controls the complete system. The Central Work Place includes network connections between its various elements, and particularly an equipment directly connected to the patient, which monitors a number of heamodynamic parameters, like electrocardiogram (ECG), oxygen saturation (SpO2), invasive and non invasive blood pressure, respiration and temperature.

The development of the monitoring system is organised as a project. Development activities take place on two sites: in Lübeck, the domestic city of Dräger in Germany, and in Best in The Netherlands. The PROFES improvement methodology has been applied within Best. To develop the product, multiple disciplines are required, including hardware and software design and mechanics. Development and production are done partially internally and partially through suppliers. 15 sub-contractors perform the software development by approximately 15 Dräger software engineers and additionally.

3.2 Improvement Background

At the time when the improvement experience here presented started, in 1997, Dräger was establishing procedures to fulfil ISO 9001 requirements. No measurements were in place. Based on a history of many years in the medical equipment business Dräger decided to invest to improve its product quality. This decision created the background for joining the PROFES Esprit project, offering an industrial experiment environment for development of the PROFES improvement methodology.

3.3 Improvement Cycles

Two subsequent improvement cycles were conducted according to the objectives of the PROFES project, but also taking into account the development project milestones. The first improvement cycle lasted from June ’97 to June ’98. The second improvement cycle lasted from June ’98 to June ’99.

3.4 The First Improvement Cycle

At the beginning of the first improvement cycle, based on the analysis of overall business goals the following product improvement goals were identified and prioritised:

1. Improve **predictability** and control of time, cost and quality of product development
2. Improve **functionality** of the product to meet the customer needs and market requirements,
3. Ensure fulfilment of the **safety** requirements, and
4. Improve **correctness** of the operations.

A process assessment was conducted using the BOOTSTRAP methodology [4]. As no previous assessment data were available it was decided to perform a complete assessment, though, based on the selected goals, a subset of processes to look more carefully was identified. This was done using the product-process dependencies (PPDs) approach. As no PPD repository was available, processes expected to affect the target goals were identified based on the knowledge of the application providers’ experts and the expertise of the assessment teams (see Table 1).

Goal	Process	Goal	Process
	MAN.1 Project Management		CUS.2 Customer needs management
Predicta	MAN.2 Quality Management	**Functio**	ENG.1 System Requirement analysis
bility	MAN.3 Risk Management	**nality**	ENG.2 System architecture design

1		**3**	ENG.3 Software requirement analysis ENG.8 System integration & testing
Safety **2**	ENG.1 System Requirement analysis ENG.2 System architecture design ENG.3 Software requirement analysis ENG.8 System integration & testing SUP.3 Quality assurance	**Correctness** **4**	ENG.1 System Requirement analysis ENG.2 System architecture design ENG.3 Software requirement analysis ENG.6 Software implementation & testing ENG.7 Software integration & testing ENG.8 System integration & testing MAN.2 Quality Management SUP.4 Verification SUP.5 Validation SUP.2 Configuration Management

Table 1: Product quality improvement goals and BOOTSTRAP processes which were assumed to have most significant impact onto the goals

Assessment resulted in recommendation to improve the following processes: system and software integration and testing, process definition, risk management, configuration management, quality management and quality assurance, customer need management, validation, incremental design approach.

After presentation of the assessment results, it was decided to focus on the following *product improvement goals*:

- Improve the reliability of the overall product (focusing on the number of defects found)
- Improve the fitness for use of the overall product (focusing on the ability of meeting user requirements)

For these product improvement goals, using the PPD approach, the following *process improvement goals* were selected:

- Related to reliability of overall product:

    - Improve inspections
    - Improve testing
    - Improve configuration management
- Related to fitness for use of overall product:
    - Improve customer needs management

This resulted in several improvement initiatives. From these, two were selected to start a measurement, namely:

- Inspection procedure
- Problem reporting related to testing.

Measurement goals were established. Measurement data were collected and feedback sessions organised following the GQM method. Feedback sessions resulted as follows:

- Many minor defects were found in documents. This was not cost effective, so it was decided to perform informal reviews before inspections
- It came out that analysis of documents required more time than expected. It was decided to schedule more time for inspections
- The defect rate of documents started to decrease, then the question was: "was that a sign of achieved improvement?" Testing was going to answer this question.

3.5 The Second Improvement Cycle

For the second improvement cycle it was agreed that in addition to reliability and fitness for use, also the predictability of the development process with respect to quality, cost and time had to be included.

A second BOOTSTRAP process assessment was performed in June 1998.

The main purpose of the assessment was to evaluate the impact of improvements carried out during the first improvement cycle. Therefore a focused assessment was performed. The results of the second process assessment were as follows:

- Processes evaluated at the organisational level, i.e. based on existing organisational procedures, showed the following aggregated results:
    - Management processes were evaluated at level 2.5 with an increment of 0.5
    - Engineering processes were evaluated at level 3 with an increment of 2

- Processes evaluated at project level, i.e. based on project practices obtained the following rating:
  - Management processes were evaluated at level 3 with an increment of 1
  - Engineering processes were evaluated at level 3 with an increment of 2

The following improvements were decided:

- To improve the reliability:
  - To adopt evolutionary development
  - To strengthen people competencies
- To improve the fitness for use:
  - To establish a problem report board
- To improve predictability:
  - To establish a continuous integration process instead than performing a final integration of all the software
  - To reinforce sub-contract management

In order to monitor effectiveness and efficiency of inspection activities, following the GQM approach it was decided to focus the measurements to the inspections performed in each development phase (e.g. number of defects found, time spent).

Data were collected and feedback sessions were held with the following main conclusions:

- Data showed that inspecting large documents was quite inefficient: it was therefore decided to split documents into smaller ones
- It came out that inspection meetings were taking too much time, resulting in unforeseen costs. The company management decided that it was worth anyway to continue despite the increase in costs.
- Despite the inspection effort, 4.75% defects were found in field test. This was considered acceptable, as anyway it is impossible to completely simulate the user operation environment, i.e. the hospital, during integration and system test.
- The average time to solve defect was 2 months, due to project management limitations.

3.6 Improvement Costs and Benefits

The first improvement cycle used 4.1 person years including Dräger internal personnel and external support as follows:

- Management 0,1
- Facilitator 1

- External experts 0,5
- QA-engineers 2
- Engineers 0,5

Dräger recognised the following as main benefits of the first improvement cycle:

- There was a tremendous improvement of process capability (from BOOTSTRAP level 0,5 to 2,5 at the organisational level and from level 2 to level 3 at project level)
- An ISO 9001 quality system was established
- The company started to focus on procedures and measurements
- Early feedback on product quality could be obtained
- Only 4.75% errors were found in field test, which was considered positively.

Costs of the second improvement cycle were 2.7 person years as follows:

- Management 0,1
- Facilitator 0,5
- External experts 0,2
- QA-engineers 0,5
- Engineers 0,5

Costs could be reduced from the first improvement cycle as quite much of the experience could be reused. For instance GQM plan and measurement plan could be reused and complemented according to the second improvement cycle focus. At the same time the PROFES framework was established supporting integration of process assessment and measurement [20], so that the execution of improvement activities itself could become more efficient.

Benefits of the second improvement cycle were as follows:

- Overall monitoring of defects was improved
- The second project increment was delivered exactly in time
- Functionality of the second increment were close to the final ones
- Only 4.75% errors was detected in field test

4. Conclusions

In this paper a new product-driven process improvement methodology called PROFES was presented. The PROFES improvement methodology links product quality characteristics to process characteristics. For this purpose a new software engineering item is introduced, called the Product

Process Dependency. The PROFES improvement methodology assists organisations in improving their final product quality by improving their development processes. For this purpose the PROFES improvement methodology builds on existing internationally recognised approaches, including software process assessment, goal-driven measurement, process modelling, the experience factory concept, and ISO 9126.

As part of the methodology, data on costs to apply it and related benefits were collected and used to validate the methodology.

Data from the application experiment presented in this paper show improvements in product quality and process quality. The company understanding was that improvements through the use of PROFES are feasible and do pay off. In specific the process-product dependencies are the area where Dräger figured quite much need to learn in the future. Application of the PROFES improvement methodology has also shown how improvement costs can be reduced by applying it.

As a final conclusion the PROFES methodology was validated, and felt useful, effective and beneficial in the industrial environment.

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