



XXX Thesis in \*\*\*\*\*Unknown subject area\*\*\*\*\*

# **This is the title in the language of the thesis**

**A subtitle in the language of the thesis**

**FAKE A. STUDENT**

KTH ROYAL INSTITUTE OF TECHNOLOGY



# This is the title in the language of the thesis

A subtitle in the language of the thesis

FAKE A. STUDENT

Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the Degree of XXX of Engineering on Tuesday 15th April 2025 at 2 p.m. in SAL-C and via Zoom <https://kth-se.zoom.us/j/ddddddddddd>, Isafjordsgatan 22 (Kistagången 16).

XXX Thesis in \*\*\*\*\*Unknown subject area\*\*\*\*\*

Supervisors: A. Busy Supervisor, Another Busy Supervisor, Third Busy Supervisor

Swedish title: Detta är den svenska översättningen av titeln

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Keep in mind that your thesis is an archival document that will be accessible (ideally) for all time. Therefore, you should only say what you would want others to read in 1, 5, 10, ... years.

*To xxxxx.*



# Abstract

All theses at KTH are **required** to have an abstract in both *English* and *Swedish*.

Exchange students may want to include one or more abstracts in the language(s) used in their home institutions to avoid the need to write another thesis when returning to their home institution.

Keep in mind that most of your potential readers are only going to read your title and abstract. This is why the abstract must give them enough information so that they can decide if this document is relevant to them or not. Otherwise, the likely default choice is to ignore the rest of your document.

An abstract should stand on its own, *i.e.*, no citations, cross-references to the body of the document, acronyms must be spelled out, ... .

Write a draft abstract *early* and *revise as necessary*. This will help keep you focused on what you are trying to do.

Enter your abstract here and remove this line!

An abstract is (typically) about 250 and 350 words (1/2 A4-page) with the following components:

- What is the topic area? (optional) Introduces the subject area for your research.
- Short problem statement
- Why was this problem worth a third-cycle thesis? (*i.e.*, why is the problem both significant and of a suitable degree of difficulty for your intended degree? Why has no one else solved it yet?)
- How did you solve the problem? What was your method/insight?

- **Results/Conclusions/Consequences/Impact:** What are your key results/conclusions? What will others do based on your results? What can be done now that you have finished - that could not be done before your research was completed?

The following are some notes about what can be included (in terms of LaTeX) in your abstract.

Choice of typeface with `\textit`, `\textbf`, and `\texttt`:  $x$ ,  $\mathbf{x}$ , and  $\mathsf{x}$ .

Text superscripts and subscripts with `\textsubscript` and `\textsuperscript`:  $A_x$  and  $A^x$ .

Some symbols that you might find useful are available, such as: `\textregistered`, `\texttrademark`, and `\textcopyright`. For example, the copyright symbol: `\textcopyright` Maguire 2022 results in ©Maguire 2022. Additionally, here are some examples of text superscripts (which can be combined with some symbols): `\textsuperscript{99m}Tc`, `A\textsuperscript{*}`, `A\textsuperscript{\textregistered}`, and `A\texttrademark` resulting in  $^{99m}\text{Tc}$ ,  $A^*$ ,  $A^{\text{®}}$ , and  $A^{\text{™}}$ . Two examples of subscripts are: `H\textsubscript{2}O` and `CO\textsubscript{2}` which produce  $\text{H}_2\text{O}$  and  $\text{CO}_2$ .

You can use simple environments with `begin` and `end`: `itemize` and `enumerate` and within these use instances of `\item`.

The following commands can be used: `\eg`, `\Eg`, `\ie`, `\Ie`, `\etc`, and `\etal`: *e.g.*, *E.g.*, *i.e.*, *I.e.*, *etc.*, and *et al.*

The following commands for numbering with lowercase Roman numerals: `\first`, `\Second`, `\third`, `\fourth`, `\fifth`, `\sixth`, `\seventh`, and `\eighth`: *(i)*, *(ii)*, *(iii)*, *(iv)*, *(v)*, *(vi)*, *(vii)*, and *(viii)*. Note that the second case is set with a capital 'S' to avoid conflicts with the use of `second` as a unit in the `siunitx` package.

Equations using `\( xxxx \)` or `\[ xxxx \]` can be used in the abstract. For example:  $(C_5O_2H_8)_n$  or

$$\int_a^b x^2 dx$$

Note that you **cannot** use an equation between dollar signs.

LaTeX comments starting with the percent symbol (%) to the end of the line will be removed. Note that one can include percentages, such as: 51% or 51 %.

## Keywords

KeywordA, KeywordB, KeywordC

**Choosing good keywords can help others to locate your paper, thesis, dissertation, ...and related work.**

Choose the most specific keyword from those used in your domain, see for example: the ACM Computing Classification System (<https://www.acm.org/publications/computing-classification-system/how-to-use>), the IEEE Taxonomy (<https://www.ieee.org/publications/services/thesaurus-thank-you.html>), PhySH (Physics Subject Headings)



(<https://physh.aps.org/>), ...or keyword selection tools such as the National Library of Medicine's Medical Subject Headings (MeSH) (<https://www.nlm.nih.gov/mesh/authors.html>) or Google's Keyword Tool (<https://keywordtool.io/>)

A helpful script for those who are comfortable with Python

For assistance in identifying suitable keywords, a dedicated Python utility, `thesis_keyword_extractor.py`, has been developed. This tool processes the main textual content of the thesis (as a PDF input) and generates a list of potential keywords and specialized terminology. Crucially, it attempts to assign a linguistic proficiency level to each term, based on the Common European Framework of Reference for Languages (CEFR) scale. This analysis is intended to assist the author in selecting precise and appropriately specialized keywords for the thesis. \*

**Formatting the keywords:**

- The first letter of a keyword should be set with a capital letter and proper names should be capitalized as usual.
- Spell out acronyms and abbreviations.
- Avoid "stop words" - as they generally carry little or no information.
- List your keywords separated by commas (",").

Since you should have both English and Swedish keywords - you might think of ordering the keywords in corresponding order (*i.e.*, so that the  $n^{\text{th}}$  word in each list correspond) - this makes it easier to mechanically find matching keywords.

---

\*The source code for the keyword extractor and supporting files can be found at <https://github.com/gqmaguirejr/Canvas-tools>.



# Sammanfattning

Inside the following `scontents` environment, you cannot use a `\includefilename`, as the command itself, rather than the file's contents, will end up in the for DiVA information. Additionally, you should not use a straight double quote character in the abstracts or keywords, but rather use two single quote characters instead.

Alla avhandlingar vid KTH **måste ha** ett abstrakt på både *engelska* och *svenska*. Om du skriver din avhandling på svenska ska detta göras först (och placera det som det första abstraktet) - och du bör revidera det vid behov.

If you are writing your thesis in English, you can leave this until the draft version that goes to your internal reviewer. In this way, you can provide the English and Swedish abstract/summary information that can be used in the announcement for your oral defense.

If you are writing your thesis in English, then this section can be a summary targeted at a more general reader. However, if you are writing your thesis in Swedish, then the reverse is true – your abstract should be for your target audience, while an English summary can be written targeted at a more general audience.

This means that the English abstract and Swedish sammnfattning or Swedish abstract and English summary need not be literal translations of each other.

Do not use the `\glspl{}` command in an abstract that is not in English, as my programs do not know how to generate plurals in other languages. Instead, you will need to spell these terms out or give the proper plural form.

In fact, it is a good idea to **not use** the glossary commands at all in an abstract/summary in a language other than the language used in the `acronyms.tex` file - unless one is going to define a new `\glsaddkey` for the long and short Swedish (or other languages that you are using) versions of acronyms.

An example of this might be shown in a future version of this template.

The abstract in the language used for the thesis should be the first abstract, while the Summary/Sammanfattning in the other language can follow

Skriv in din svenska sammanfattning eller abstrakt här!

### Nyckelord

NyckelordA, NyckelordB, NyckelordC

Nyckelord som beskriver innehållet i uppsatsen eller rapporten

If you add the class option `includeExtraAbstracts` in your `documentclass`, then you can enable abstracts/summaries in a number of languages. Include those versions of abstracts that you need.

If you are an exchange student, use the relevant language or languages for abstracts for your home university, as this will often avoid the need for writing another thesis for your home university.

If you are fluent in other languages, feel free to add the abstracts in one or more of them.

The set of languages that can be easily included are based on those languages that were used in theses at KTH in the period 2018-2019, along with several others that have been used in theses since.

Note that you may need to augment the set of languages used in `babel` (see the file `kththesis.cls`). If you add a new language, when specifying the language for the abstract, use the three-letter ISO 639-2 Code – specifically the "B" (bibliographic) variant of these codes (note that this is the same language code used in DiVA).



# Acknowledgments

## Författarnas tack

It is nice to acknowledge the people who have helped you. It is also necessary to acknowledge any special permissions that you have gotten – for example, getting permission from the copyright owner to reproduce a figure. In this case, you should acknowledge them and this permission here and in the figure's caption.

Note: If you do **not** have the copyright owner's permission, then you **cannot** use any copyrighted figures/tables/.... Unless stated otherwise, all figures/tables/...are generally copyrighted.

I detta kapitel kan du ev nämna något om din bakgrund om det påverkar rapporten på något sätt. Har du t ex inte möjlighet att skriva perfekt svenska för att du är nyanländ till landet kan det vara på sin plats att nämna detta här. OBS, detta får dock inte vara en ursäkt för att lämna in en rapport med undermåligt språk, undermålig grammatik och stavning (t ex får fel som en automatisk stavningskontroll och grammatikkontroll kan upptäcka inte förekomma)

En dualism som måste hanteras i hela rapporten och projektet

Be sure that you acknowledge your funding source(s).

Se till att du anger din/dina finansieringskällor.

I would like to thank xxxx for having yyyy. Or in the case of two authors:  
We would like to thank xxxx for having yyyy.

Stockholm, December 2025

Fake A. Student





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If you have listings in your thesis. If not, then remove this preface page.



## List of Acronyms and abbreviations

CRedit	Contribution Roles Taxonomy
ICT	Information and Communication Technology
LAN	Local Area Network
OS	operating system
SDG	Sustainable Development Goal
UN	United Nations
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

The list of acronyms and abbreviations should be in alphabetical order based on the spelling of the acronym or abbreviation.



## List of Publications

When defending a thesis, you must mention which scientific papers, patents, artifacts, datasets, ... are included. Note that peer-reviewed artifacts are increasingly common, as some publications have “badges” for publications that include code, code that has been shown by a reviewer to be reproducible, *etc.* See, for example, Artifact A.

The titles of the publications are to be set in Figtree; however, this may not be possible, as Figtree lacks Greek characters, math symbols, *etc.*, that may appear in the titles. Therefore, you may need to change the font you are using for such a title. Papers E and F show two approaches for doing this. Paper E uses math mode to get the Greek characters, while Paper F uses a font that has the Greek characters. Further note that `\mystixmathfont` has been used, rather than a font such as `\NotoSansFont` - as the overbar in the latter font is too low. The font could have been applied to the whole title, but this would result in serified letters for the whole title. Both of these commands for fonts were introduced in `kththesis.cls`.

The use of math mode in the title of Paper E will generate a warning “Font shape ‘U/stmry/m/n’ in size <5.5> not available” - since scaling the 11pt math font for the superscripts and subscripts leads to 5.5pt letters - for which LaTeX substitutes 5pt letters. Both for this font scaling issue and to improve readability (see, for example, the fictitious title of Report A), I would think that the publication titles should be set in a font larger than 11pt.

Paper A Coherent File Distribution Protocol[1]

Paper B A New Automated Way to MeasurePolyethylene Wear in THA Using a High Resolution CT Scanner: Method and Analysis [2]

Paper C Make the Most out of Last Level Cache in Intel Processors [3]

Paper D Do Small-Mass Neutrinos Participate in Gauge Transformations? [4]

Paper E FMM-Head: Enhancing Autoencoder-based ECG anomaly detection with prior knowledge

Patent A Authenticatable graphical bar codes [6]

Patent B Methods and devices for controlling memory handling [7]

Artifact A PacketMill: Toward Per-Core 100-Gbps Networking - Artifact for ASPLOS'21 [8]

Those who want can also list other peer-reviewed original scientific publications not included in the thesis. I would include granted patents (relevant to the thesis) in this list.

If you are using BibTeX, **Paper F** shows an example of how you can easily include the title by simply citing the title field of a reference. The alternative uses math mode to set the special characters.

In contrast, **Paper G** shows how you can use the unicode version of the characters and explicitly control the font used to set them.

## Scientific papers not included in the thesis

Paper F Calculation of  $\bar{E}_\beta$ ,  $\Gamma$  and  $\Delta_i$  for  $^{99m}\text{Tc}$

Paper G Calculation of  $\bar{E}_\beta$ ,  $\Gamma$  and  $\Delta_i$  for  $^{99m}\text{Tc}$

Patent C Title of patent

Patent D Title of patent

Those who want can also list other patent applications/posters/reports/artifacts/... not included in the thesis.

## Patent applications/posters/... not included in the thesis

Patent Application A Title of patent application

Patent Application B Title of patent application

Poster A Title of poster

Poster B Title of poster

Report A Comparing Bose-Einstein statistics  $\Gamma_{HH \rightarrow SS}^{B-E}$  to Maxwell-Boltzmann statistics  $\Gamma_{HH \rightarrow SS}^{M-B}$  in the context of Feebly Interacting Massive particles

Report B Title of report

Artifact B Title of artifact

Artifact C Title of artifact

Dataset A Title of dataset

Part I

Kappa





# 1 Introduction

svensk: Introduktion

Ofta kommer problemet och problemägaren från industrin där man önskar en specifik lösning på ett specifikt problem. Detta är ofta "för smalt" definierat och ger ofta en "för smal" lösning för att resultatet skall vara intressant ur ett mer allmänt ingenjörsperspektiv och med "nya" erfarenheter som resultat. Fundera tillsammans med projektets intressenter (student, problemägare och akademi) hur man skulle kunna använda det aktuella problemet/förslaget för att undersöka någon ingenjöraspekt och vars resultat kan ge ny eller kompletterande erfarenhet till ingenjörssamfundet och vetenskapen.

Slöser man en del eller hela delen av det ursprungliga problemet.

Erfarenheten kommer ur en frågeställning som man i avhandling försöker besvara med tidigare och andras erfarenhet, egna eller modifierade metoder som ger ett resultat vilket kan användas för att diskutera ett svar på undersökningsfrågan.

Detta stycke skall alltså, förutom det ursprungliga "smala" problemet, innehålla vad som skall undersökas för att skapa ny ingenjörserfarenhet och/eller vetenskap.

The first paragraph after a heading is not indented, all of the subsequent paragraphs have their first line indented.

This chapter describes the specific problem that this thesis addresses, the context of the problem, the goals of this thesis, and outlines the structure of the thesis.

Give a general introduction to the area. (Remember to use appropriate references in this and all other sections.)

We use the *biblatex* package to handle our references. We use the command `\parencite` to get a reference in parentheses or square brackets, like this `\parencite{hioannidis_coherent_1991}`, resulting in [1]. It is also possible to include the author as part of the sentence using `\textcite`, when talking about the work of `\textcite{maguire_jr_new_2014}` resulting in Maguire Jr. *et al.* [2]. This also means that you have to change the include files to include *biblatex* and change the way that the `reference.bib` file is included.

Use the *glossaries* package to help yourself and your readers. Add the acronyms and abbreviations to `lib/acronyms.tex`. Some examples are shown below:

In this thesis, we will examine the use of **Local Area Networks (LANs)**. In this thesis, we will assume that **LANs** include **Wireless Local Area Networks (WLANs)**, such as **Wireless Fidelity (Wi-Fi)**.

## 1.1 Background

svensk: Bakgrund

Present the background for the area. Set the context for your research – so that your reader can understand both your research and this thesis. (Give detailed background information in Chapter 2 - together with related work.) Sometimes it is useful to insert a system diagram here so that the reader knows what are the different elements and their relationship to each other. This also introduces the names/terms/... that you are going to use throughout your thesis (be consistent). This figure will also help you later delimit what you are going to do and what others have done or will do.

As one can find in RFC 1235 [1], multicast is useful for xxxx. A number of different **operating systems (OSes)** have been used in this work, such as the following **OSes**: UNIX, Linux, Windows, *etc.* The main focus will be on one **OS**, namely Linux.

## 1.2 Problem

svensk: Problemdefinition eller Frågeställning

Lyft fram det ursprungliga problemet om det finns något och definiera därefter den ingenjörsmässiga erfarenheten eller/och vetenskapen som kan komma ur projektet.

Longer problem statement

If possible, end this section with a question as a problem statement.

### 1.2.1 Original problem and definition

Ursprungligt problem och definition

Clearly state the research questions your thesis addresses.

**RQ 1** research question 1,

**RQ 2** research question 2,

**RQ 3** research question 3, and

**RQ 4** research question 4.

### 1.2.2 Scientific and engineering issues

Vetenskaplig och ingenjörsmässig frågeställning

some text

## 1.3 Purpose

Syfte

Skilj på syfte och mål! Syfte är att förändra något till det bättre. I avhandling finns ofta två aspekter på detta. Dels vill problemägaren (företaget) få sitt problem löst till det bättre men akademien och ingenjörssamfundet vill också få nya erfarenheter och vetenskap. Beskriv ett syfte som tillfredställer båda dessa aspekter.

Det finns även ett syfte till som kan vara värt att beakta och det är att du som student skall ta examen och att du måste bevisa, i ditt avhandling, att du uppfyller examensmålen.

State the purpose of your thesis and the purpose of your research. Describe who benefits and how they benefit if you achieve your goals. Include anticipated ethical, sustainability, social issues, *etc.*, related to your research. (Return to these in your reflections in Section 7.4.)

## 1.4 Goals

Mål

Skilj på syfte och mål. Syftet är att åstadkomma en förändring i något. Målen är vad som konkret skall göras för att om möjligt uppnå den önskade förändringen (syfte).

State the goal/goals of your research.

The goal of this research is XXX. This has been divided into the following three sub-goals:

### 1. Subgoal 1

för att tillfredsställa problemägaren – industrin?

2. Subgoal 2

för att tillfredsställa ingenjörssamfundet och vetenskapen – akademien)

3. Subgoal 3

eventuellt, för att uppfylla kursmålen – du som student

In addition to presenting the goal(s), you might also state what the deliverables and results of the research are.

The goals should relate to the knowledge gaps and research questions that you identified in Section 1.2. If you have written a compilation thesis, couple your description to your included publications.

## 1.5 Research Methodology

### Undersökningsmetod

Här anger du vilken vilken övergripande undersökningsstrategi eller metod du skall använda för att försöka besvara den akademiska frågeställning och samtidigt lösa det e v ursprungliga problemet. Ofta kan man använda ”lösandet av ursprungsproblemet” som en fallstudie kring en akademisk frågeställning. Du undersöker någon intressant fråga i ”skarpt” läge och samlar resultat och erfarenhet ur detta.

Tänk på att företaget ibland måste stå tillbaka i sin önskan och förväntan på projektets resultat till förmån för ny eller kompletterande ingenjörserfarenhet och vetenskap (ditt avhandling). Det är du som student som bestämmer och löser fördelningen mellan dessa två intressen men se till att alla är informerade.

Introduce your choice of methodology/methodologies and method/methods – and the reason why you chose them. Contrast them with and explain why you did not choose other methodologies or methods. (The details of the actual methodology and method you have chosen will be given in Chapter 3. Note that in Chapter 3, the focus could be research strategies, data collection, data analysis, and quality assurance.)

In this section you should present your philosophical assumption(s), research method(s), and research approach(es).

## 1.6 Delimitations

### Avgränsningar

Describe the boundary/limits of your thesis and what you are explicitly not going to do. This will help you bound your efforts – as you have clearly defined what is out of the scope of this thesis. Explain the delimitations. These are all the things that could affect the study if they were examined and included in your thesis.

## 1.7 Thesis contributions

### Avhandlingsbidrag

How does your thesis contribute to addressing the research questions?

If you have done this work with others, clearly state what your own contributions were. If you have written a compilation thesis, give this description for each of your included publications. You might use the taxonomy defined in **Contribution Roles Taxonomy (CRediT)**[10]\*.

## 1.8 Structure of the thesis

### Rapportens disposition

Chapter 2 presents relevant background information about xxx. Chapter 3 presents the methodology and method used to solve the problem.

---

\*See <https://authorservices.wiley.com/author-resources/Journal-Authors/open-access/credit.html>



## 2 Background

### Bakgrund

When you do your literature study, you should have a nearly complete Chapters 1 and 2.

You may also find it convenient to introduce the future work section into your report early – so that you can put things that you think about but decide not to do now into this section.

Note that later you can move things between this future work section and what you have done as you may change your mind about what to do now versus what to put off to future work.

What does a reader (another x student – where x is your study line) need to know to understand your report? What have others already done? (This is the “related work”.) Explain what and how prior work/prior research will be applied on or used in your research (described in this thesis). Explain why and what is not used in your research and give valid reasons for rejecting the work/research.

This chapter provides basic background information about xxx. Additionally, this chapter describes xxx. The chapter also describes related work xxxx.

Vilken viktig litteratur och (forsknings-)artiklar har du studerat inom området (litteraturstudie)?

### 2.1 Major background area 1

#### Viktigt bakgrundsområde 1

There are xxx characteristics that distinguish yyy from other **Information and Communication Technology (ICT)** systems, as shown in Figure 2.1. Table 2.1 summarizes these characteristics.

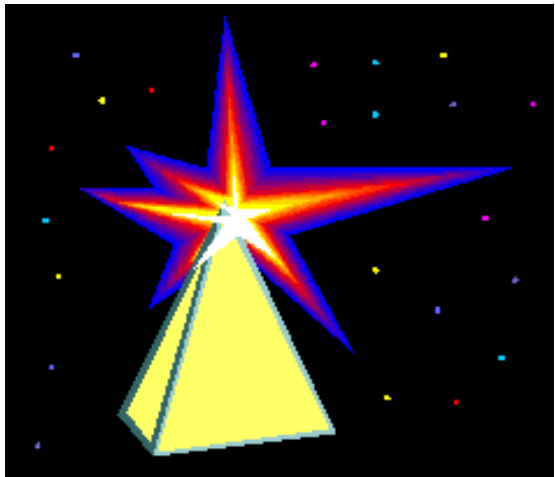


Figure 2.1: Lots of stars (Inspired by Figure x.y on page z of [xxx])

Massor av stjärnor (Inspirerad av figur x.y på sidan z i [xxx])

Table 2.1: xxx characteristics

Characteristics	Description
$\alpha$	$\beta$
1	1 110.1
2	10.1
3	23.113 231

Egenskaper
Beskrivning

2.1.1 Subarea 1.1

Entangled states are an important part of quantum cryptography, but also relevant in other domains. This concept might be relevant for neutrinos, see for example [4].

2.1.2 Subarea 1.1.2

Computational methods are increasingly used as a third method of carrying out scientific investigations. For example, computational experiments were used to find the amount of wear in a polyethylene liner of a hip prosthesis in [2]. ...

2.1.3 Subarea 1.1.2

Using the nearest data center may improve performance, see [11]



### 2.1.4 Link layer Encapsulation

See Figure 2.2 which uses the `bytefield` L<sup>A</sup>T<sub>E</sub>X package.

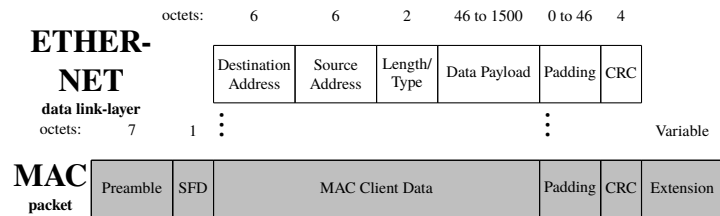


Figure 2.2: Ethernet data link layer protocol encapsulated into a IEEE 802.3 MAC packet

### 2.1.5 IP packet headers

The data link layer will receive a packet from the IP layer. The layout of an IPv4 packet is shown in Figure 2.3. This should be contrasted with the IPv6 header shown in Figure 2.4.

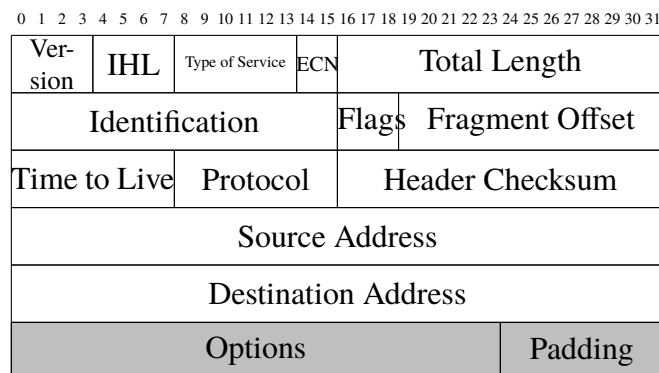


Figure 2.3: IPv4 datagram header. Light grey-colored fields are optional.

### 2.1.6 Test for accessibility of formulas

As can be seen in these equations:  $c = 2 \cdot \pi \cdot r$  or

$$\int_a^b x^2 dx$$

a chemical formula:  $(C_5O_2H_8)_n \dots$

## 2.2 Major background area 2

Viktigt bakgrundsområde 2

...

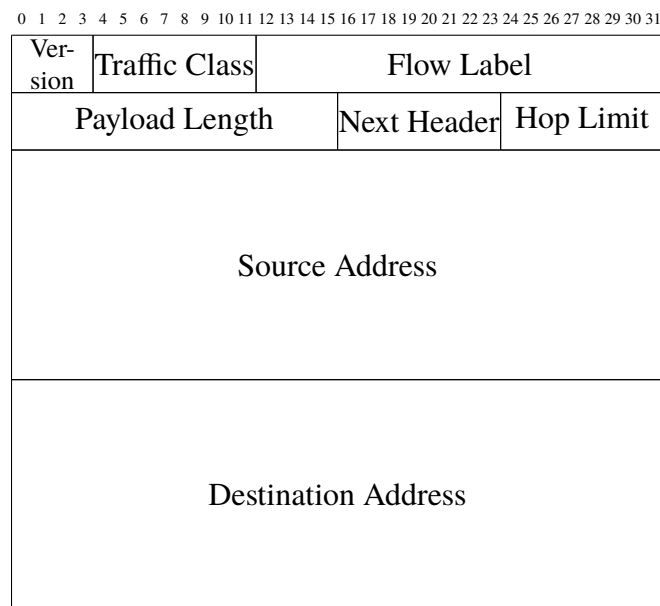


Figure 2.4: IPv6 datagram header

### 2.2.1 WLAN Security

### 2.2.2 Network layer security

...

## 2.3 Related work area

Relaterade arbeten

### 2.3.1 Major related work 1

Relaterade arbeten 1

Carrier clouds have been proposed as a means to reduce the delay between users and the cloud server that provides them with content. However, there is a question of how to find the available resources in such a carrier cloud. One approach has been to disseminate resource information using an extension to OSPF-TE, see Roozbeh, Sefidcon, and Maguire [12].

### 2.3.2 Major related work n

Relaterade arbeten

### 2.3.3 Minor related work 1

Mindre relaterat arbete 1

...

### 2.3.4 Minor related work n

Mindre relaterat arbete n

## 2.4 Summary

Sammanfattning

Det är trevligt om detta kapitel avslutas med en sammanfattning. Till exempel kan du inkludera en tabell som sammanfattar andras idéer och fördelar och nackdelar med varje - så som senare kan du jämföra din lösning till var och en av dessa. Detta kommer också att hjälpa dig att definiera de variabler som du kommer att använda för din utvärdering.

It is nice to have this chapter conclude with a summary. For example, you can include a table that summarizes other people's ideas and benefits and drawbacks with each – so that later you can compare your solution to each of them. This will also help you define the variables that you will use for your evaluation.



### 3 Method or Methods

#### Metod eller Metodval

This chapter is about Engineering-related content, Methodologies and Methods. Use a self-explaining title.

The contents and structure of this chapter will change with your choice of methodology and methods.

Describe the engineering-related contents (preferably with models) and the research methodology and methods that are used in your research.

Give a theoretical description of the scientific or engineering methodology you are going to use and why have you chosen this method. What other methods did you consider and why did you reject them?

In this chapter, you describe what engineering-related and scientific skills you are going to apply, such as modeling, analyzing, developing, and evaluating engineering-related and scientific content. The choice of these methods should be appropriate for the problem. Additionally, you should be conscious of aspects relating to society and ethics (if applicable). The choices should also reflect your goals and what you (or someone else) should be able to do as a result of your solution - which could not be done well before you started.

The purpose of this chapter is to provide an overview of the research method used in this thesis. Section 3.1 describes the research process. Section 3.2 details the research paradigm. Section 3.3 focuses on the data collection techniques used for this research. Section 3.4 describes the experimental design. Section 3.5 explains the techniques used to evaluate the reliability and validity of the data collected. Section 3.6 describes the method used for the data analysis. Finally, Section 3.7 describes the framework selected to evaluate xxx.

Vilka vetenskaplig eller ingenjörsmetodik ska du använda och varför har du valt den här metoden. Vilka andra metoder gjorde du övervägde du och varför du avvisar dem. Vad är dina mål? (Vad ska du kunna göra som ett resultat av din lösning - vilken inte kan göras i god tid innan du började) Vad du ska göra? Hur? Varför? Till exempel, om du har implementerat en artefakt vad gjorde du och varför? Hur kommer du utvärdera den. Syftet med detta kapitel är att ge en översikt över forskningsmetod som används i denna avhandling. Avsnitt 3.1 beskriver forskningsprocessen. Avsnitt 3.2 beskriver forskningsparadigmen detaljerat. Avsnitt 3.3 fokuserar på datainsamlingstekniker som används för denna forskning. Avsnitt 3.4 beskriver experimentell design. Avsnitt 3.5 förklarar de tekniker som används för att utvärdera tillförlitligheten och giltigheten av de insamlade uppgifterna. Avsnitt 3.6 beskriver den metod som används för dataanalysen. Slutligen, Avsnitt 3.7 beskriver ramverket som valts för att utvärdera xxx.

Ofta kan man koppla ett antal följdfrågor till undersökningsfrågan och problemlösningen t ex

- (1) Vilken process skall användas för konstruktion av lösningen och vilken process skall kopplas till denna för att svara på undersökningsfrågan?
- (2) Hur och vilket resultat (storheter) skall presenteras både för att redovisa svar på undersökningsfrågan (resultatkapitlet i denna rapport) och redovisa resultat av problemlösningen (prototypen, ofta dokument som bilagor men vilka dokument och varför?).
- (3) Vilken teori/teknik skall väljas och användas både för undersökningen (taxonomi, matematik, grafer, storheter mm) och problemlösning (UML, UseCases, Java mm) och varför?
- (4) Vad behöver du som student leverera för att uppnå hög kvalitet (minimikrav) eller mycket hög kvalitet på avhandling?
- (5) Frågorna kopplar till de följande underkapitlen.
- (6) Resonemanget bygger på att studenter på hing-programmet ofta skall konstruera något åt problemägaren och att man till detta måste koppla en intressant ingenjörfråga. Det finns hela tiden en dualism mellan dessa aspekter i exjobbet.

### 3.1 Research Process

#### Undersökningsprocess och utvecklingsprocess

Figure 3.1 shows the steps conducted to carry out this research.

Figur 3.1 visar de steg som utförs för att genomföra Beskriv, gärna med ett aktivitetsdiagram (UML?), din undersökningsprocess och utvecklingsprocess. Du måste koppla ihop det akademiska intresset (undersökningsprocess) med ursprungsproblemet (utvecklingsprocess) denna forskning.

Aktivitetsdiagram från t ex UML-standard

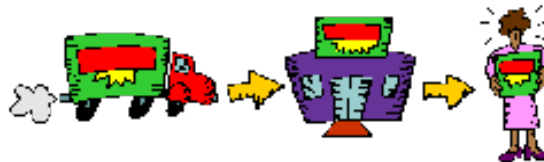


Figure 3.1: Research Process

Example of using customized item labels.

Some steps in the process:

- Step 1** plan experiment,
- Step 2** conduct experiment,
- Step 3** analyze data from the experiment, and
- Step 4** discuss the results of the analysis.

Forskningsprocessen

## 3.2 Research Paradigm

Undersökningsparadigm

Exempelvis

Positivistisk (vad/hur fungerar det?) kvalitativ fallstudie med en deduktivt (förbestämd) vald ansats och ett induktivt (efterhand uppstår dataområden och data) insamlade av data och erfarenheter.

## 3.3 Data Collection

Datainsamling

(Detta bör också visa att du är medveten om de sociala och etiska frågor som kan vara relevanta för dina data insamlingsmetod.)

This should also show that you are aware of the social and ethical concerns that might be relevant to your data collection method.

### 3.3.1 Sampling

Stickprovsundersökning

### 3.3.2 Sample Size

Provstorleken

### 3.3.3 Target Population

Målgruppen

## 3.4 Experimental design and Planned Measurements

Experimentdesign/Mätuppställning

### 3.4.1 Test environment/test bed/model

Describe everything that someone else would need to reproduce your test environment/test bed/model/... .

Testmiljö/testbädd/modell

Beskriv allt att någon annan skulle behöva återskapa din testmiljö / testbädd / modell / ...

### 3.4.2 Hardware/Software to be used

Hårdvara / programvara som ska användas

## 3.5 Assessing reliability and validity of the data collected

Bedömning av validitet och reliabilitet hos använda metoder och insamlade data

### 3.5.1 Validity of method

Giltigheten av metoder

Har dina metoder gett dig de rätta svaren och lösningarna? Var metoderna korrekta?

How will you know if your results are valid?



Remember that validity is about the *accuracy* of a measurement while reliability is about the *consistency* of the measurement values under the same conditions (*i.e.*, repeatability).

### 3.5.2 Reliability of method

Tillförlitlighet av för metoder

Hur bra är dina metoder, finns det bättre metoder? Hur kan du förbättra dem?

How will you know if your results are reliable?

### 3.5.3 Data validity

Giltigheten av uppgifter

Hur vet du om dina resultat är giltiga? Är ditt resultat rättvisande?

### 3.5.4 Reliability of data

Tillförlitlighet av data

Hur vet du om dina resultat är tillförlitliga? Hur bra är dina resultat?

## 3.6 Planned Data Analysis

Metod för analys av data

### 3.6.1 Data Analysis Technique

Dataanalysteknik

### 3.6.2 Software Tools

Mjukvaruverktyg

## 3.7 Evaluation framework

Utvärdering och ramverk

Metod för utvärdering, jämförelse mm. Kopplar till kapitel 5.

### 3.8 System documentation

#### Systemdokumentation

Med vilka dokument och hur skall en konstruerad prototyp dokumenteras? Detta blir ofta bilagor till rapporten och det som problemägaren till det ursprungliga problemet (industrin) ofta vill ha.

Bland dessa bilagor återfinns ofta, och enligt någon angiven standard, kravdokument, arkitekturdokument, designdokument, implementationsdokument, driftsdokument, testprotokoll mm.

If this is going to be a complete document consider putting it in as an appendix, then just put the highlights here.

## 4 What you did

Choose your own chapter title to describe this

[Vad gjorde du? Hur gick det till? – Välj lämplig rubrik (“Genomförande”, “Konstruktion”, ”Utveckling” eller annat)]

What have you done? How did you do it? What design decisions did you make? How did what you did help you to meet your goals?

Vad du har gjort? Hur gjorde du det? Vilka designval gjorde du? Hur kom det du hjälpte dig att uppnå dina mål?

### 4.1 Hardware/Software design .../Model/Simulation model & parameters/...

Hårdvara / Mjukvarudesign ... / modell / Simuleringsmodell och parametrar / ...

Figure 4.1 shows a simple icon for a home page. The time to access this page when served will be quantified in a series of experiments. The configurations that have been tested in the test bed are listed in Table 4.1. In 7.0 % of cases, there was an error indicating xxxxx.

Figur 4.1 visar en enkel ikon för en hemsida. Tiden för att få tillgång till den här sidan när den laddas kommer att kvantifieras i en serie experiment. De konfigurationer som har testats i provbänk listas i tabell 4.1.  
Vad du har gjort? Hur gjorde du det? Vilka designval gjorde du?

Table 4.1 shows an example of how one can automatically resize a table so that it fills the column width.

Testade konfigurationer

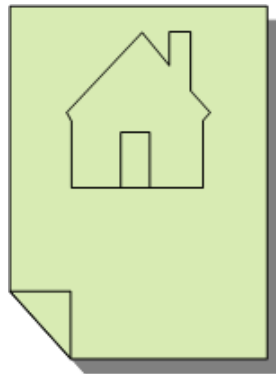


Figure 4.1: Homepage icon

Table 4.1: Configurations tested

Configuration	Description
1	Simple test with one server
2	Simple test with two servers

## 4.2 Implementation .../Modeling/Simulation/...

Implementering ... / modellering / simulering / ...

Two commonly used simulators are:

**Mininet** This simulator uses traffic control ( $tc$ ) to simulate network devices connected by links with specific bandwidth, packet loss rates, qdisc methods, *etc.*

**ns-2 or ns-3 simulator** These simulators are very useful for simulating wireless communication links between moving devices. You can specify the mobility patterns of the nodes.

### 4.2.1 Some examples of coding

This section is simply to show some example of how you can include code in your thesis - this is not a section you would have in your thesis.

Det här avsnittet är helt enkelt för att visa ett exempel på hur du kan inkludera kod i ditt avhandling - det här är inte ett avsnitt du skulle ha i ditt avhandling.

Listing 4.1 shows an example of a simple program written in C code.

Listing 4.1: Hello world in C code

```
int main() {
    printf("hello ,\u world");
    return 0;
}
```

This template uses the package `lstlistings` for many different listings. Alternatively, one could use the `minited` package together with the `listings` environment, see, for example, [Code Highlighting with minted](#) and Listing 4.3.

In contrast, listing 4.2 is an example of code in Python to get a list of all of the programs at KTH. Note that starting on 2025-06-01 the KOPPS API will no longer work.

Note that the change to the iso date format in the line above was done in a group so that afterwards the date style returns to what it was, resulting in June 1, 2025.

Listing 4.2: Using a python program to access the KTH API to get all of the programs at KTH

```
KOPPSbaseUrl = 'https://www.kth.se '

def v1_get_programmes():
    global Verbose_Flag
    #
    # Use the KOPPS API to get the data
    # note that this returns XML
    url = "{0}/api/kopps/v1/programme".format(KOPPSbaseUrl)
    if Verbose_Flag:
        print("url:\u" + url)
    #
    r = requests.get(url)
    if Verbose_Flag:
        print("result\uof\ugetting\uv1\uprogramme:\u{}".format(r.text))
    #
    if r.status_code == requests.codes.ok:
        return r.text          # simply return the XML
    #
    return None
```

In Listing 4.3, we create a `ExcelWriter` function and use it to write a panda dataframe (named `comp`) to the spreadsheet. Finally, `writer.close()` closes the open spreadsheet.

---

**Listing 4.3** Using minted with python code

---

```

1 import pandas as pd
2 def make_spreadsheet_of_differences(pds):
3     global school
4     publishers=set()
5     writer =
6         ↪ pd.ExcelWriter(f'/tmp/{school}_compare_duplicates.xlsx',
7         ↪ engine='xlsxwriter')
8     print("starting")
9     for idx, p in enumerate(pds):
10         p0=list(p)[0]
11         p1=list(p)[1]
12         print(f"\nfor {p0} and {p1}")
13         comp, publisher1,
14         ↪ publisher2=compare_two_records_silent(p0, p1)
15         sheet_name=f'{p0}'.split(':')[1]
16         print(f'Wrote {sheet_name=}')
17         comp.to_excel(writer, sheet_name=sheet_name)
18         publishers.add(publisher1)
19         publishers.add(publisher2)
20
21         # Close the Pandas Excel writer and output the Excel
22         ↪ file.
23     writer.close()
24     print(f"{publishers=}")
25     return publishers

```

---

#### 4.2.2 Some examples of figures in tikz

This section is simply to show some example of how you can draw your own figures for in your thesis - this is not a section you would have in your thesis.

Det här avsnittet är helt enkelt för att visa ett exempel på hur du kan rita dina egna figurer i ditt avhandling – det här är inte ett avsnitt du skulle ha i ditt avhandling.

These figures are just some examples to show that you can draw your own figures for in your thesis. This has two advantages: (i) you do not have to worry about copyrights – as these are your own figures and (ii) the text is now readable and not simply a picture of text – so screen readers can read the figure’s contents to someone who is listening to the contents of your thesis.

#### 4.2.2.1 Azure's Form Recognizer

Figure 4.2 shows the processing of key-value extraction from a PDF document using Azure's Form Recognizer.

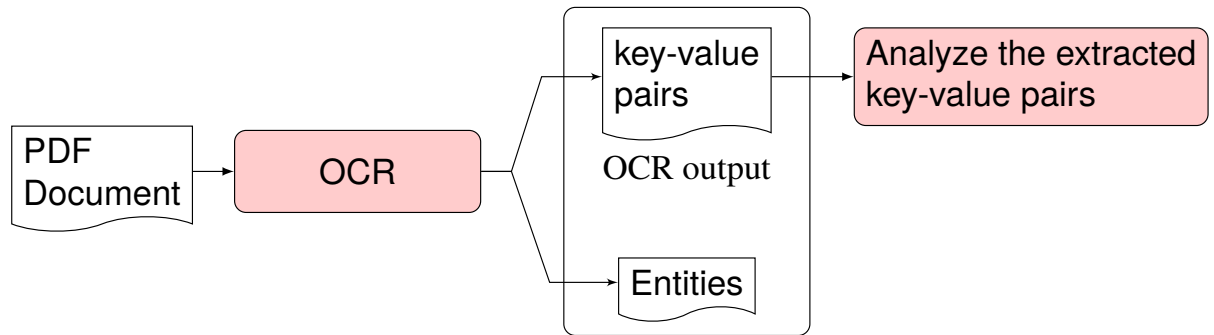


Figure 4.2: The processing of key-value extraction from a PDF document using Azure's Form Recognizer

#### 4.2.2.2 Hyper-V with Containers

Figure 4.3 shows how Hyper-V deals with containers.

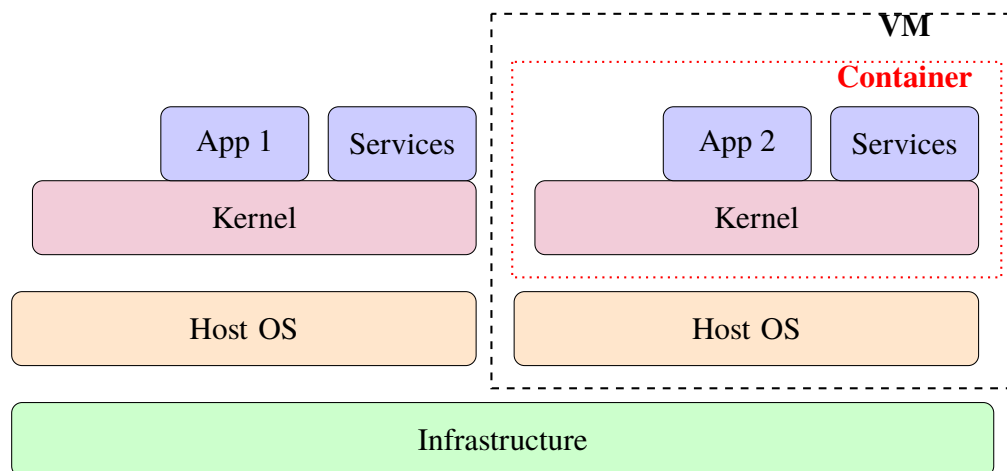


Figure 4.3: Hyper-V with containers

#### 4.2.2.3 VM versus Containers

Figure 4.4 shows a comparison of virtual machines (VMs) versus containers.

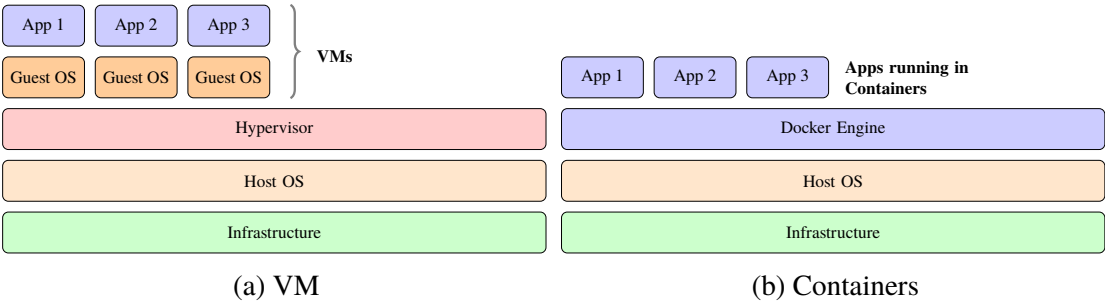


Figure 4.4: Virtual machines (VMs) versus Containers



## 5 Results and Analysis

svensk: Resultat och Analys

Sometimes this is split into two chapters.

Keep in mind: How you are going to evaluate what you have done? What are your metrics?

Analysis of your data and proposed solution.

Does this meet the goals which you had when you started?

In this chapter, we present the results and discuss them.

I detta kapitel presenterar vi resultaten och diskutera dem.

Ibland delas detta upp i två kapitel.

Hur du ska utvärdera vad du har gjort? Vad är din statistik?

Analys av data och föreslagen lösning

Innebär detta att uppfyllelse av de mål som du hade när du började?

### 5.1 Major results

Huvudsakliga resultat

Some statistics of the delay measurements are shown in Table 5.1. The delay has been computed from the time the GET request is received until the response is sent.

Lite statistik av fördröjningsmätningarna visas i Tabell 5.1. Förseningen har beräknats från den tidpunkt då begäran GET tas emot fram till svaret skickas.

Table 5.2 shows the measurement of round-trip times from four hosts to and from a server.

Table 5.1: Delay measurement statistics

Configuration	Average delay (ns)	Median delay (ns)
1	467.35	450.10
2	1 687.5	901.23

Table 5.2: Result for the ping measurements of RTT for 4 hosts

Host	host to server RTT in ms			
	min	avg	max	mdev
h1	5.625	5.625	5.625	0.0
h2	2.909	2.909	1.909	0.0
h3	5.007	5.007	5.007	0.0
h4	2.308	2.308	2.308	0.0

## Fördröj mätstatistik

Konfiguration | Genomsnittlig fördröjning (ns) | Median fördröjning (ns)

Figure 5.1 shows an example of the performance as measured in the experiments.

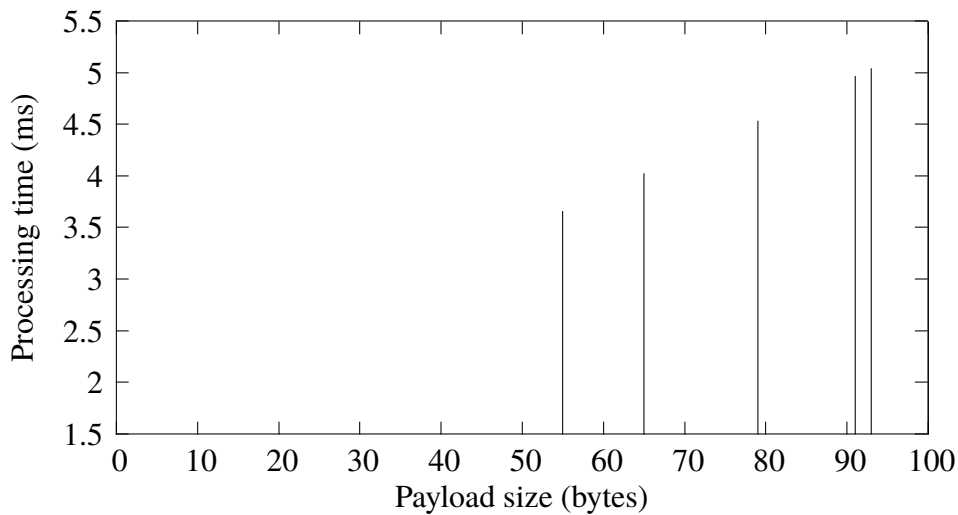


Figure 5.1: Processing time vs. payload length

Given these measurements, we can calculate our processing bit rate as the inverse of the time it takes to process an additional byte divided by 8 bits per byte:

$$\text{bit rate} = \frac{1}{\frac{\text{time}_{\text{byte}}}{8}} = 20.03 \text{ kb/s}$$

Table 5.3 shows another table in which some values have been set in bold (using \B) to emphasize them. Note how the S formatting has been modified so that it considers the weight of the characters and this is able to decimal align even these hold-faced numbers with the numbers in the column above them.

Table 5.3: Median values of sandwich attributes

Attribute	sites	
	A	B
price (in SEK)	36.5	71.3
protean (g)	97.2	100.0
salt (mg)	9.7	9.3
<b>Average customer rating in %</b>	<b>82.2</b>	<b>89.9</b>

Figure 5.2 shows a stacked bar chart using pgfplots. It illustrates how easy it is to take a set of data and make a stacked bar plot. One of the features is the shifted values – this is very useful when the bar itself is too small to put the value into.

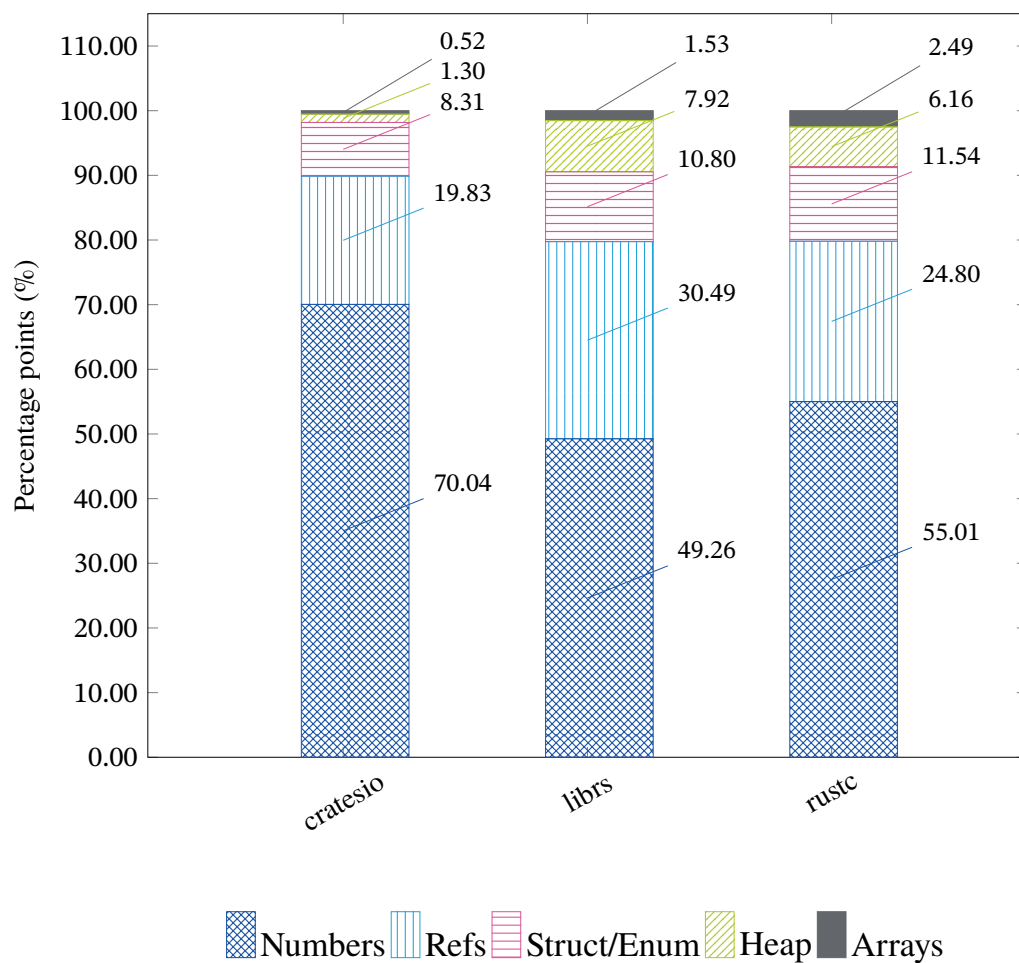


Figure 5.2: Rust types distribution for the compiler, crates.io, and lib.rs. (percentage) - appears here with the permission of the author - see the thesis at <https://urn.kb.se/resolve?urn=urn%3Anbn%3Ase%3Akt%3Adiva-332124>

## 5.2 Reliability Analysis

Analys av tillförlitlighet  
Tillförlitlighet i metod och data

## 5.3 Validity Analysis

Analys av validitet  
Validitet i metod och data

## 6 Discussion

Diskussion  
Förbättringsförslag?

This can be a separate chapter or a section in the previous chapter.



## 7 Conclusions and Future work

Slutsats och framtida arbete

Add text to introduce the subsections of this chapter.

### 7.1 Conclusions

Slutsatser

Describe the conclusions (reflect on the whole introduction given in Chapter 1).

Discuss the positive effects and the drawbacks.

Describe the evaluation of the results of your research.

Did you meet your goals?

What insights have you gained?

What suggestions can you give to others working in this area?

If you had it to do again, what would you have done differently?

Uppfyllde du dina mål?

Vilka insikter har du fått?

Vilka förslag kan du ge till andra som arbetar inom detta område? Om du skulle göra detta igen, vad skulle du ha gjort annorlunda?

### 7.2 Limitations

Begränsande faktorer

Vad gjorde du som begränsade dina ansträngningar? Vilka är begränsningarna i dina resultat?

What did you find that limited your efforts? What are the limitations of your results?

### 7.3 Future work

Vad du har kvar ogjort?  
Vad är nästa självklara saker som ska göras?  
Vad tips kan du ge till nästa person som kommer att följa upp på ditt arbete?

Describe valid future work that you or someone else could or should do.  
Consider: What you have left undone? What are the next obvious things to be done? What hints can you give to the next person who is going to follow up on your work?

Due to the breadth of the problem, only some of the initial goals have been met. In these sections, we will focus on some of the remaining issues that should be addressed in future work. ...

#### 7.3.1 What has been left undone?

The prototype does not address the third requirement, *i.e.*, a yearly unavailability of less than 3 minutes; this remains an open problem. ...

##### 7.3.1.1 Cost analysis

###### Example of a missing component

The current prototype works, but the performance from a cost perspective makes this an impractical solution. Future work must reduce the cost of this solution; to do so, a cost analysis needs to first be done. ...

##### 7.3.1.2 Security

###### Example of a missing component

A future research effort is needed to address the security holes that results from using a self-signed certificate. Page filling text mass. Page filling text mass. ...

#### 7.3.2 Next obvious things to be done

In particular, the author of this thesis wishes to point out xxxxxx remains as a problem to be solved. Solving this problem is the next thing that should be done. ...

### 7.4 Reflections

#### Reflektioner



Vilka är de relevanta ekonomiska, sociala, miljömässiga och etiska aspekter av ditt arbete?

What are the relevant economic, social, environmental, and ethical aspects of your work?

One of the most important results is the reduction in the amount of energy required to process each packet, while at the same time reducing the time required to process each packet.

The thesis contributes to the **United Nations (UN) Sustainable Development Goals (SDGs)** numbers 1 and 9 by xxxx.

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In the references, let Zotero or other tool fill this in for you. I suggest an extended version of the IEEE style, to include URLs, DOIs, ISBNs, *etc.*, to make it easier for your reader to find them. This will make life easier for your opponent, grading committee, and readers.

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# A Supporting materials

Here is a place to add supporting material that can help others build upon your work. You can include files as attachments to the PDF file or indirectly via URLs. Alternatively, consider adding supporting material uploaded as separate files in DiVA.

## A.1 Directly: Attach files to the PDF file

The BibTeX references used in this thesis are attached. 

Here we have used `\attachfile` and attached the file. There is also a mechanism for **embedding** files into PDF, but I do not use it or describe it further here – for reasons of (i) simplicity, (ii) `\attachfile` supports any type of file, (iii) the attached files are visible as annotations on the page where they are included, and (iv) potential compatibility with PDF/A-3.

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An argument for including supporting material in the PDF file is that it will be available to anyone who has a copy of the PDF file. As a result, they do not have to look elsewhere for this material. This comes at the cost of a larger PDF file. However, the attached files are encoded into a compressed stream within the PDF file; thus, reducing the number of additional bytes. For example, the references.bib file that was used in this example is 18 093 B in size but only occupies 7 087 B in the PDF file.

Note that the figures are for an earlier version of the `references.bib` file; hence, the size does not match that stated in the above paragraph.

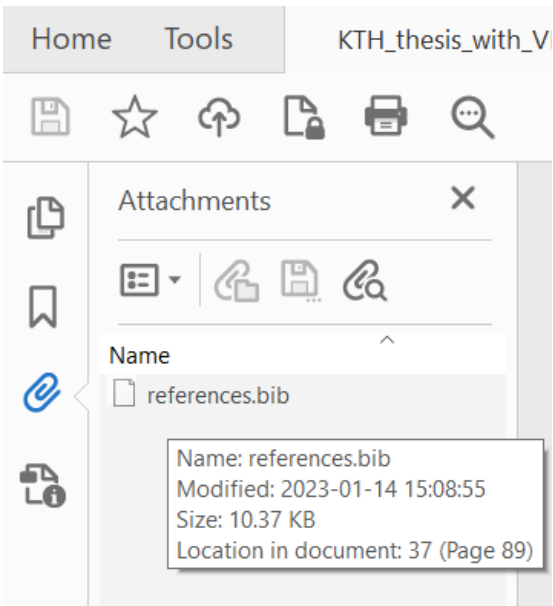


Figure A.1: Adobe Acrobat Reader using the paperclip icon for the attached references.bib file

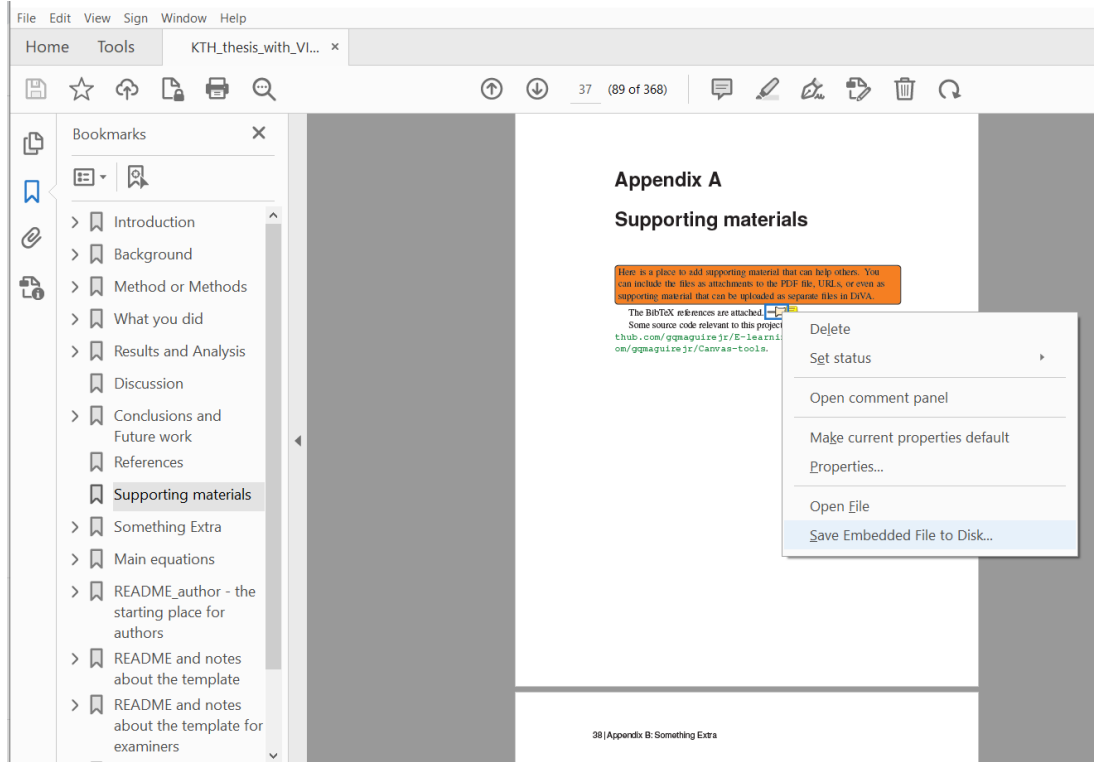


Figure A.2: Adobe Acrobat Reader after right-clicking on the push-pin icon for the attached references.bib file



## A.2 Indirectly: Using a URL

Some source code relevant to this thesis can be found at <https://github.com/gqmaguirejr/E-learning> and <https://github.com/gqmaguirejr/Canvas-tools>.

If you used a research data repository, you should include a URL to your data (at some point in the thesis or, at worst, in an appendix such as this). Some potential data repositories are: Svensk nationell datatjänst ([SND](#)) and [Researchdata.se](#); Sveriges dataportal ([DIGG](#)); [Zenodo](#) and [EU Open Research Repository](#); and [Figshare](#).

## A.3 Uploading supporting materials into DiVA

DiVA is limited to  $\approx 1$  GB for each supporting file. If you have very large amounts of supporting material, you will probably want to use one of the data repositories. For additional help with this, contact KTH Library via [researchdata@kth.se](mailto:researchdata@kth.se).

As of Spring 2024, there are plans to migrate this supporting data from DiVA to a research data repository.



## B Something Extra

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### B.1 Just for testing KTH colors

**You have selected to optimize for print output**

- Primary color

- kth-blue 
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- Secondary colors

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- kth-lightred80 
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- kth-coolgray 
- kth-coolgray80 

black 



## Part II

### Included publications



J. Ioannidis and G. Maguire, “Coherent File Distribution Protocol”, *Internet Request for Comments*, vol. RFC 1235 (Experimental), Jun. 1991, ISSN: 2070-1721. doi: 10.17487/RFC1235. [Online]. Available: <http://www.rfc-editor.org/rfc/rfc1235.txt>

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Network Working Group  
Request for Comments: 1235

J. Ioannidis  
G. Maguire, Jr.  
Columbia University  
Department of Computer Science  
June 1991

## The Coherent File Distribution Protocol

### Status of this Memo

This memo describes the Coherent File Distribution Protocol (CFDP). This is an Experimental Protocol for the Internet community. Discussion and suggestions for improvement are requested. Please refer to the current edition of the "IAB Official Protocol Standards" for the standardization state and status of this protocol. Distribution of this memo is unlimited.

### Introduction

The Coherent File Distribution Protocol (CFDP) has been designed to speed up one-to-many file transfer operations that exhibit traffic coherence on media with broadcast capability. Examples of such coherent file transfers are identical diskless workstations booting simultaneously, software upgrades being distributed to more than one machines at a site, a certain "object" (bitmap, graph, plain text, etc.) that is being discussed in a real-time electronic conference or class being sent to all participants, and so on.

In all these cases, we have a limited number of servers, usually only one, and  $\langle n \rangle$  clients (where  $\langle n \rangle$  can be large) that are being sent the same file. If these files are sent via multiple one-to-one transfers, the load on both the server and the network is greatly increased, as the same data are sent  $\langle n \rangle$  times.

We propose a file distribution protocol that takes advantage of the broadcast nature of the communications medium (e.g., fiber, ethernet, packet radio) to drastically reduce the time needed for file transfer and the impact on the file server and the network. While this protocol was developed to allow the simultaneous booting of diskless workstations over our experimental packet-radio network, it can be used in any situation where coherent transfers take place.

CFDP was originally designed as a back-end protocol; a front-end interface (to convert file names and requests for them to file handles) is still needed, but a number of existing protocols can be adapted to use with CFDP. Two such reference applications have been developed; one is for diskless booting of workstations, a simplified

BOOTP [3] daemon (which we call sbootpd) and a simple, TFTP-like front end (which we call vtftp). In addition, our CFDP server has been extended to provide this front-end interface. We do not consider this front-end part of the CFDP protocol, however, we present it in this document to provide a complete example.

The two clients and the CFDP server are available as reference implementations for anonymous ftp from the site CS.COLUMBIA.EDU (128.59.16.20) in directory pub/cfdp/. Also, a companion document ("BOOTP extensions to support CFDP") lists the "vendor extensions" for BOOTP (a-la RFC-1084 [4]) that apply here.

## Overview

CFDP is implemented as a protocol on top of UDP [5], but it can be implemented on top of any protocol that supports broadcast datagrams. Moreover, when IP multicast [6] implementations become more widespread, it would make more sense to use a multicast address to distribute CFDP packets, in order to reduce the overhead of non-participating machines.

A CFDP client that wants to receive a file first contacts a server to acquire a "ticket" for the file in question. This server could be a suitably modified BOOTP server, the equivalent of the tftpd daemon, etc. The server responds with a 32-bit ticket that will be used in the actual file transfers, the block size sent with each packet (which we shall call "BLKSZ" from now on), and the size (in bytes) of the file being transferred ("FILSZ"). BLKSZ should be a power of two. A good value for BLKSZ is 512. This way the total packet size (IPheader+UDPheader+CFDPheader+data=20+8+12+512=552), is kept well under the magic number 576, the minimum MTU for IP networks [7]. Note that this choice of BLKSZ supports transfers of files that are up to 32 Mbytes in size. At this point, the client should allocate enough buffer space (in memory, or on disk) so that received packets can be placed directly where they belong, in a way similar to the NetBLT protocol [8].

It is assumed that the CFDP server will also be informed about the ticket so that it can respond to requests. This can be done, for example, by having the CFDP server and the ticket server keep the table of ticket-to-filename mappings in shared memory, or having the CFDP server listening on a socket for this information. To reduce overhead, it is recommended that the CFDP server be the same process as the front-end (ticket) server.

After the client has received the ticket for the file, it starts listening for (broadcast) packets with the same ticket, that may exist due to an in-progress transfer of the same file. If it cannot

Gerald Q. Maguire Jr., Marilyn E. Noz, Henrik Olivecrona, Michael P. Zeleznik, and Lars Weidenhielm, "A New Automated Way to Measure Polyethylene Wear in THA Using a High Resolution CT Scanner: Method and Analysis", *The Scientific World Journal*, vol. 2014, pp. 1–9, 2014, ISSN: 2356-6140, 1537-744X. DOI: [10.1155/2014/528407](https://doi.org/10.1155/2014/528407). [Online]. Available: <http://www.hindawi.com/journals/tswj/2014/528407/>

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## Research Article

# A New Automated Way to Measure Polyethylene Wear in THA Using a High Resolution CT Scanner: Method and Analysis

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As the most advantageous total hip arthroplasty (THA) operation is the first, timely replacement of only the liner is socially and economically important because the utilization of THA is increasing as younger and more active patients are receiving implants and they are living longer. Automatic algorithms were developed to infer liner wear by estimating the separation between the acetabular cup and femoral component head given a computed tomography (CT) volume. Two series of CT volumes of a hip phantom were acquired with the femoral component head placed at 14 different positions relative to the acetabular cup. The mean and standard deviation (SD) of the diameter of the acetabular cup and femoral component head, in addition to the range of error in the expected wear values and the repeatability of all the measurements, were calculated. The algorithms resulted in a mean ( $\pm$ SD) for the diameter of the acetabular cup of 54.21 ( $\pm$ 0.011) mm and for the femoral component head of 22.09 ( $\pm$ 0.02) mm. The wear error was  $\pm$ 0.1 mm and the repeatability was 0.077 mm. This approach is applicable clinically as it utilizes readily available computed tomography imaging systems and requires only five minutes of human interaction.

## 1. Introduction

Total hip arthroplasty (THA) devices are being utilized for longer periods of time as younger and more active patients receive them [1]. Although there are a variety of common reasons for long-term failure [2, 3], this study concerns only wear [4]. *In vivo* wear rates of several different acetabular cups, with and without polyethylene liners, have been reported [5–13] with the most recent liner wear rates ranging from 0.037 mm/year to 0.005 mm/year and total wear at revision being about 1.0 to 3.5 mm. Higher precision and accuracy of wear assessment methods would shorten the time for clinical studies of new implants and enable detection of clinically significant wear [14].

Previously our group showed that CT volumes can be used to evaluate acetabular cup position and migration in hip

phantoms and patients [15, 16] and to determine 3D migration of the femoral component head into the acetabular cup at 1 mm, later reduced to 0.51 mm [17]. However, this required considerable user interaction time as about 200 landmarks (points) had to be placed on the 3D surfaces of the femoral component head and acetabular cup.

Here the interaction time to choose landmarks is reduced by limiting the number of landmarks to a total of seven (requiring only five minutes on average per CT volume) and the skill level of the operator was reduced. Surfaces were automatically extracted based on these landmarks plus a threshold for the electron density of the prosthetic material; the center and diameter of the prosthetic components viewed as (parts of) spheres were automatically determined, and from these centers, the distance between the acetabular cup and femoral



Alireza Farshin, Amir Roozbeh, Gerald Q. Maguire, and Dejan Kostić, “Make the Most out of Last Level Cache in Intel Processors”, in *Proceedings of the Fourteenth EuroSys Conference 2019 CD-ROM on ZZZ - EuroSys '19*, Dresden, Germany: ACM Press, 2019, pp. 1–17, ISBN: 978-1-4503-6281-8. DOI: [10.1145/3302424.3303977](https://doi.org/10.1145/3302424.3303977). [Online]. Available: <http://dl.acm.org/citation.cfm?doid=3302424.3303977>

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## Research Article

# Do Small-Mass Neutrinos Participate in Gauge Transformations?

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Neutrino oscillation experiments presently suggest that neutrinos have a small but finite mass. If neutrinos have mass, there should be a Lorentz frame in which they can be brought to rest. This paper discusses how Wigner's little groups can be used to distinguish between massive and massless particles. We derive a representation of the  $SL(2, c)$  group which separates out the two sets of spinors: one set is gauge dependent and the other set is gauge invariant and represents polarized neutrinos. We show that a similar calculation can be done for the Dirac equation. In the large-momentum/zero-mass limit, the Dirac spinors can be separated into large and small components. The large components are gauge invariant, while the small components are not. These small components represent spin-1/2 non-zero-mass particles. If we renormalize the large components, these gauge invariant spinors represent the polarization of neutrinos. Massive neutrinos cannot be invariant under gauge transformations.

## 1. Introduction

Whether or not neutrinos have mass and the consequences of this relative to the Standard Model and lepton number are the subject of much theoretical speculation [1, 2], as well as cosmological [3–5], nuclear reactor [6, 7], and high energy experimentation [8–11]. Neutrinos are fast becoming an important component of the search for dark matter and dark radiation [12, 13]. Their importance within the Standard Model is reflected in the fact that they are the only particles which seem to exist with only one direction of chirality; that is, only left-handed neutrinos have been confirmed to exist thus far. It was speculated some time ago that neutrinos in constant electric and magnetic fields would acquire a small mass and that right-handed neutrinos would be trapped within the interaction field [14]. Additionally there are several physical problems which right-handed neutrinos might help solve [15–17]. Solving generalized electroweak models using left- and right-handed neutrinos has also been discussed [18]. Today right-handed neutrinos which do not participate in

weak interactions are called “sterile” neutrinos [19]. A comprehension discussion of the place of neutrinos in the present scheme of particle physics has been given by Drewes [12].

In this paper, we use representations of the Lorentz group to understand the physical implications of neutrinos having mass. In Section 2, two-by-two representations of the Lorentz group are presented. In Section 3, the internal symmetries of massive and massless particles are derived. A representation of the  $SL(2, c)$  group, which separates out the two sets of spinors contained therein, is presented in Section 4. One set of spinors is gauge dependent and represents massive particles. The other is gauge invariant and represents polarized neutrinos. In Section 5, we show how, in the large-momentum/zero-mass limit, the Dirac spinors can be separated into two components, one of which can represent a spin-1/2 non-zero-mass particle. The question of gauge invariance is then discussed. In Section 6, we discuss the zero-mass limit and gauge invariance in the Lorentz transformation framework. Some concluding remarks are made in Section 7.

## 2. Representations of the Lorentz Group

The Lorentz group starts with a group of four-by-four matrices performing Lorentz transformations on the four-dimensional Minkowski space of  $(t, z, x, y)$  which leaves the quantity  $(t^2 - z^2 - x^2 - y^2)$  invariant. Since there are three generators of rotations and three boost generators, the Lorentz group is a six-parameter group.

Einstein observed that the Lorentz group is also applicable to the four-dimensional energy and momentum space of  $(E, p_z, p_x, p_y)$ . He derived the Lorentz-covariant energy-momentum relation commonly known as  $E = mc^2$ . As this transformation leaves  $(E^2 - p_z^2 - p_x^2 - p_y^2)$  invariant, the particle mass is a Lorentz invariant quantity.

In his 1939 paper [20], Wigner studied the symmetry properties of free particles by using operators which commute with the specified four-momentum of the particle. His “little groups” were defined to be those transformations that do not change this four-momentum. For massive particles, the little group is isomorphic to  $O(3)$ ; indeed the  $O(3)$ -like little group’s kinematics is well understood. Massless particles are isomorphic to the Euclidean group commonly known as  $E(2)$ . Wigner noted that the  $E(2)$ -like subgroup of  $SL(2, c)$  is isomorphic to the Lorentz group of transformations [21], but the kinematics of this group is not as well established as that of the  $O(3)$ -like little group as there is no Lorentz frame in which a massless particle is at rest.

It is possible to construct the Lie algebra of the Lorentz group from the three Pauli spin matrices [22–25] as

$$\begin{aligned} J_i &= \frac{1}{2}\sigma_i, \\ K_i &= \frac{i}{2}\sigma_i. \end{aligned} \quad (1)$$

These two-by-two matrices satisfy the following set of commutation relations:

$$\begin{aligned} [J_i, J_j] &= i\epsilon_{ijk}J_k, \\ [J_i, K_j] &= i\epsilon_{ijk}K_k, \\ [K_i, K_j] &= -i\epsilon_{ijk}J_k, \end{aligned} \quad (2)$$

where the generators  $J_i$  represent rotations and the generators  $K_i$  represent boosts. There are six generators of the Lorentz group which satisfy the three sets of commutation relations given in (2). The Lie algebra of the Lorentz group consists of these sets of commutation relations.

These commutation relations are invariant under Hermitian conjugation; however, while the rotation generators are Hermitian, the boost generators are anti-Hermitian:

$$\begin{aligned} J_i^\dagger &= J_i, \\ \text{while } K_i^\dagger &= -K_i. \end{aligned} \quad (3)$$

Thus, it is possible to construct two representations of the Lorentz group, one with  $K_i$  and the other with  $-K_i$ . For this purpose, we will use the notation [24, 26, 27]

$$\dot{K}_i = -K_i. \quad (4)$$

To demonstrate that this set of generators do perform Lorentz transformations, let us consider a point  $X$  in four-dimensional space such as the Minkowskian four-vector  $(t, z, x, y)$ . A Hermitian matrix of the form

$$X = \begin{pmatrix} t+z & x-iy \\ x+iy & t-z \end{pmatrix}, \quad (5)$$

with determinant

$$t^2 - z^2 - x^2 - y^2, \quad (6)$$

can be written where all the components of  $X$  are real. Indeed, every Hermitian matrix can be written this way with real components. Consider next a matrix of the form

$$G = \begin{pmatrix} \alpha & \beta \\ \gamma & \delta \end{pmatrix}, \quad (7)$$

with four complex matrix elements, thus eight real parameters, and require that the determinant be equal to one. If

$$G^\dagger = \begin{pmatrix} \alpha^* & \gamma^* \\ \beta^* & \delta^* \end{pmatrix} \quad (8)$$

is the Hermitian conjugate of  $G$ , then

$$X' = GXG^\dagger \quad (9)$$

defines a linear transformation with real coefficients such that the determinant of  $X'$  is equal to the determinant of  $X$ . This constitutes a real Lorentz transformation. The transformation of (9) can be explicitly written as

$$\begin{aligned} &\begin{pmatrix} t' + z' & x' - iy' \\ x' + iy' & t' - z' \end{pmatrix} \\ &= \begin{pmatrix} \alpha & \beta \\ \gamma & \delta \end{pmatrix} \begin{pmatrix} t+z & x-iy \\ x+iy & t-z \end{pmatrix} \begin{pmatrix} \alpha^* & \gamma^* \\ \beta^* & \delta^* \end{pmatrix}. \end{aligned} \quad (10)$$

It is important to note that the transformation of (9) is not a similarity transformation. In the  $SL(2, c)$  regime, not all the matrices are Hermitian [25]. Moreover, since the determinants of  $G$  and  $G^\dagger$  are one, the determinant of  $GG^\dagger$  is also one. As

$$\text{Tr}(GG^\dagger) = (\alpha\alpha^* + \beta\beta^* + \gamma\gamma^* + \delta\delta^*) \geq 1, \quad (11)$$

(9) is a proper Lorentz transformation [25, 28, 29].

Since the determinant of  $G$  is fixed and is equal to one, there are six independent parameters. This six-parameter group is commonly called  $SL(2, c)$ . As the Lorentz group has six generators, this two-by-two matrix can serve as a representation of the Lorentz group.

Likewise, the two-by-two matrix for the four-momentum of the particle takes the form

$$P = \begin{pmatrix} p_0 + p_z & p_x - ip_y \\ p_x + ip_y & p_0 - p_z \end{pmatrix} \quad (12)$$

Giacomo Verardo, Magnus Boman, Samuel Bruchfeld, Marco Chiesa, Sabine Koch, Gerald Q. Maguire Jr., and Dejan Kostic, *FMM-Head: Enhancing autoencoder-based ECG anomaly detection with prior knowledge*, 2023. arXiv: 2310 . 05848 [cs.LG]. [Online]. Available: <https://arxiv.org/abs/2310.05848>

This paper is unpublished but appears as an arXiv preprint.



# FMM-HEAD: ENHANCING AUTOENCODER-BASED ECG ANOMALY DETECTION WITH PRIOR KNOWLEDGE

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## ABSTRACT

Detecting anomalies in electrocardiogram data is crucial to identifying deviations from normal heartbeat patterns and providing timely intervention to at-risk patients. Various AutoEncoder models (AE) have been proposed to tackle the anomaly detection task with machine learning (ML). However, these models do not consider the specific patterns of ECG leads and are unexplainable black boxes. In contrast, we replace the decoding part of the AE with a reconstruction head (namely, FMM-Head) based on prior knowledge of the ECG shape. Our model consistently achieves higher anomaly detection capabilities than state-of-the-art models, up to 0.31 increase in area under the ROC curve (AUROC), with as little as half the original model size and explainable extracted features. The processing time of our model is four orders of magnitude lower than solving an optimization problem to obtain the same parameters, thus making it suitable for real-time ECG parameters extraction and anomaly detection.

## 1 INTRODUCTION

Cardiovascular conditions are the main causes of death worldwide (Kaplan Berkaya et al., 2018). Tools such as electrocardiogram (ECG) measurements are utilized to monitor and identify these conditions. An ECG records the heart activity by detecting electrical signals. Electrodes positioned on different parts of the body measure the signal propagation through different planes (*i.e.*, *leads*), thus allowing the analysis of multiple heart sections. Collecting ECG data is standard procedure for both hospitalized patients and outpatients since it allows detection of various cardiovascular conditions, such as myocardial infarction and arrhythmia. In recent years, the amount of available ECG data has increased considerably due to the availability of new data sources. Given the vast amount of available data, (*deep learning* (DL)) has been extensively employed to tackle multiple ECG-related tasks. In this paper, we propose to include ECG prior knowledge in neural networks to increase the detection of anomalies in ECG data and, at the same time, enhance explainability.

Three types of sources are driving the rapid increase in ECG data that needs to be processed. The first of these is smartwatches, such as Apple watches (Apple Inc., 2018) and Fitbit (Google, 2013) while wearable smart textiles (Nigusse et al., 2021) provide continuous and long-term ECG recording. The increasing adoption of smart, low-powered, ECG-capable devices produces a huge quantity of data, but moves the bottleneck from *monitoring* to **processing** the collected data. A second data source is the large shared databases of ECG signals. Institutions and governmental bodies are establishing digital spaces for health data to provide citizens access to their health records as well as supplying de-identified health data to companies for secondary use. Given access to these new data resources, it is expected that both foundational and clinical research will improve care processes by increasing precision in both measurement and downstream mapping onto patients. Thirdly, continuous ambulatory monitoring of high-risk patients produces a huge quantity of data,

whose analysis can be difficult since it requires expert knowledge of cardiac conditions and their related effect on ECG measurements (Sampson, 2018a;b).

Anomaly detection through deep learning and (ML) models is a promising technique to improve care by spotting health records that deviate from the patterns of normal data *without* any knowledge of what the underlying conditions might be<sup>1</sup>. AutoEncoders (AEs) are a family of ML models that are trained to be able to reconstruct the original input signal. AEs are trained only on data which show no anomaly, so that during the testing and inference phases an anomaly alert will be raised if the input sample does not belong to the normal class. Since loss functions in AEs depend on the difference between the original and reconstructed data, one could infer the presence of an anomaly by looking at the reconstruction error (Hinton & Salakhutdinov, 2006). Specifically, an anomaly can be detected when the reconstruction loss is considerably higher than in the normal case. Multiple rule-based ECG anomaly detection methods have been proposed (Bortolan et al., 2021). Unlike ML models, these techniques rely on extracting well-known parameters that are indicators for specific heart conditions. However, these methods lack generalization capabilities since they rely on strong *a priori* knowledge of what these parameters are; therefore, these assumptions hinder their usability for anomaly detection of *unknown diseases*, i.e., there is no *a priori* knowledge of them.

Although the most prominent strength of AEs is the lack of assumptions regarding the classes and shapes of different inputs, the inclusion of *a priori* information about the structure of input data may be beneficial for the learning procedure. While ECG signals demonstrate different patterns depending on the underlying heart condition, their shape is composed of five waves (shown in Figure 1a), which correspond to different instants of the heart’s electrical signal, as measured via the electrodes. For different heart conditions, the shape of these waves change, but the number of waves and their general structure are steady. This *weak a priori* knowledge is valid for almost all ECG classes, but this knowledge is currently not exploited by state-of-the-art anomaly detectors.

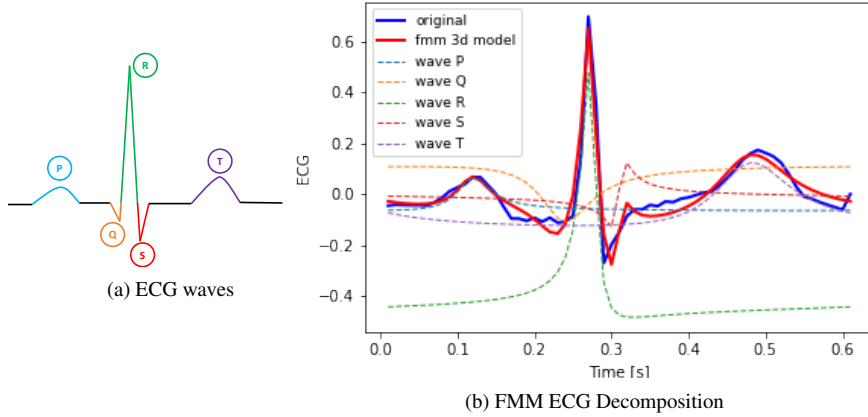


Figure 1: (a) shows the ECG shape, while (b) shows the FMM decomposition of an ECG wave

Recently, Rueda et al. (2019) proposed *Frequency Modulated Möbius (FMM)* waves to provide explainable parameters for ECG data (Rueda et al., 2022). They proposed an optimization algorithm to iteratively compute the amplitude, position, direction, and frequency parameters for the five waves composing the ECG signal through a cycle of polarization and depolarization. However, this optimization takes tens of seconds to be solved for a single heartbeat, thus making it unsuitable for real-time monitoring of critical patients and processing of voluminous quantities of ECG data. Yang et al. (2022) have shown that a neural network (NN) can be used to approximate the FMM coefficients and correctly classify heartbeats, but did not apply it for anomaly detection.

Our contributions are threefold. Firstly, we develop FMM-Head, a first approach for incorporating *weak a priori* knowledge of the ECG leads’ structure into an AE model. In particular, FMM-Head

<sup>1</sup>In contrast, ML *classification* requires labeled data from different health conditions (i.e., classes) that are used to train the model.



Jonathan Yen, Gerald Q. Maguire Jr., Chit Wei Saw, and Xu Yihong, “Authenticatable graphical bar codes”, 7107453B2, Granted US 7107453 B2 (2006-09-12), EP 1340188-B1 (2007-03-07); JP 4495908-B2 (2010-07-07), Dec. 2000. [Online]. Available: <https://patentimages.storage.googleapis.com/cc/f0/90/578b04737a117e/US7107453.pdf>

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Patent A





US007107453B2

(12) **United States Patent**  
**Yen et al.**

(10) **Patent No.:** **US 7,107,453 B2**  
(45) **Date of Patent:** **Sep. 12, 2006**

(54) **AUTHENTICATABLE GRAPHICAL BAR CODES**

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(SE); **Chit Wei Saw**, Cupertino, CA  
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(US)

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(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 1016 days.

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(65) **Prior Publication Data**

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(51) **Int. Cl.**

<b>H04L 9/00</b>	(2006.01)
<b>G09C 3/00</b>	(2006.01)
<b>G09C 5/00</b>	(2006.01)
<b>G06K 9/18</b>	(2006.01)
<b>G06K 9/72</b>	(2006.01)
<b>G06K 9/36</b>	(2006.01)

*Primary Examiner*—Emmanuel L. Moise  
*Assistant Examiner*—Nadia Khoshnoodi

(52) **U.S. Cl.** ..... **713/180**; 380/54; 382/183;  
382/234

(58) **Field of Classification Search** ..... 380/239,  
380/51, 54; 713/180–181; 382/183, 234;  
283/17, 73; 359/2, 893

See application file for complete search history.

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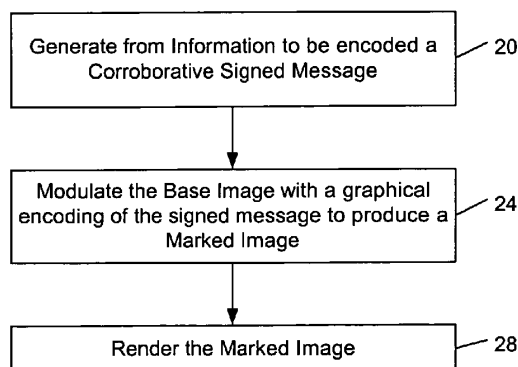
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(57) **ABSTRACT**

Systems and methods for generating and decoding authenticatable graphical bar codes are described. In one aspect, a corroborative signed message is generated from information to be encoded, and a base image is modulated with a graphical encoding of the signed message to produce a marked image. In another aspect, a signed message is extracted from a marked image based upon a comparison of the marked image and a base image. The extracted signed message is decoded to produce a decoded message. Information encoded in the marked image is extracted from the decoded message and authenticated.

**26 Claims, 6 Drawing Sheets**



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Patent B





US012111768B2

(12) **United States Patent**  
**Roozbeh et al.**

(10) **Patent No.:** **US 12,111,768 B2**  
(45) **Date of Patent:** **Oct. 8, 2024**

(54) **METHODS AND DEVICES FOR CONTROLLING MEMORY HANDLING**

(71) Applicant: **Telefonaktiebolaget LM Ericsson (publ)**, Stockholm (SE)

(72) Inventors: **Amir Roozbeh**, Stockholm (SE); **Alireza Farshin**, Stockholm (SE); **Dejan Kostic**, Solna (SE); **Gerald Q Maguire, Jr.**, Stockholm (SE)

(73) Assignee: **Telefonaktiebolaget LM Ericsson (publ)**, Stockholm (SE)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 178 days.

(21) Appl. No.: **17/427,626**

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§ 371 (c)(1),

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(65) **Prior Publication Data**

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(51) **Int. Cl.**  
**G06F 12/00** (2006.01)  
**G06F 9/455** (2018.01)

(Continued)

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CPC ..... **G06F 12/0871** (2013.01); **G06F 9/45558** (2013.01); **G06F 12/0646** (2013.01);  
(Continued)

(58) **Field of Classification Search**

CPC ..... G06F 12/0871; G06F 9/45558; G06F 12/0646; G06F 12/0811; G06F 12/0846;  
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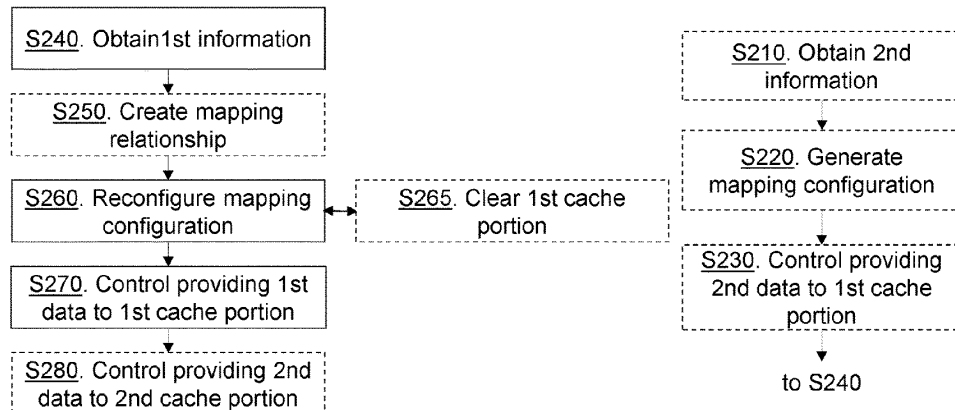
*Primary Examiner* — Shawn X Gu

*Assistant Examiner* — Mohammad S Hasan

(74) *Attorney, Agent, or Firm* — Nicholson De Vos Webster & Elliott LLP

(57) **ABSTRACT**

A method and device for controlling memory handling in a processing system comprising a cache shared between a plurality of processing units, wherein the cache comprises a plurality of cache portions. The method comprises obtaining first information pertaining to an allocation of a first memory portion of a memory to a first application, an allocation of a first processing unit of the plurality of processing units to the first application, and an association between a first cache portion of the plurality of cache portions and the first processing unit. The method further comprises reconfiguring a mapping configuration based on the obtained first information, and controlling a providing of first data associated with the first application to the first cache portion from the  
(Continued)



# US 12,111,768 B2

Page 2

first memory portion using the reconfigured mapping configuration.

## 19 Claims, 10 Drawing Sheets

### (51) Int. Cl.

**G06F 12/06** (2006.01)  
**G06F 12/0811** (2016.01)  
**G06F 12/0846** (2016.01)  
**G06F 12/0871** (2016.01)  
**G06F 12/0873** (2016.01)

### (52) U.S. Cl.

CPC ..... **G06F 12/0811** (2013.01); **G06F 12/0846**  
(2013.01); **G06F 12/0873** (2013.01); **G06F**  
**2009/45583** (2013.01)

### (58) Field of Classification Search

CPC ..... G06F 12/0873; G06F 2009/45583; G06F  
12/1433; G06F 12/1483; G06F 12/0292;  
G06F 2212/1052; G06F 2212/152; G06F  
12/0284; G06F 2212/601; G06F 12/0842;  
G06F 12/084

See application file for complete search history.

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Alireza Farshin, Tom Barbette, Amir Roozbeh, Gerald Q. Maguire Jr., and Dejan Kostić, *PacketMill: Toward Per-Core 100-Gbps Networking - Artifact for ASPLOS'21*, 2021. [Online]. Available: <https://doi.org/10.5281/zenodo.4435970>

For details see [13]. The following pages are based on hand-editing the web page <https://dl.acm.org/doi/10.5281/zenodo.4435970/full/> to keep only the essential content related to the artifact.

Artifact A



MAR 2021 • SOFTWARE

## PacketMill: Toward Per-Core 100-Gbps Networking – Artifact for ASPLOS'21



Artifacts Evaluated & Functional / v1.1



Artifacts Available / v1.1



Results Reproduced / v1.1

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**Authors/Contributors:** [Alireza Farshin](#), [Tom Barbette](#), [Amir Roozbeh](#), [Gerald Q. Maguire Jr.](#),  
[Dejan Kostić](#) [Authors Info & Affiliations](#)

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**Related Articles:** [PacketMill: toward per-Core 100-Gbps networking](#)

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**DOI:** <https://doi.org/10.5281/zenodo.4435970> **Version:** 1.0

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### Description

This is the artifact for the “PacketMill: Toward per-core 100-Gbps Networking” paper published at ASPLOS’21.

PacketMill is a system that optimizes the performance of network functions via holistic inter-stack optimizations. More specifically, PacketMill provides a new metadata management model, called X-Change, enabling the packet processing frameworks to provide their custom buffer to DPDK and fully bypass `rte_mbuf`. Additionally, PacketMill performs a set of source-code & intermediate representation (IR) code optimizations.

Our paper’s artifact contains the source code, the experimental workflow, and additional information to (i) set up PacketMill & its testbed, (ii) perform some of the experiments presented in the paper, and (iii) validates the reusability & effectiveness of PacketMill.

For more information, please refer to <https://github.com/aliireza/packetmill>

## *Instructions*

### **General Installation**

#### **Hardware Dependencies:**

PacketMill's metadata management model (X-Change) only supports MLX5 driver in DPDK. Although MLX5 driver is used by several Mellanox NICs, we have only tested Mellanox Connect-X 5 NICs. To perform PacketMill's experiments, you need two servers (preferably with Xeon processors) equipped with Mellanox Connect-X 5 NICs and interconnected via a 100-Gbps link.

#### **General Installation:**

PacketMill's README.md (<https://github.com/aliireza/packetmill/blob/master/README.md>) describes the testbed preparation, installation process, and the experimental workflow to use PacketMill and perform different experiments.

## *Provenance*

Our artifact provides some scripts to perform some experiments with synthetic traces (i.e., using fixed-size packets) to validate the reusability and effectiveness of PacketMill, where it uses NPF tool and FastClick. Please check <https://github.com/aliireza/packetmill/tree/master/experiments> for more information.

## *License*

[free](#)





# €€€€ For DIVA €€€€

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    "ORCID":"xxxxx-xxxx-xxxx-xxxx",
    "E-mail":"XXXXXXXXXXXX@kth.se",
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    },
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    "Main title":"This is the title in the language of the thesis",
    "Subtitle":"A subtitle in the language of the thesis",
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↳ (optional) Introduces the subject area for your research. \\item Short problem statement \\item Why was
↳ this problem worth a third-cycle thesis? (\\ie why is the problem both significant and of a suitable degree
↳ of difficulty for your intended degree? Why has no one else solved it yet?) \\item How did you solve the
↳ problem? What was your method/insight? \\item Results/Conclusions/Consequences/Impact: What are your key
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