MASTER

"Testing driven by operational profiles"

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Master Thesis Graduation Project

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“Testing driven by Operational Profiles”

Master thesis graduation project

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Preface

The findings described in this report are realised as a result of a graduation project at Philips Medical Systems. The project is carried out at the Test Management department of the business group Medical IT.

This work is the final part of my study Industrial Engineering and Management Science at the Technology Management department, part of the Technical University Eindhoven.

The report describes an investigation in the consequences of determining and applying operational profiles on the test process. This is investigated from a practical view by the application of developed operational profiles on a project. Also, the consequences are investigated from a more theoretical view by comparing this test method with other approaches through simulations done with a model.

The nine months were very interesting, where the possibility was created to experience the development and testing process of medical imaging software from nearby. In this period, much is learned about the requirements concerning reliability, functionality and time-to-market for products that are launched in the medical sector.

I would like to thank all the people at Philips Medical Systems who provided help and information. Special thanks go out to my mentors at the Medical IT business group, Jarmila Bökkerink and Harold van Dongen. Together with my mentor Herman Hartmann from Philips CFT, they supported me by giving input and feedback. Thanks for the efforts!

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Finally, I want to thank my family and friends for their support and encouragement.

Arjan den Hartog

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Abstract
Operational profiles give a quantitative characterization of system-usage in practice. When testing is driven by operational profiles, functions that are used often in practice are allocated more test time. In this way, more relevant faults can be found earlier, and testing time can be reduced. This method is applied at Philips Medical Systems. The consequences are investigated, and the process steps gone through are described in extensive form.

Management Summary

This master thesis is performed at Philips Medical Systems, which is one of the divisions of the multinational Philips Electronics. Philips Medical Systems delivers an extensive portfolio of medical systems for faster and more accurate diagnosis and treatment through technologies such as X-ray, ultrasound, magnetic resonance, computed tomography etc. Part of this division is located in Best.
The graduation project is executed at one of the business groups of Philips Medical Systems in Best, namely Medical IT. This business group is responsible for the development and marketing of software solutions for visualization, processing, archiving and distribution of medical information.

Motive for Assignment

Medical IT develops and tests several products per year, which are released into the market. After the release, there is a maintenance team executing additional testing, if necessary, and taking care of failures experienced by the end-user. Dealing with these failures in the maintenance phase is a process that currently costs a lot of effort.
Failures can be defined as occurrences of faults. Faults can be defined as defects in software caused by human errors. To reduce the number of failures found by the end-user, the relevant faults must be found and resolved. A fault is considered relevant if it leads to a failure in the field. Medical IT would like to know where these relevant faults could be found in the software.
Medical IT wants to know more about the location of the relevant faults; when focus is put on these areas during testing, a more effective test method can possibly be applied. To determine which faults will occur in practice, information should be obtained about the usage of the application at the customer.
The sub department Quality and Reliability Engineering (QRE) of the department Technology Management from the Technical University Eindhoven, is doing research in modelling the relation of the growth in reliability of an item with the required test time to achieve that growth. A model that can compare different test methods concerning these factors is currently being developed together with Philips CFT.

Assignment formulation

A method, in which insight can be gained in the customer-usage of software, is SRE that stands for Software Reliability Engineering. This method is developed in the 1980's and implemented at several companies. One of the steps of this method is the determination of operational profiles. These operational profiles (O.P.) give a quantitative characterization of the usage in practice. SRE focuses on the frequently used areas of the product, in order to find and resolve most relevant faults. Besides a focus on high-usage functions, more attention is paid on the functions that have a high impact in case of a failure; failures with a high impact on the functioning of the product, such as a crash, have higher priority than failures that are hardly noticed (e.g. small colour inconsistencies in the icons).
When focus is put on these two areas during testing, it is likely that more relevant faults can be found and resolved, and fewer failures will occur in the field. This could lead to a reduction in maintenance effort. The framework given below illustrates this approach:

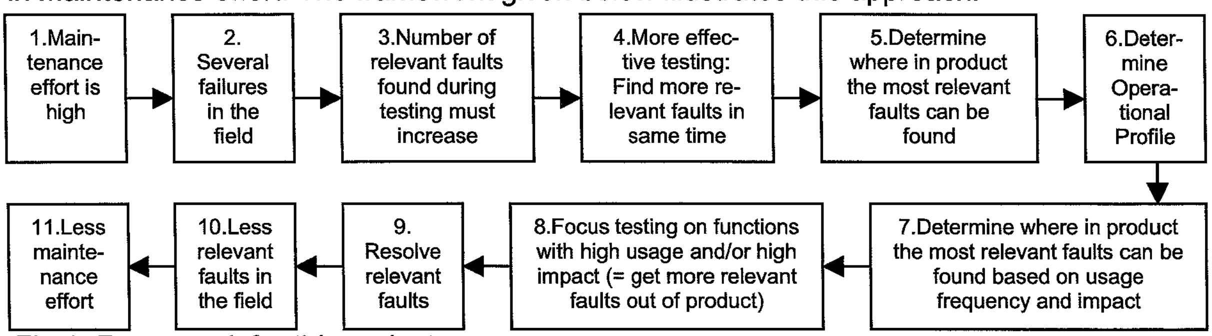

Fig.1: Framework for this project

The assignment formulation for this graduation project can be formulated as:

"Investigate the consequences of applying SRE techniques (especially the development and application of Operational Profiles) for improving the effectiveness of the Test Process"

The objective of this project is:

"Describe the process of establishing and applying operational profiles and investigate the possible benefits of testing driven by these operational profiles"

Three research questions are defined, which are:

1. *What factors are important for the determination of an operational profile?*
2. *What factors are important for the application of testing driven by operational profiles?*
3. *What consequences are encountered in the determination and application of operational profiles?*

Pilot Project

An operational profile is developed for MIP DICOM Viewer serving as a pilot project, to gain experience in the development of these profiles, and to document all process steps.
MIP DICOM Viewer is a small application, with which medical images can be viewed and some adjustments can be made (such as zoom and adjustment of the grey level). The first step executed is the definition of the functions and operations that this product consists of. Also, the different user types are defined, such as cardiologist and orthopedist.
To determine the usage in practice for MIP DICOM Viewer, the most reliable option would be the recording of the steps executed in practice by the end-user (i.e. in the hospital). Since this product is not released into the market yet, and recording in the hospital gives several difficulties, applicants are involved in the determination of the usage. Applicants are employees from Philips Medical Systems that are familiar with the way this product is used in practice. They represent the end-user within the organisation, are often former radiologists and have a lot of contacts with the hospitals. For MIP DICOM Viewer, several applicants imitated reality through the eyes of the different user types. A record-and-playback tool, originally meant for the creation and execution of automated tests, registers the steps executed by the applicants. After recording, the obtained information is used to determine the usage frequencies of the different operations for the defined user types. An example is given in figure 2.

Function	Usage Frequency	Occurrence Probability (%)
1	25	50
2	10	20
3	15	30
Total	50	100

Fig. 2: Example of operational profile

To take into account more factors than solely the usage frequencies for differentiating test time among the functions and operations, user and functional weights are determined for MIP DICOM Viewer. These user weights make a distinction in:

- The different user types by looking at the percentage of all users that each type forms for this product
- The impact that the different functions have in case of a failure
- The representation of the importance of a function by its usage frequency.

These weights are incorporated in the profile to improve the representativeness of the profile. However, there are several difficulties that could lead to the opposite.

Applying Operational Profiles on Test Strategy

After the pilot project was finished, the operational profile was developed of another product; EasyWeb 4.1 Cardio. This is a product used for the distribution of medical images through the web. The operational profile for this application is also determined with the help of

applicants that imitated reality through the eyes of a cardiologist, while the steps taken were recorded. The results made clear that the applicants used a small percentage of all available functions and operations, which indicates that the offered functionality is too large. This is partly due to the fact that this application is originally developed for Radiology-purposes and therefore only a part of the functionality is useful for the Cardiology-environment.
Compared to the pilot project, this project is extended by also taking step 8 from the framework in figure 1; the operational profile of EasyWeb 4.1 Cardio is applied on the development of the successive version of this product, EasyWeb 5. The SRE-method is implemented on this system. In this way, the current method of testing can be compared with the SRE-method that is applied on EasyWeb 5.
An allocation of test time to the different functions and operations is not made with user and functional weights, but with a so-called risk analysis matrix. This method takes into account several types of risks determined by employees of MIT for the functions that the application consists of. These risks are divided in risks concerning probability of a failure, and impact in case of a failure. This matrix is used as input for the individual process test plans and designs with respect to the order in which functions will be tested, and the depth in which functions will be tested. This depends on the position of each function in the matrix; a division is made in four quadrants, with quadrant 1 representing the factors with the highest importance. An example is given in figure 3.
One of the factors concerning Impact in this risk matrix is Usage Frequency. This factor is rated for the functions and operations with the help of the determined operational profile.

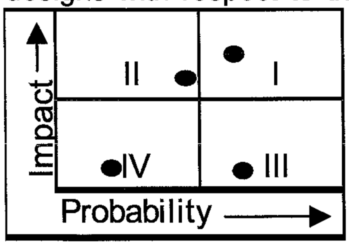

Fig.3: Example risk matrix

This risk matrix is created for EasyWeb 5, after which decisions are made about the prioritised functions and the thoroughness that each function will be tested. After the product is released, a maintenance team will take care of failures experienced by the end-user. When this phase is finished, more conclusions can be drawn about the implementation of the SRE-method compared to the current method.

Determination of Consequences Testing Driven by O.P. with Model
Besides an investigation in the consequences from a practical view (by comparing the execution of the current method with the SRE-method through two projects), this is also viewed from a more theoretical perspective. The model that is developed by the QRE sub department and Philips CFT can represent the test process for different test strategies. In this way, the reliability growth and the effort required to achieve that growth can be compared for several methods. Through simulations done with this model, more insight is gained about the consequences of testing driven by operational profiles in terms of reliability improvement and test time reduction. Part of the simulations is done to make a comparison with a uniform strategy, where all functions are allocated the same amount of test time. This is illustrated in an example given in table 1. The model represents the reliability for the different situations in terms of the Mean Time Between Failure (MTBF). Comparisons are illustrated by graphs; an example of representations of the MTBF for the two strategies is given in figure 4:

Table 1 Different strategies

Allocation By Different Strategies		
	Uniform	O.P.
Function 1	25	50
Function 2	25	30
Function 3	25	15
Function 4	25	5
Total	100	100

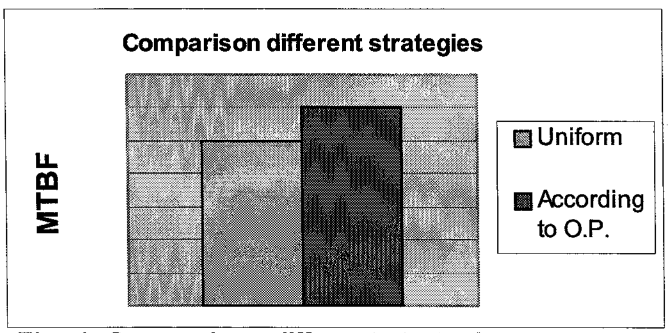

Fig. 4: Comparison different strategies

Conclusions

1. Which factors are important for the determination of an operational profile?

a) *User types, functions and operations*
The different user types of an application can be defined by e.g. applicants, marketeers. The functions and operations that an application contains are defined in the requirements documents. Also, the functions and operations that are represented on the screen (so-called Graphical User Interfaces) of the existing product or prototype can provide input.

b) *Usage information*
Operations executed during the usage of an application are the input for the operational profile of an application, and can be registered by a record-and-playback tool.

c) *Involve suitable persons for obtaining usage information*
Information for the operational profiles can be obtained in a fast way through imitating reality with the help of applicants. Although involving real end-users is a more reliable option, an indication can already be given with using applicants.

d) *Effort needed to determine O.P.*
The determination of an operational profile took approximately 138 man-hours for the pilot project (MIP DICOM Viewer). The determination of the O.P. for the second project (EasyWeb 4.1 Cardio) took approximately 88 man-hours. This effort seems to be limited in comparison with the total effort put into development.

e) *Incorporating impact into O.P.*
Impact and other factors can be integrated in the operational profile with functional and user weights. These weights do however also raise uncertainties.

2. Which factors are important for the application of testing driven by operational profiles?

a) *Applying the O.P. in the test strategy*
The information from the operational profile can provide input for one of the risk factors used by a so-called risk analysis matrix, namely Usage Frequency.

b) *Effort needed to apply O.P. in testing*
Estimating the effort for solely the activities concerning applying operational profiles is difficult, because most activities are interrelated with other tasks. Nevertheless, these tasks have to be done anyway (in another form) and do not require extra effort when compared to other projects that do not apply operational profiles.

c) *Reusability of an operational profile*
Information about the occurrence probabilities of an application can also be useful for future releases of that application, on condition that there are no big differences in:
- The offered functionality for that release
- The intended user types of the application
- The usage behaviour of these user types

3. What consequences are encountered in the determination and application of operational profiles?

Encountered benefits in general

a) An addition to the test strategy is provided with the O.P. in the form of realistic values for the risk factor Usage Frequency, that is part of the risk analysis matrix

b) The O.P. provides input for the development of requirements and use cases that are defined by the Application and Infoware department, and Marketing.

c) The operational profile does also provide input for the development of reliability tests. Because the tests should simulate the situation in practice as good as possible, the file that registered the successively executed operations during recording can be used as basis for the creation of new tests.

Consequences found from executed simulations with the model

d) The simulations suggest that testing according to the O.P. provides benefits (in terms of reliability improvement and test time reduction) compared to an allocation strategy on a uniform basis, if:
   - *The occurrence probabilities of the functions are more non-uniform.*
   - *The available test time is limited.*

e) Simulations made clear that testing according to the O.P. is less advantageous than the uniform test strategy, if:
   - *An excessive amount of test time is available.*

f) Other simulations indicated that testing a product in short cycles instead of one large cycle can provide the following benefit:
   - *Total amount of failures occurring during testing will decrease*, although the number of faults found remains equal in comparison with the one-cycle test strategy.

g) Since not all values used by the model are currently representative enough, the encountered consequences cannot be quantified concretely in terms of reliability improvement and/or test time reduction. At this moment, only indications of the amount of reliability improvement and/or test time reduction can be given, as well as the factors of influence given in sections 7.2 and 7.3. This indication, which represents the average result of the executed simulations, is:
   - *Approximately 70% of the test checks are needed for the O.P.-strategy to realise the same MTBF as the uniform distribution needs for that value.*

   However, because each project contains different features under different circumstances, it is difficult to determine input for the model that is representative for several situations.

Recommendations and Future Research Steps

- *In order to fully take advantage of operational profiles, cooperation between the departments of MIT is necessary.*
- *To determine consequences of testing driven by O.P., field failure information of EasyWeb 5 is also necessary.*
- *Requirements that are used in the risk analysis matrix should contain a better explanation.*
- *Investigate the representativeness of the risk analysis matrix.*
- *Improve the representativeness of simulations done with the developed model.*
- *Investigate the usage behaviours of applicants vs. real end-users.*
- *Investigate other possibilities in determination of the usage behaviour.*
- *Reuse the information from the operational profiles in future products*

Based on the current experiences, MIT is advised to continue with the application of SRE-techniques on the Test Process, as well as on other processes such as Requirements Engineering.

List of Abbreviations

- *CAA:* Clinical Advanced Applications
- *CFT:* Centre for Industrial Technology
- *CMM:* Capability Maturity Model
- *CMS:* Cardiac and Monitoring Systems
- *CR:* Computed Radiography
- *CT:* Computed Tomography
- *CV:* Cardio-Vascular
- *DICOM:* Digital Imaging and COmmunications in Medicine
- *DIS:* Digital Imaging Systems
- *DDTS:* Distributed Defect Tracking System
- *DTS:* Defect Tracking System
- *ETRF:* Electronic Test Results Form
- *EW:* EasyWeb
- *FI/FIO:* Failure Intensity to Failure Intensity Objective
- *FPR:* Field Problem Report
- GUI: Graphical User Interface
- *HIS:* Hospital Information System
- *ISA:* Infrastructure, Storage and Archiving
- *IT:* Information Technology
- *MCS:* MIP Component Suite
- *MIP:* Medical Imaging Platform
- *MIT:* Medical IT
- *MR:* Magnetic Resonance
- *MTBF:* Mean Time Between Failure
- *MTP:* Master Test Plan
- *NM:* Nuclear Medicine
- *OEM:* Overall Equipment Manufacturer
- *O.P.:* Operational Profile
- *PACS:* Picture Archiving and Communication System
- *PCP:* Product Creation Process
- *PET:* Positron Emission Tomography
- *PMG:* Program Management Group
- *PMS:* Philips Medical Systems
- *PR:* Problem Report
- *PRS:* Product Requirement Specification
- *QA:* Quality Assurance
- *QRE:* Quality and Reliability Engineering
- *QTP:* Quick Test Professional
- *RIS:* Radiology Information System
- *SI:* System Integration
- *SIT:* System Integration Test
- *S.O.P.:* System Operational Profile
- SR: Software Reliability
- *SRE:* Software Reliability Engineering
- *SRS:* System Requirement Specification
- *SVE:* Standard Viewing Environment
- *TC:* Test Case
- *TCHK:* Test Check
- *TPI:* Test Process Improvement
- *VCS:* Viewing Component Suite