



FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Thesis Committee

MASTER'S THESIS GUIDE

Master's Thesis
Degree Programme in Computer Science and Engineering
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ABSTRACT

This document provides general guidance for a degree student of Computer Science and Engineering in preparing his/her master's thesis. This guide defines the role of a thesis in the M.Sc. Degree, presents the actions to be taken in different phases of the thesis procedure and introduces the way that master's thesis is written. The document has been formatted based on these guidelines to serve as an example how the thesis should look like.

Key words: M.Sc. degree, master's thesis instructions, structure of a master's thesis.

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TIIVISTELMÄ

Näissä ohjeissa opastetaan valmistumisvaiheessa olevaa opiskelijaa diplomityön tekemisessä. Ohjeissa selvitetään työn asema diplomi-insinööritutkinnossa, kerrotaan toimenpiteet, joihin työn tekijän on ryhdyttävä työn eri vaiheissa, sekä määritellään yksityiskohtaisesti diplomityön kirjallinen rakenne. Ohje on muotoiltu noudattaen näitä kirjoitusohjeita ja toimii siten esimerkkinä, miltä diplomityön tulisi näyttää.

Avainsanat: diplomi-insinöörin tutkinto, opinnäytetyön ohjeet, diplomityön rakenne.

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TIIVISTELMÄ

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FOREWORD

These guidelines are based on thesis instructions of the former Department of Electrical and Information Engineering, the instructions of the publication series Acta Universitatis Fennica, and the book “Teknisen kirjoituksen laatiminen” [1, 2, 3]. Several persons from the former Department of Electrical and Information Engineering have participated in setting up these instructions. The preparation of the first version was led by Prof. Pentti Lappalainen.

The Finnish guidelines were edited by the Study Committee of the Department of Electrical and Information Engineering in 2005 and 2010-2011, and revised by the Degree Programme Committee of Computer Science and Engineering in 2011 and 2012. The original English version was written by the Degree Programme Committee of Electrical Engineering; this version is based on that version and the Finnish instructions for Computer Science and Engineering. This English version has been updated to comply with the new conventions for archiving the electronic versions of master’s theses in 2013, and the organization renewal in 2016 where the Department of Computer Science and Engineering was disbanded and divided into three research units. This document is applicable for master’s theses completed in and after 2016.

Oulu, June 28th, 2016

Degree Programme Committee of Computer Science and Engineering

LIST OF ABBREVIATIONS AND SYMBOLS¹

CSE	Computer Science and Engineering
GUI	graphical user interface
LBP	local binary pattern
NCC	normalized cross-correlation
SVM	support vector machine
UML	unified modeling language
f	focal length
N	number of samples
\mathbf{R}	orthogonal matrix
r_{ij}	matrix element
\mathbf{v}	velocity vector
\mathbf{x}	planar coordinate
β	shape factor
ε_k	error signal at instant k
Φ_k	state transition matrix at instant k
θ	parameter vector
σ^2	variance
$\lfloor \rfloor$	integer part
\oplus	logical XOR operation
$\arg()$	argument

¹ Even though a symbol or an abbreviation is explained on this page, it should be written out full when appearing in the text for the first time.

1. INTRODUCTION

Writing a thesis takes on a major part of completing the master's degree studies. The thesis assignment prepares for the independent engineering work. Hence, supervision plays a smaller role in thesis procedure than during previous studies. A typical master's thesis represents a solution to a relatively extensive technical problem. Additional studies in the given field are often necessary; however, the aim of the thesis work is to make use of the knowledge and skills acquired during preceding studies. Furthermore, technical and scientific documentation skills will be strengthened. The thesis work can be conducted as a part of a larger project, but the master's thesis itself should be written individually.

The thesis work is undertaken in the final phase of the studies. It is recommended to begin the thesis work during the autumn term of the 2nd study year in the master's programme or the 5th year after starting in the bachelor's programme. However, timing is flexible and it is also possible to begin earlier depending on advancement in studies. As a general rule, it is time to get started, when there are 15 to 30 credit points left of the total coursework (in addition to the master's thesis). Some fields of study require certain courses to be completed before the master's thesis. Requirements should always be checked in advance with the supervisor. Information on the degree specific requirements is provided by the secretary of the degree program and the registered credit points can be viewed in WebOodi.

The aim of these instructions is to give detailed guidelines for composing and writing a master's thesis. This document describes the thesis work process; starting from searching the topic to the formal approval of the completed thesis. The process has otherwise stayed the same for quite a while, but the final stages were changed in the beginning of 2013 due to the new electronic archiving for all master's theses at the University of Oulu. Hence, the older versions of this document are no longer valid and should not be used. Moreover, this document offers practical instructions for the writing of the thesis: for the literary structure, the layout, and for the writing process as well. This document itself has been edited according to the instructed layout, though the literary structure is not similar to that of a master's thesis.

Before starting your master's thesis work, **please read first this document carefully**. Following these instructions closely is likely to produce a better result and a higher grade. When the supervisor does not have to point out about these instructions (specifically about the layout) she/he can focus on instructing on the content and how the best grades can be achieved. The degree programme web pages [11] offer instructions for master thesis as well. When neither of these sources gives an answer to your questions, please ask your supervisor or from the study affairs office. And remember: Although writing the thesis can be difficult at times, every M.Sc. graduated from Computer Science and Engineering has succeeded in this effort!

2. GENERAL INSTRUCTIONS

2.1. Thesis Process

Figure 1 below presents the general thesis process, with emphasis on the administrative issues and supervision. The process starts with specifying the topic of the thesis and applying for its formal approval by the degree programme committee head. You need to define the topic together with the commissioner and the supervisors (see the next section). The topic, commissioner, and supervisors are specified in the topic application form that is used to apply the approval of the topic.

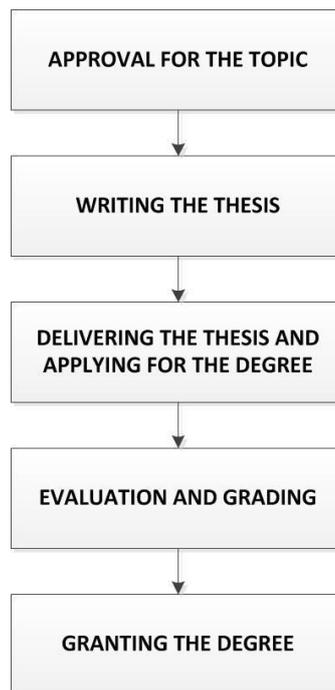


Figure 1. Thesis process.

The second stage is the most laborious part, which includes writing the thesis and performing the actual work, for example, designing, building and testing a piece of software. When the thesis is ready, it is reviewed by the supervisors, modified by you if necessary, and then delivered to the Laturi system. The next step is to apply for the degree certificate and to perform the other tasks that are required from graduating students. The supervisors download the thesis from the archive and evaluate it. The degree programme committee approves the grading in its meeting and the faculty grants the degree. The thesis is transferred to the university archive and published according to the publicity level you defined when uploading the thesis to Laturi. The graduation ceremony ends your M.Sc. studies. The process is explained in more detail in the rest of this document and on the degree programme web pages [11].

2.2. Approval of the topic

Your first task is to find a commissioner for your thesis that is typically a company which hires you to make a thesis project. For example, a summer job or training in a company or some other organization gives a good starting point to continue in a thesis project. A research unit in the Faculty of Information Technology and Electrical Engineering can also act as the commissioner, in which case the topic will most likely be linked with ongoing research at the unit. Research units provide information about current master's thesis topics in their web pages. You can also directly ask topics from the research unit personnel. In some cases the research units can pay salary to the master's thesis worker, but in most cases you need to be prepared to make the thesis for free.

There are 2-3 supervisors involved in the master's thesis process, and they are assigned after the topic is confirmed. *Principal supervisor* is a professor or a doctor who belongs to the personnel of some CSE research unit. A list of potential supervisors and their fields of expertise can be found from the degree program web page [11]. The professor or doctor you approach first can decide based on the thesis topic to act as a principal supervisor her/himself or suggest someone else. Usually, the thesis is done on a topic within the area of your orientation (major). However, topics proposed by companies are often multi-disciplinary or cross-scientific and the topic does not fit into the realm of any particular orientation. In these cases the supervision should be agreed with a professor or doctor who best represents the overall field of the thesis work.

If the master's thesis is made to a university research unit, the commissioner often becomes the principal supervisor. If the thesis is made to a company or some other organization outside the university, the commissioner should assign a *technical supervisor* who is responsible for advising you in the technical matters. It is also common to have a technical supervisor for theses made to university research units. In that case the role of the principal supervisor is mainly to ensure that the requirements set for a master's thesis are fulfilled. In addition, there is always a *second examiner* from the university who is selected by the principal supervisor. The second examiner evaluates the thesis together with the principal supervisor and sometimes also participates to supervision in the issues related to her/his expertise.

If the thesis work is conducted outside the university, it is important to find the principal supervisor as soon as possible in order to make sure that the topic is suitable and to agree on the scope of the thesis. It is recommended to organize a meeting together with the commissioner and the principal supervisor to discuss about the thesis work before it has been started. It is also recommended to write a short project plan that describes the background, motivation, and objectives of the work as well as a timetable and possible risks. The project plan gives a good basis for following the progress of the work.

After the supervisors have been selected and the aims have been agreed, you are ready to apply for the formal approval of the thesis topic by filling out a form available at the degree programme web pages ("Topic application form"). The head of the CSE degree programme will formally approve the topic and appoint the supervisor and the second examiner. You should apply for approval as soon as possible, to be able to take the possible feedback into account in your thesis work.

Once approved, the topic is binding. However, the thesis title can still be fine-tuned in agreement with the supervisor, if changes occur during the process.

The approval for writing the thesis in English is applied at the same time as the thesis topic by using the corresponding form (“Application to write the master’s thesis in English”). If the work is written in English, proofreading by a professional translator can be required. The decision is made by the principal supervisor. The author is responsible for paying the proofreading costs unless it is specified otherwise in the application. It should be also noticed that language is one of the thesis evaluation criteria.

2.3. Writing the Thesis

During the actual work, you are expected to communicate regularly with the technical and principal supervisors. In the beginning, meetings with the principal supervisor can be less frequent, but during the write-up phase, regular meetings are more important.

Every master’s thesis is a unique project and it is difficult to define general rules what the individual steps are and how frequently the meetings with the supervisors should be arranged. Master’s thesis gives an opportunity for demonstrating your professional maturity, but it is also the final learning possibility at the university. Hence, it is important to find the balance between the independent work and the amount of supervision required, which is one of the thesis evaluation criteria. You are entitled to get the necessary supervision, but do not expect that the supervisor will make the thesis for you. During the actual work it is recommended to have frequent appointments with the technical supervisor for discussing about the issues that help you to solve the problems encountered in the work. These meetings also keep the supervisor updated and ensure that you are not stuck or going to wrong direction.

At the beginning of the write-up phase, guidance from the principal supervisor is crucial concerning the structure, presentation order and style of the thesis. During the write-up, meetings with the principal supervisor should be held in order to discuss a) whether the information order and emphases are right, b) whether the issues being covered or planned to be covered are relevant to the thesis, and c) whether some areas have been overlooked. The emphasis in the meetings with the principal supervisor should mainly concern the structuring of the thesis.

At minimum, you should present the table of contents to the principal supervisor before you start writing the thesis, present the first complete draft when it is ready and in this meeting agree the necessary modifications, and then review the modifications in follow-up meetings. In these final meetings (one or more), special attention needs to be paid to correct referencing of others’ work and to the rights and permissions to the content included in the thesis. When the supervisor judges the thesis to be ready, she/he permits electronic publication of the thesis.

2.4. Delivering the Thesis and Applying for the Degree

Starting from January 2013, master’s thesis are published only in an electronic form. When the thesis is ready and the supervisor has given the permission, the student

delivers an electronic version of the thesis to the Laturi system¹. Since the supervisors fetch your thesis for evaluation from Laturi, you need to deliver the thesis no later than 10 days prior to a degree programme committee meeting approving your thesis. You can discuss details of the schedule with the supervisor. Committee meetings are held mainly once per month, and the meeting schedule can be found from the degree programme web pages.

The delivered version must be the final version of the thesis manuscript². The thesis must have the official title page and the layout and general structure presented in this document. **Pay special attention to the title page, as it has been renewed in 2016.** The new template can be downloaded from degree programme web pages [11]; old title page templates are no longer valid.

Once the thesis is accepted by the supervisors and graded by the degree programme committee, it is transferred to the university archive and published at the Jultika repository³ or e-thesis workstations in the university library according to the publicity level you determined when you delivered the thesis.

The degree certificate is applied with the form “Request for Degree Certificate”. This document, and its attachment “Survey for Graduates” can be downloaded from [11]. The filled forms need to be returned to the study affairs office no later than two weeks prior to the degree programme committee meeting. The secretaries will prepare your papers, calculate your GPA, etc. Finnish students are asked to fill also the questionnaire by the Technical Society of Finland.

Before graduation you also need to attend the **maturity test**. Passing the maturity test is required for all degree students and it is taken after the completion of the thesis. The students with Finnish/Swedish as the language of their elementary education will write the test in Finnish/Swedish. If the elementary education has been taken in some other language, the maturity test is taken in English. The maturity test is a written examination based on the thesis, where the candidate is asked to write an essay about the topic(s). The registration for the maturity test should be discussed with the supervisor as you are getting your thesis approved. Finally, you need to return all books, keys, equipment, machinery, and tools that belong to the university.

2.5. Evaluation and Grading

The principal supervisor and the second examiner download the thesis from Laturi for **final evaluation and grading**. They fill out the evaluation form with the proposed grading and deliver it to the study affairs office. If the thesis was commissioned by a company or an organization outside the university, the technical supervisor is expected to fill out a separate evaluation form and send it to the principal supervisor well in advance before the grading. The degree programme committee approves the thesis based on the evaluation by the principal supervisor and the second examiner. The forms and a document describing the evaluation criteria can be found from the degree programme web pages [11].

¹ <http://laturi oulu.fi/>. A good name for your thesis file is <year>-<month>-<familyname>-<firstname>-Thesis.pdf. When several theses are downloaded for review from Laturi, this naming convention helps to identify the files.

² A second version of the thesis can be uploaded to the Laturi system only for a cogent reason and requires a permission from the university library (this permission has to be applied by the student).

³ <http://jultika oulu.fi>

A master's thesis that has been approved will be graded according to the university regulations with the following 5-point scale: satisfactory (1), very satisfactory (2), good (3), very good (4), and excellent (5). In addition to the thesis grades, the degree can be granted the mark "outstanding" if the grade of the thesis was at least "very good" and the weighted average of all M.Sc. level grades (weighted GPA) is 4.00 or higher. The title of the thesis, the name of the supervisor, as well as the grade will be printed on the Master's Degree Certificate.

The student has the right to see the grade proposed by the supervisor, as well as the evaluation form, **three** days prior to the committee meeting. In case the student feels mistreated, she/he has the opportunity to issue a written **appeal** to the board of examiners of the University of Oulu concerning the evaluation of his/her thesis no later than **fourteen days** after having received the information. This process evidently delays the graduation.

2.6. Publicity

A master's thesis is a public document. A thesis must therefore not reveal any business secrets or confidential information. The thesis can only be evaluated based on its written contents. For this reason, it is crucial to discuss thesis publicity with company representatives as early as possible, when the topic is defined. Should any major conflicting interests arise between the author and the customer concerning the publication of information, the author should turn to the principal supervisor for consultation.

The Ministry of Education has issued a set of written statements concerning the public nature of master's theses to universities and colleges. According to the statements the thesis must not contain classified information, and once approved, the thesis should be public. The ownership as well as the publication and/or patent rights should be agreed upon together with the supervisor, author, and the possible commissioner.

Starting from January 2013, all master's thesis written at the University of Oulu will be published electronically by the university library. The publicity level is decided by the author when the thesis is delivered to Laturi; whether the electronic version will be available to everyone from an open access repository or only at special workstations in university libraries.

2.7. Thesis Awards

The Technological Society of Finland and the IEEE Finland section issue the Best Thesis of the Year Award, chosen from a list of candidates that is compiled by Finnish universities and colleges and is including almost all theses published annually in Finland.

3. THESIS WRITING INSTRUCTIONS

3.1. Introduction

A Master's thesis in engineering usually consists of an implementation part (literature survey, hardware development, software development, measurements, etc.), and a written part (the text body). How the implementation part is carried out depends on the topic, so no general guidelines can be issued. However, each type of publication has its distinct layout and structure to be followed. The following set of instructions will explain in detail the writing and layout style for the master's theses published in the Degree Programme in Computer Science and Engineering. Typography affects the readability of the text greatly, so the instructions should be followed strictly. By following these instructions, the thesis authors can properly learn a proper way of expressing themselves formally in writing. After having learned one way of formal writing, it is easier to get used to the formalism used at your future workplace. Presentation and layout style have an effect on the grade of the thesis.

Before starting to write your thesis, it is a good idea to mind-map or chart out the various issues that will be included in a thesis. After that, you should divide them into themes, actual chapters with actual titles, and estimated numbers of pages to be included in each chapter. The contents should be discussed in detail with your principal supervisor. Pay attention on the weighting and focus of different topics. You should reserve enough time for writing your thesis, so that its content and structure will be as good as possible. It should be remembered that the archived thesis book is usually the only document through which your whole thesis work will later be assessed.

3.2. Linguistic Style

As a general rule, students who have completed their matriculation exam in Finland write their Master's thesis in Finnish or Swedish. Foreign students who are not fluent in Finnish write their thesis in English. The thesis can be also written in English if it is well-justified, for example, when the supervisor or the project team does not understand Finnish well enough. A permission to write the thesis in English is applied using a form that can be downloaded from the degree programme web pages.

The language of a thesis written in English has to be flawless. If the thesis does not meet this requirement, or the principal supervisor feels that she/he is not capable of checking the language well enough, the supervisor can demand the thesis to be checked by a proofreading company, a person qualified to edit technological vocabulary in English, a native English speaker, or a person holding the degree of M.A. in English Philology. One should notice that the correctness of the language affect the grading of the thesis.

The thesis should have an abstract and a title in both English and Finnish. The only exceptions are the international master's degree students who do not need to have the Finnish abstract or title. If the language of the thesis is English, the abstract in English comes before the abstract (tiivistelmä) in Finnish.

A Master's thesis is written for an engineering audience. The author should therefore avoid presenting issues and topics that go beyond this scope. You should apply professional terminology when available. This rule also applies to all figures and tables.

The aim is a clear and well-structured thesis, **without unnecessary excessive use of words** – a thesis usually has 50-80 pages. The language (English/Finnish/Swedish) should be fluent and readable, and it should adhere to the conventions and recommendations applied in a particular language. Advice on such issues can be obtained from various language guides (in Finnish, e.g., [4]). There are also several excellent sources on the internet, e.g., [5, 6] in Finnish and [7, 8] in English.

3.3. Typography

In the text typography, you need to use the following guidelines and rules.

- Font: Times New Roman
- Page margin settings:
 - Left margin: 4,5 cm
 - Right margin: 2,0 cm
 - Top margin: 2,5 cm
 - Bottom margin: 3,0 cm
- Spacing:
 - Before a heading: 2 empty rows
 - After a heading: 1 empty row
 - Between two headings: 1 empty row
- Line spacing: the default value for each font size, which is usually the font size + 2 pts.
- 1 empty row should be left between chapters. The 1st paragraph after a heading should not be indented. Subsequent paragraphs should be indented by 0.5 cm.
- 1 empty row should be left between text and the figure or table caption.
- Table structure and the different fonts used in different instances are explained in Table 1.
- In tables, the heading has to be placed above the table. The table heading should not end in a full stop. The permission to publish a table copied from another source has to be mentioned as part of the table heading. Many publishers inform the correct form to write this permission when such a permission has been granted.
- The figure caption text is positioned underneath the table and the caption text ends in a full stop. There should be no references in a caption text. The permission to publish a figure copied from another source has to be mentioned as part of the figure text. Many publishers inform the correct form to write this permission when such a permission has been granted.
- Do not start a chapter with a figure, but embed it in the text content. A figure is supposed to always appear in the text after its reference. If there is not enough space for the figure directly after the first reference, the word processor moves the figure automatically to the next page. In such case, the figure can be moved

forward so that text originally after the figure fills the empty space. However, a figure should always be placed in the same chapter - hence sometimes empty space at the bottom of some spaces cannot be avoided. (The same rules applies for tables.)

Table 1. The font types used in a Master's thesis

Font size (p.)	Layout			
	Regular	Bold	<i>Italic</i>	<i>Bold italic</i>
10	Footnotes and endnotes			
12	Standard text, equations, references, tables, captions, table headings	1st level subheadings, abstract, abstract in Finnish (tiivistelmä)	<i>3rd level subheadings</i>	<i>2nd level sub- headings</i>
14		CHAPTER TITLE¹		
16		Author name		
18		THESIS TITLE		

¹⁾ Each full chapter should start on a new page.

You should not use single subsections – for example, Section 2.1 needs to be accompanied by Section 2.2. Also, please do not number sections beyond the 3rd grade (e.g., 1.2.1.1 should not be used). Should the need arise for further decimalization the following method (a bolded, unnumbered title) should be applied:

Formatting the figure captions

Figures, tables and appendices are a part of the written presentation. All these need to be referenced to in the text body, preferably before the figure is placed in the text – i.e., first the referring text, then the figure or table. Figures and tables have a running number through the document – or chapter wise, if there are plenty of figures.

Figure 2 serves as an example of a figure and a text referring to it. Figure captions are below the figure, and the caption text ends with a full stop. A short caption is centered, while a long caption extending to a several lines is justified on both sides. According to the copyright enactments, you must always have the permission from the copyright holder to use the figure in your work. **Copyright infringement may lead to legal actions and penalties, and in those cases the author is responsible.** The writer should grow towards to mainly using figures of his own in the thesis.

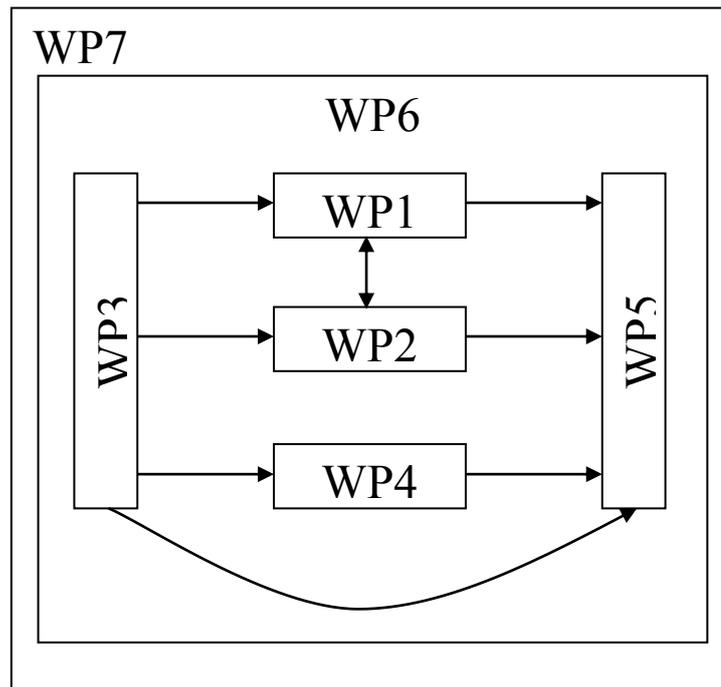


Figure 2. Connections between work packages (WP).

3.4. Practical Advice

On average, it takes between two to three months of full-time work to write a Master's thesis – around one finalized page per day. You might be able to write a thesis in a shorter time, but you should understand that **it takes much longer than you think to edit and re-edit a thesis, considering both structure and presentation style**. In the following we have listed some practical advice, which serves the purpose of making it easier to start the writing phase.

Do not leave the writing to the end

Working on the implementation and written thesis in parallel will force the author to clarify and reformulate ideas, which might often lead to new ideas and save time on editing, re-editing and restructuring later. At the least you should start gathering and getting acquainted with your literature and charting out your written part into clearly defined units and chapters at an early stage. Once you have done this and you know where you are going, you will have a much more secure feeling of the scope of your thesis.

Discuss in detail with your supervisor before you start writing and design a body for your thesis

It is in the best interest of the supervisor that the student graduates as fast as possible and is left without wider difficulties. She/he therefore has an excellent motive to give

help in time. A typical problem at the beginning stage that can be fixed easily is a content structure, in which theory and practice have been clearly divided into two separate parts. If left unfixed, this may often lead to repetition and problems in combining the parts.

Hence, start your writing by planning a content structure, (table of contents), which will function as your backbone all throughout your work. Usually it is a good idea to construct your chapters so that you first give each heading and subheading a working name even if you do not have a final idea of the exact title at this stage. Each structural unit (heading) should have a few code words that act as the key to each heading. You can also look at it this way: code words convey a message to the reader, a message you as the author want to tell them. Later when you have started doing the actual writing, you should look at these code words and crystallize the message in each section to correspond to these code words. Thinking ahead like this will reduce the pain of creation, give you confidence and help you feel that your thesis is solid.

Write things in the right order

Most people find it convenient to write their thesis in the order of their table of contents. It is usually a good idea to start by writing the introduction, because the introduction spells out and defines the aims and scope of the thesis. The other chapters in the opening part of the thesis usually lay out the parameters and working environment, the needed theoretical basis of the thesis etc.; they can also be written fairly early on in the process. The opening part of the thesis also includes the literature review. It is highly recommended that you keep track of your references and document them while you are writing, because you might forget or lose track of your sources later.

Write simply

The first sentence of a paragraph should define its contents. The following sentences clarify the issue. This method results in a clear and easily understandable way of presenting, since each paragraph should contain information only on one or two separate issues. Paragraphs structured like that will be easy to cut and paste elsewhere, if structural rearrangements are later required. To avoid fragmentation, it is important to not present the same things again in different chapters. It will be easier for the reader to follow the idea when your thesis structure is logical and its linguistic style is systematic throughout the thesis. Hence, do not go “over the top” and try to impress the reader with too extravagant ways of presenting your ideas. Instead, present your case as you would like others to present their thesis.

Ask your technical supervisor to go through what you have written

Sometimes the principal supervisor and a technical supervisor are two separate persons, especially in the case where the thesis work is done in a company. In this case you should first have your work read by your technical supervisor. After that edit your work according to his/her advice before you bring it for revision to your principal supervisor. The technical supervisor has a better impression of your work

as he/she interacts with you on a regular basis, and can therefore go through your work much faster. Your principal supervisor, however, can form a better view of your work when you bring him/her a more finished document. You should make good use of the expertise provided by your technical supervisor at all stages of your research and write-up phases. However, do not feel intimidated to show your work to your principal supervisor at the beginning of your writing phase (see Chapter 2 above). It is your official supervisor who makes the final evaluation together with the second examiner. It is therefore important to listen to his/her comments at an early stage to ensure that you are not surprised or disappointed when seeing the completed evaluation form.

It is very usual to get blind to typos in one's own text, and one also easily assumes some topics to be so self-evident that a reader has difficulties to follow the text. This is most easily found by a colleague who is not so familiar with the topic. Alternatively, you can take a break of a few days to look your text with fresh eyes – or just concentrate very carefully on what you are really saying and what you just know without writing it.

Do not get stuck

Figure 3 shows how difficult the writing can be sometimes. If you feel you are not advancing with your writing, although you feel like you know your topic, there might be something wrong in the way you work. In this case, do not waste time in wondering and fretting; instead seek advice in the instructions above. If this does not help, then usually your supervisor(s) can help you in solving your problem. At the most difficult time it is good to remember that every engineer you see out there has once been in the same situation as you are now, and yet they were still able to graduate.



Kuva 3. Kirjoittamisen vaikeus ja ahdistus.

Figure 3. Writing angst and the pain of creation. “Writing your thesis can sometimes make you run outside and howl at the moon. - It’s already the fourth week and I haven’t been able to write anything else besides my name down.”

Hints for editing

A well-prepared document template with pre-defined paragraph formats speeds up writing. Also the use of automatic numbering helps to minimize manual corrections, when the order of figures, for example, is changed.

Most word processors have a spelling checker feature that is recommended to be used. This way your supervisor does not need to spend time on spotting and correcting typos, but can concentrate on the actual contents of the thesis.

3.5. Electronic version

University of Oulu started archiving electronic versions of M.Sc. theses in January 2013. All theses will be uploaded to the Laturi system and transferred from there to the university archive once accepted. The theses will also be published in the university repository, but each student can her/himself decide the level of publicity (see 2.7. “Publicity”). It should be noted that the repository provides a short link to a published thesis. Hence, the student can include the link, for example, in her/his CV, and generally use a publicly available thesis in advertising her/his skills and experience.

As part of the new archiving process, each student has to guarantee that she/he has the necessary rights and permissions to the content included in the thesis. Specifically, a student needs to ask a permissions for each figure and table not created by the student her/himself but copied from another source.

Moreover, each student can her/himself decide whether the thesis will be analyzed with a program called Urkund. This program checks the amount of similar text in the thesis and already published documents (i.e. theses delivered earlier and documents in various databases and in the Internet). The role of Urkund is twofold: First, it checks whether a student has copied text from others’ documents. Copying of few sentences is acceptable when the copied text is referenced and quoted properly; otherwise such copying is not permitted and causes official consequences - the thesis can even be rejected. Second, when the thesis is in Urkund’s databases, it checks whether others have copied text from this thesis.

We recommend allowing the thesis it be delivered to Urkund as then the thesis is protected against incorrect copying by others. However, as thesis once delivered to Urkund cannot be deleted from its databases, the text copied from others’ documents must be referenced and quoted properly in the first version delivered to Urkund. Hence, a student must **always** check correct referencing and quoting with the supervisor before delivering the work to Urkund! CSE professors have additional tools for performing this check. The rights and permissions for thesis content can be checked at the same time.

More information can be found from the degree programme web pages [11] and from Laturi’s web pages: <http://laturi.oulu.fi>.

4. THE LITERARY STRUCTURE OF A MASTER'S THESIS

The structure of a text is based on a pre-designed content structure (table of contents and the body) that can vary a great deal from thesis to thesis depending on the topic as well as the scope of the thesis. The presentation order of the first few pages is fixed, and should be presented as it is described in Sections 3.1 to 3.7 in these instructions. When applying page numbering, the title page has page number '1', but page numbers are shown (at the right upper corner of each page, Arabic numerals) only from Chapter 1, Introduction, onwards..

4.1. First Pages

4.1.1. Front Cover

The **front cover** is included only into a bound thesis. The electronic version does not have a front page, but the title page is the first page of the thesis. Starting from January 2013, only the electronic version has to be submitted, it is not anymore mandatory to bind the thesis at a printing house. However, a student is free to bind the thesis when she/he wants to have a high-quality copy for relatives, for example.

For the bound thesis, the words MASTER'S THESIS should be printed in the middle of the front cover. The NAME OF THE AUTHOR of the thesis should be printed in the lower right hand corner of the front cover. The NAME OF THE AUTHOR and year of publication should be printed in the spine of the thesis. You must have your thesis bound at a printing house specialized in printing theses. The printing house will also produce and attach the cover to the printout that you have brought with you. The color of the cover has to be black. The text has to be printed on the cover, i.e., stickers should not be applied!

4.1.2. Title Page

Title page template can be downloaded from the degree programme web pages. If the word processor you use cannot import the template, you can produce the title page yourself; some PDF tools can also combine several PDF files into a single file. Your name should be written into the middle. The title should be written below your name with capital letters, centered, and divided into several lines as necessary to produce a balanced appearance. University logo and the faculty name are placed at the top and the type of the thesis, degree programme name, and date are placed at the bottom.

4.1.3. Abstract

The abstract of your thesis will be fed into various databases and catalogues. It should crystallize the essence of your thesis. A good abstract is a bait that attracts the reader to take a closer look of the content. The abstract should be self-contained, i.e., the reader should be able to get a clear picture of your thesis from the abstract alone. There must not be any references to your thesis or other sources, but it should also not include any information not found in your thesis. The abstract should include the main elements, as well as the methods used and results obtained, and main

conclusions of your thesis. The recommended length of an abstract is 200 words. Rare terminology and abbreviations should be avoided.

The bibliographic information of the thesis should be printed at the top of the abstract page. The keywords of your thesis should be printed below the abstract. The recommended number of keywords is 2-6 keywords or word sets. It is recommended that the keywords are not any words included in the title of the thesis. Keywords serve an important purpose for anyone performing literature searches in a library and other information catalogues. An example abstract is presented in Appendix 1.

4.1.4. Abstract in Finnish

You also have to write your thesis abstract in Finnish, or have your abstract translated into Finnish. It should be written in flawless Finnish. If the language of the thesis is English, the abstract in English is placed first, and abstract in Finnish (Tiivistelmä) after it. If the language of the thesis is Finnish the order is opposite. The requirement of the Finnish abstract does not apply to international master's degree students.

4.1.5. Table of Contents

The table of contents lists the chapters with their headings and subheadings and their respective page numbers. However, the page number is shown in the table of contents only from the first chapter, Introduction, onwards.

4.1.6. Foreword

The foreword page should describe the aim of the thesis, and its various research stages, and present the partners, funding and circumstances involved in the thesis project. The forewords should also include words of gratitude, addressed to people who have been incremental in your thesis-writing process. The supervisor, the second examiner, and the technical supervisor can be mentioned as well.

4.1.7. List of Abbreviations and Symbols

All abbreviations and symbols used in the thesis have to be listed on this page. You should first explain all mathematical (and other similar) symbols, then abbreviations, so that Latin, Greek, etc. letters are all grouped separately. Abbreviations need to be explained in text as well, when they are used the first time. You should check the validity of all abbreviations and symbols from reliable sources. Concerning measurement units, you should apply the internationally approved SI-system of symbols [9, 10] and quantities and units specified in the IEC 80000-13 standard. For example, 1000 bytes is one kilobyte (1 kB, 'B' is Bytes, 'b' is bits) and 1024 bytes is one kibibyte, 1 KiB. Similarly, 1 048 576 bytes mebi (Mi); the larger units are gibi (Gi), tebi (Ti), pebi (Pi), and exbi (Ei).

4.2. Introduction

In the introduction, you should describe the background and motivation of your thesis, introduce the reader to your research questions and methodology, describe in detail the objectives of your thesis (i.e. what is your aim to achieve), and on what basis the scope of your research area has been chosen. You can also state explicitly what will not be covered. When needed, you can make references to earlier work done in the field. You should **not** discuss the results of your thesis in the introduction.

You can start by introducing some need of an individual user or the society, or some well-known application or technology. Specifying your own topic as part of such larger entity helps the reader to understand the work and estimate its significance and success. Note that you should avoid specifying too challenging objectives, as failing to meet the objectives can reduce the grade.

Nowadays master's theses in engineering are often a part of wider research projects at universities or industries, and it might therefore be difficult for the reader to discern when the author is describing her/his personal work, and when is s/he describing the work of a research group. In cases like these, the author should describe as well as possible what exactly was his/her role and contribution in the research/project. At the end of the introduction, you might want to give an overview about the structure of your thesis.

4.3. How to Manage the Core Text Part of Your Thesis

How you handle the core topic of your thesis depends essentially on the nature of your research/project. Most theses first describe the technological and scientific environment of the thesis and state-of-the-art related to the topic. This part should focus on presenting context for the author's own work and for the decisions made by the author, so that it is later clear why one approach, technology, or method was chosen over another.

When the author develops a part for a larger system, it is necessary to describe this larger system as well. For example, when an author develops a software component for an LTE base station, the base station and LTE telecommunication network need to be described. However, the author needs to pay attention to describe the larger system only at a reasonable level of detail. The rule of thumb is that detailed information should be given only when this information is necessary to understand the rest of the thesis.

In the beginning, you can describe and analyze optional approaches or methods, e.g., by applying system-level modeling. As stated above, you can also present solutions proposed in literature sources. The best grades require presenting the state of the art of both technology and science - that is, presenting both the already available solutions and the ongoing research. Such presentation shows that the author possesses good knowledge on the thesis' topic. Hence, it is crucial to get familiar with the latest literature on the thesis's topic as soon as possible. Books, scientific articles, and patents can be searched from the sources offered by the university

library. The library's subject guide on information technology¹ is a good starting point for searching literature.

Some thesis can include a theoretical analysis of a given topic, in which you present the grounds on which you analyze the topic, based either on literature sources or your own reasoning. However, you should avoid unnecessary writing-up, that is, the theory you present should be closely linked to the focus of your thesis.

Mathematical equations and denotations often play an important role in describing a theory. However, one must bear in mind that mathematics is a useful tool in writing, and not an end purpose in itself. It is not necessary to present theory and equations in detail when they can be found from the literature - proper referencing suffices in such situations. It is more crucial to present general principles about the methods and solutions that are essential for the thesis. Usually it is not necessary to prove theorems or to derive the methods in detail but it suffices to present the basic equations, the relevant variables, and the end results. However, when the proving or derivation is done by the author her/himself, details need to be described. You can also include lengthy derivations as appendices if you need to.

When presenting numerical results, the unit should always be separated with a space from the numerical value preceding it (e.g., 5 Gbit/s). The mathematic variables and symbols used in equations should be *italicized*. Vectors and matrices should be ***italicized*** in bold. Numbers, units, and sub-indices or subscripts should not be italicized (sub-indices or subscripts that include symbols of equations should all be italicized). Greek letters should not be italicized. Every equation should be a part of complete sentence. An empty row should be left at the top and at the bottom of an equation, and equations should be numbered by applying running numbering, from the beginning to the end of the thesis. However, if you have a large number of equations, you can number them per chapter. The numbering should take place at the right side of the equation in parentheses. You should refer to the equation in the text by referring to the number of the equation, e.g.: "As seen in Equation (1), the..."

An example: In steady movement, speed v is

$$v = \frac{s}{t}, \quad (1)$$

where t is the amount of time required by the movement, and s is the distance.

After the opening sections of your thesis, you should present the actual personal contribution your thesis is making, although some of this can already be included in the previous chapters. Describing the phases of the development work provides a clear structure, that is, describing first the requirements for the solution, then the design and implementation, followed by testing (i.e. verification).

The requirements can be either given by the customer or the author might need to determine the requirements her/himself by interviewing experts, for example. In either case, the actual work must not be straightforward following of instructions given by others but the author must provide a significant contribution to the solutions. Thesis work is independent, analytical problem solving and engineering work, in which the author weighs different solutions for the encountered problems and presents the reasoning and justifications for the selections you make during this process. Essential selections can be presented, for example, in a table listing the

¹ <http://libguides oulu.fi/c.php?g=58694>

alternatives and selection criteria, and giving justified points for the alternatives for each criterion. For example, when a certain device needs to be selected, the criteria can be price, performance, and reliability, and each candidate devices is given points for each criterion.

The design should be presented using the established tools and representations. For example, UML diagrams can be used to describe software design. The aim of testing is to verify the solution. When the requirements are presented in an earlier chapter, it is natural to test the solution against the requirements. So that your observations will benefit your readers, you should record and publish them in your thesis in as thorough and detailed a way as possible in their original format (such as tables, etc.). You must be careful not to mix actually obtained results and your estimates of the results. The reliability of the results can be analyzed using statistical methods, though strong conclusions require large samples.

In construction, or software-based theses, you should approach your research questions by means of system planning. You should only describe the necessary details of your basic theory and construction, which are directly relevant to the construction or software. You can include a broader description of the constructions and/or software in an appendix if you deem it important. You should describe the details of your construction/software in sections, starting from a general level, and then going into more detail, level by level. You should avoid a too detailed description concerning the operational principles of software structures and electronic circuits. However, details that are essential to the thesis - especially details that cover new ground or are not clear even to experts in the field - should be included in the thesis.

Measurements are in most cases essential to verify the developed solution and they should be well planned. A master's thesis is not a measurement report, though, and all results are not necessary to report. Instead, every figure and every table you present should have a clear statement that you want to show.

These instructions give guidelines on writing the core text of your thesis when your topic is to develop a concrete solution that can be tested, like a device, piece of software, or an algorithm. Even if the work does not produce such a concrete result, the analytical problem solving has to be present in the documentation and the result be presented clearly. For example, for a literature study, presenting the subject matter and the essential content found from the literature is not enough, but the author has to classify this content or otherwise analyze it. In topics not producing concrete results, such analysis is a mandatory requirement for the best grades. Specifically, it is always crucial to analyze how well the results meet the objectives set in the introduction. This analysis can be placed in the discussion chapter.

4.4. Discussion

A good thesis or other scientific work always has a discussion. In order to write this, you should be able to look at your work as if from a distance, to "step out of the box", as they say. You should be self-critical, compare your work to similar work in the field, and think analytically. You should be able to crystallize the results of your work, and put them into words. This can often be difficult even for an experienced writer, but it helps if you are well acquainted with published literature in the field.

A justified analysis of meeting the thesis' objectives is an important part of the discussion, and generally analysis of the results. When the requirements for the developed solution are presented earlier in the thesis, it is natural to first discuss how these requirements were fulfilled and from that conclude how well the objectives were met. Own solution should also be compared to the state of the art (technology and science) presented at the beginning. Your solution does not have to be better, but this kind of analysis is essential in engineering work and hence an important part of master thesis as well. Such a comparison is needed for the best grades.

The analysis can contain also more general commenting, for example, what was easy and what was difficult in the work. You can also discuss the overall significance of your thesis on a more general level. Outlining potential further development based on your thesis, is valuable, especially if you have put forth clearly new or ground-breaking ideas. However, you should avoid unnecessary speculation here, as well as elsewhere: all statements should be well reasoned and brief. Other requirements for discussion can be found from the supervisors' evaluation instructions that are available at the degree programme web pages [11].

4.5. Summary

In the summary (or conclusions) you should present clearly in a nutshell the objectives of your thesis, its main content, your results, and the significance of your results. You should lay special emphasis on your results if you feel you have accomplished something. In summary you should not make references, or present any results not found elsewhere in your thesis.

The abstract and the summary overlap to a certain extent; they both describe the main contents and results of a thesis. However, the nature of the summary is broader and it does not have to be self-contained. In it, you should describe your aims, and you could describe any optional solutions or approaches, and motive the choices you have made. The abstract on the other hand could just describe in detail the solutions and approaches chosen for the thesis, leaving the optional approaches out.

4.6. References

The use of references serves many purposes. Scientific method relies on familiarizing with the topic and state of the art. However, efficient referencing can also compress your text, as you can leave the details in the references and repeat only the most important results.

The literature survey should be close to exhaustive, and this means that most of the information you present is taken from references. If a piece of information is not derived or devised by you, it is borrowed, and the origin of the information must be stated. Presenting somebody else's finding as your own is a scientific theft (plagiarism) that has serious consequences.

You should refer to original sources of the data – for example, to a book and not the handouts made based on the book. Be careful when referencing: the things you state really need to be found from the reference.

The references are mostly cited in your own words, and direct quoting is used only if you want to emphasize the source. In this case you place the quote in hyphens,

for example saying that the exact phrasing of Moore's law is of form "The complexity for minimum component costs has increased at a rate of roughly a factor of two per year." [x]. Note that correct referencing is even more important starting from January 2013 when the archiving of electronic versions starts and the theses are easily accessible (either in library or in the Internet, depending on the publicity level selected by the thesis author).

The list of references is written according to the instructions of the Acta Universitatis Ouluensis series [2]; using the running numbering. Present your reference sources **in the order in which they appear in the text**. Reference in the text should be indicated with a reference number, e.g., [1] or [1, 2, 5]. References to books should include also page number, for example [1 p.15] or [1 p.15-17].

References need to be presented so that it is clear what information is from a source and what is created by the author. Also the sources of equations, figures, and tables need to be given, when not created by the author her/himself. In addition, permissions need to be asked for tables and figures. Special attention needs to be paid to web sources, as web content can have a short life cycle. Hence, the date of downloading referenced web content should always be mentioned in the reference.

Examples below illustrate correct references. All authors should be listed, the names of journals and series should be written completely without abbreviations, and only the first letter of the title and proper nouns in the title should have uppercase letters. The DOI (Digital Object Identifier) of the publication should be included in the reference, when possible. This identifier locates the publication in an unambiguous fashion and hence facilitates the work of a reader searching the reference. DOI can be found from the publications front page or from publishers' databases (e.g. IEEE Xplore, Springer Link, ACM Digital Library).

Journal:

- [1] Ojala T, Pietikäinen M & Mäenpää T (2002) Multiresolution gray scale and rotation invariant texture classification with Local Binary Patterns. IEEE Transactions on Pattern Analysis and Machine Intelligence 24(7): 971-987. DOI: <http://dx.doi.org/10.1109/TPAMI.2002.1017623>.

Series:

- [2] Riekkilä J (1998) Reactive task execution of a mobile robot. Acta Universitatis Ouluensis C 129.

Book:

- [3] Pietikäinen M, Hadid A, Zhao G & Ahonen A (2011) Computer vision using local binary patterns. London, Springer-Verlag.

A section of compiled work:

- [4] Cvejic N & Seppänen T (2005) Digital audio watermarking. In: Seitz J (ed) Digital watermarking for digital media. Hershey, PA, Idea Group: 135-181.

Conference proceedings:

- [5] Heikkilä J & Silven O (1997) A four-step camera calibration procedure with implicit image correction. Proc. 1997 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. San Juan, Puerto Rico, 1106-1112. DOI: <http://dx.doi.org/10.1109/CVPR.1997.609468>.

Thesis:

- [6] Heikkinen K (2011) Design specification of a dashboard interface for the management of steel service centers. Master's thesis. University of Oulu, Department of Computer Science and Engineering.

Patent:

- [7] Toivonen T, Heikkilä J & Silven O (2004) Oulun yliopisto, assignee. Method and device for coding successive images. European patent 1438861.

Internet publication:

- [8] Rönning J, Tuhkanen V, Sipola R & Vallius T (2011) Facilitating software construction for nano- and microscale measurement. SPIE Newsroom. URL: <http://spie.org/x47762.xml>. DOI: <http://dx.doi.org/10.1117/2.1201103.003415>. Accessed 12.3.2012.

Author unknown:

- [9] Asumistaso: asuntoasian vuosikirja (1991). Suomen Asuntoliitto, Helsinki, 72 s.

4.7. Appendices

Things you can include as an appendix are, e.g., derivations of equations or formulas, details of important computer programs, various tables, or performance characteristics and descriptions of special equipment or components applied in the thesis work. You can also include construction drawings and parts catalogues in the appendix. Appendices are titled as shown before. As with figures and tables, all appendices you include should have a clear meaning – their number of appendices itself is not a merit.

If your text seems to contain a lot of references to an appendix, it may be easier for the reader that you copy the information (e.g., a schematic) into the text. This way the reader does not need to browse between pages.

Large block diagrams or schematics can be copied on A3 size paper. This needs to have two bends (Z-like) so that the right side of the appendix lies top and with a width of ca 2/3 of A4 page.

5. SUMMARY

These instructions describe the various stages of writing a master's thesis. We have presented the role of a Master's thesis in an engineering degree, and we have discussed about the importance of keeping close contact with your thesis supervisors. We have also described the procedure, according to which a master's thesis in the Degree Programme in Computer Science and Engineering, is to be written.

6. REFERENCES

- [1] Lappalainen P., Suutari-Jääskö L. & Silvén O. (1994) Diplomityön teko-ohjeet. Oulun yliopisto, Sähkö- ja tietotekniikan osasto, Oulu, 31 s.
- [2] Ohjeita kirjoittajille (1997). Acta Universitatis Ouluensis -sarjan julkaisu-toimikunta, toim. Leena Rautio. Oulun yliopisto, Oulu, 20 s.
- [3] Tirronen K. (1987) Teknisen kirjoituksen laatiminen. Suomen Teknillinen Seura STS r.y., Teknillisten Tieteiden Akatemia, Jyväskylä, 89 s.
- [4] Maamies S. (toim.) (1998) Kielikello. Kielenhuollon tiedotuslehti 3. Kotimaisten kielten tutkimuskeskus.
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- [6] Kielitoimisto (2013). URL: <http://www.kotus.fi/kielitoimisto/>. Accessed 20.1.2013.
- [7] Report Writing - Resources for Students (2013) URL: <http://learnhigher.ac.uk/Students/Report-writing.html>. Accessed 20.1.2013.
- [8] English Language Resources (2013) URL: <http://www.usingenglish.com/resources/>. Accessed 20.1.2013.
- [9] SI-opas: suureet ja yksiköt, SI-mittayksikköjärjestelmä (Système international d'unités) (1974). Suomen standardisoimisliitto, Vakaustoimisto, Helsinki, 23 s.
- [10] International System of Units (2013). URL: http://en.wikipedia.org/wiki/International_System_of_Units. Accessed 20.1.2013.
- [11] MSc Studies (2016). URL: <http://www oulu.fi/cse/node/22267>. Degree Programme in Computer Science and Engineering, University of Oulu. Accessed 28.6.2016.

7. APPENDICES

Appendix 1 Example Abstract

Note 1: Page numbering is done by consecutive numbering. Additional appendices, that are attached to the thesis (such as copies, drawings, etc.) are left without page numbers and placed at the end of the thesis.

Jurmu M. (2007) Resource Management in Smart Spaces Using Context-Based Leases. University of Oulu, Department of Electrical and Information Engineering. Master's Thesis, 77 p.

ABSTRACT

The convergence of wireless access networks in conjunction with the increased computing power of the handheld terminals is preparing the emergence of the ubiquitous computing paradigm. In the center of this paradigm are smart spaces, which are local environments saturated with various embedded computational resources. These spaces co-operate with mobile client devices in enabling advanced, service-oriented computation scenarios. This co-operation is typically enabled through the utilization of distributed and modular middleware frameworks. An emerging additional requirement however is the possibility to harness resources from the proximity environment to the mobile device in an on-demand fashion. This is a challenge especially to the resource management infrastructure of the smart spaces.

This thesis explores the concept of a smart space and presents a review of the current research and technologies. Subsequently, a lease-based design for resource management in smart spaces is presented. Leases in this work are negotiated agreements between the mobile clients and the resource management infrastructure, regarding the harnessed resources. Leasing is seen as a suitable solution for the management due to the transient nature of the resource usage. The inclusion of additional contextual features to the leases further facilitates the management.

Requirements for the design are derived from the review and from an example usage scenario. The requirements include dynamic mapping and contracting of resources from the proximity environment, monitoring of the contract validity, access control towards the resources and dynamic maintenance of the smart space infrastructure. Presented design is analytically compared against existing solutions, and several points for future development are listed. According to the comparison, none of the existing solutions utilize contracts with contextual validity in resource management. Two publications of this work have been accepted into an international conference and a workshop on the focus area of pervasive computing.

Keywords: Ubiquitous computing, mobile computing, task-based computing, context-awareness, QoS.