Predictive Safety Filter for Learning Controllers on Changing Dynamics

Safety guarantee for reinforcement learning controllers with uncertain dynamics

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Swedish subtitle: Säkerhetsgaranti för förstärkningsinlärning kontroller med okänd dynamik

Abstract

The first abstract should be in the language of the thesis.

Keep in mind that most of your potential readers are only going to read your title and abstract. This is why it is important that the abstract give them enough information that they can decide is this document relevant to them or not. Otherwise the likely default choice is to ignore the rest of your document.
A abstract should stand on its own, i.e., no citations, cross references to the body of the document, acronyms must be spelled out, ...
Write this early and revise as necessary. This will help keep you focused on what you are trying to do.

Write an abstract with the following components:

Use about 1/2 A4-page (250 and 350 words).

- What is the topic area? (optional) Introduces the subject area for the project.
- Short problem statement
- Why was this problem worth a Master's thesis project? (i.e., why is the problem both significant and of a suitable degree of difficulty for a Master's thesis project? 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 upon your results? What can be done now that you have finished - that could not be done before your thesis project was completed?

  The presentation of the results should be the main part of the abstract.

Keywords

Safe learning, Reinforcement learning, Model predictive control

Choose the most specific keyword from those used in your domain, see for example: ACM's Computing Classification System (2012) or (2014) IEEE Taxonomy.

Mechanics:

- 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 them in corresponding order (i.e., so that the nth word in each list correspond) - thus it would be easier to mechanically find matching keywords.

Sammanfattning

All theses at KTH are required to have an abstract in both English and Swedish.
If you are writing your thesis in English, you can leave this until the final version. If you are writing your thesis in Swedish then this should be done first – and you should revise as necessary along the way.
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.
The abstract in the language used for the thesis should be the first abstract, while the Summary/Sammanfattning in the other language can follow.
Exchange students many want to include one or more abstracts in the language(s) used in their home institutions to avoid the neeed to write another thesis when returing to their home institution.

Nyckelord

5-6 nyckelord

Nyckelord som beskriver innehållet i uppsatsrapporten

Acknowledgments

It is nice to acknowledge the people that 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/... .

I detta kapitel kan du e v 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, 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

I would like to thank xxxx for having yyyy.

Stockholm, April 2022
John Liu

Contents

List of Figures

List of Tables

Listings

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

Chapter 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 ingenjörsaspekt och vars resultat kan ge ny eller kompletterande erfarenhet till ingenjörssamfundet och vetenskapen.
Examensarbetet handlar då om att ta fram denna nya ”erfarenhet” och på köpet löser man en del eller hela delen av det ursprungliga problemet. Erfarenheten kommer ur en frågeställning som man i examensarbetet 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.

This chapter describes the specific problem that this thesis addresses, the context of the problem, the goals of this thesis project, 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.)

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

We use the *bibtex* package to handle our references. We therefore use the command [1]. For example, Farshin, et al. described how to improve LLC cache performance in [1] in the context of links running at 200 Gbps.

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

Present the background for the area. Set the context for your project – so that your reader can understand both your project 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[2] multicast is useful for xxxx .

1.1 Problem

svensk: Problemdefinition elle 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.

1.1.1 Original problem and definition

Ursprungligt problem och definition

Some text

1.1.2 Scientific and engineering issues

Vetenskaplig och ingenjörsmässig frågeställning

some text

1.2 Purpose

Syfte

State the purpose of your thesis and the purpose of your degree project.

Describe who benefits and how they benefit if you achieve your goals. Include anticipated ethical, sustainability, social issues, etc. related to your project. (Return to these in your reflections in Section 7.4.)

Skilj på syfte och mål! Syfte är att förändra något till det bättre. I examensarbetet finns ofta två aspekter på detta. Dels vill problemägaren (företaget) få sitt problem löst till det bättre men akademin och ingenjörssamfundet vill också få nya erfarenheter och vetskap. 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 examensarbete, att du uppfyller examensmålen. Dessa mål sammanfaller med kursmålen för examensarbetskursen.

1.3 Goals

Mål

Skilj på syfte och mål. Syftet är att åstakomma 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 this degree project.

The goal of this project 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 – akademin)

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 project are.

1.4 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 examensarbete). 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).

1.5 Delimitations

Avgränsningar

Describe the boundary/limits of your thesis project 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 project. Explain the delimitations. These are all the things that could affect the study if they were examined and included in the degree project.

1.6 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. ...

Chapter 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.

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

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 the degree project /work (described in this thesis). Explain why and what is not used in the degree project and give valid reasons for rejecting the work/research.

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

2.1 Model predictive control

$$\begin{aligned} \min_{u \in \mathcal{U}} \quad & x_{N|k}^T Q_N x_{N|k} + \sum_{i=0}^{N-1} x_{i|k}^T Q x_{i|k} + u_{i|k}^T R u_{i|k} \\ \text{s.t.} \quad & x_{i+1|k} = f(x_{i|k}, u_{i|k}), \quad \text{for} \quad i = 0, 1, \ldots, N-1 \\ & (x_{i|k}, u_{i|k}) \in \mathcal{X} \times \mathcal{U}, \quad \text{for} \quad i = 0, 1, \ldots, N-1 \\ & x_{N|k} \in \mathcal{X}_N \end{aligned} \tag{2.1}$$

- Very effective since it is using an optimal control based approach with a receding horizon.
- Downside is that it is based on a predetermined model of system dynamics. Performance is then dependent on the accuracy of the model.
- On the other side, using a model-based controller, we can consider input and state constraints while computing the input signals.
- Also, since MPC is utilizing a receding horizon the controller has to solve an optimization problem each time step which is very computationally expensive.

2.2 Reinforcement Learning

- [3]
- Vanilla reinforcement learning do not consider a physical model of the system. Instead, it utilizes a neural network model to perform classification and regression.
- The advantage of this approach is that the neural network can, in theory, learn extremely complex and nonlinear systems, while conventional parametric method can only learn linear approximations.
- Reinforcement learning is often used for online learning, meaning that the controller do not need to collect preliminary data for offline training.
- While this seems very promising one of the biggest challenges with reinforcement learning is that ensure convergence to a global optima, or at least a local optima with a cost close to the global cost.

- Another issue with reinforcement learning is that a neural network introduces a multitude of hyperparameters which need to be carefully tuned for good performance. This task can sometimes be seen as more an art form rather than a scientific method.

2.2.1 Policy Gradient

- [4]
- Policy gradient is a reinforcement learning method that is applied to systems with discrete actions domains and continuous state domains.
- Policy gradient can be used when we want to avoid assuming model dynamics. It instead computes the gradient with respect to network parameters based on the cost on certain actions.

2.3 Bayesian Linear Regression

- Bayesian linear regression uses prior and likelihood assumptions to estimate posterior and predictive values. This can be used to estimate linear approximations for nonlinear systems.
- This method not only estimate the considered system, it also provides an uncertainty corresponding to each value estimation.
- While other linear regression methods can compute the covariance for point in the training data it cannot, however, provide a covariance for unexplored points. Nevertheless, this is possible using bayesian system identification methods.
- Additionally, using a bayesian methods, we can model measurement noise in the prior estimation.

2.4 Predictive Safety Filter

$$
\begin{aligned}
\min_{u \in \mathcal{U}} \quad & (u_{\mathcal{L}} - u_{0|k})^2 \\
\text{s.t.} \quad & x_{i+1|k} = f(x_{i|k}, u_{i|k}), \quad \text{for} \quad i = 0, 1, \ldots, N-1 \\
& (x_{i|k}, u_{i|k}) \in \mathcal{X} \times \mathcal{U}, \quad \text{for} \quad i = 0, 1, \ldots, N-1 \\
& x_{N|k} \in \mathcal{X}_N
\end{aligned}
\tag{2.2}
$$

- [5]
- A predictive safety filter is used as a safeguard for learning controllers, such a reinforcement learning controller based on policy gradient. It applies the same theory as model predictive control to determine if the input signal from the learning controller is safe or not.
- If the input signal is unsafe, the safety filter will make necessary adjustments while being as noninvasive as possible to the learning input signal.
- With this, the predictive safety filter adopts all benefits from model predictive control and reinforcement learning as well as avoiding several of the disadvantages.
- It also decouples performance and safety since the learning controller is responsible for performance and the safety filter is responsible for safety.

2.5 Major background area 1

Viktigt bakgrundsområde 1

There are xxx characteristics that distinguish yyy from other information and communication technology (ICT) system, as shown in Figure 2.1. Table 2.1 summarizes these characteristics.

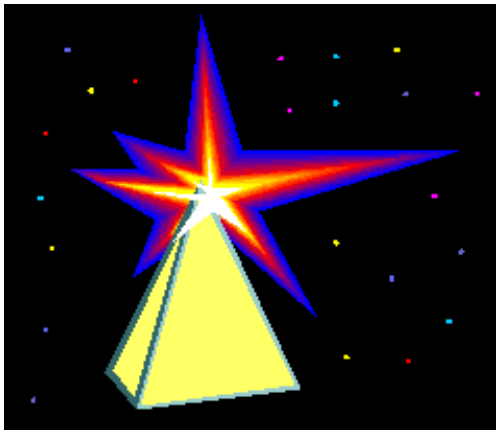

Figure 2.1: Lots of stars (Inspired by Figure x.y on page z of [xxx])

Table 2.1: xxx characteristics

Characteristics	**Description**
α	β
1	1110.1
2	10.1
3	23.113 231

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

Egenskaper

Beskrivning

2.5.1 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 [6].

2.5.2 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 [7]. ...

2.5.3 Subarea 1.1.2

Using the nearest data center may improve performance, see [8]

2.5.4 Link layer Encapsulation

See Figure 2.2 which uses the bytefield LaTeX package.

2.5.5 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.

...

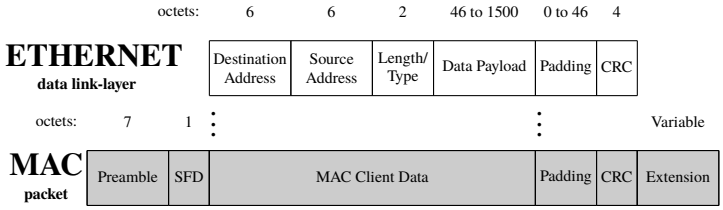

Figure 2.2: Ethernet data link layer protocol encapsulated into a IEEE 802.3 MAC packet

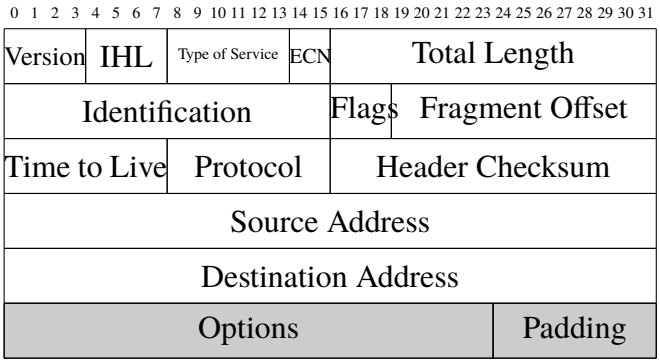

Figure 2.3: IPv4 datagram header. Light grey coloured fields are optional.

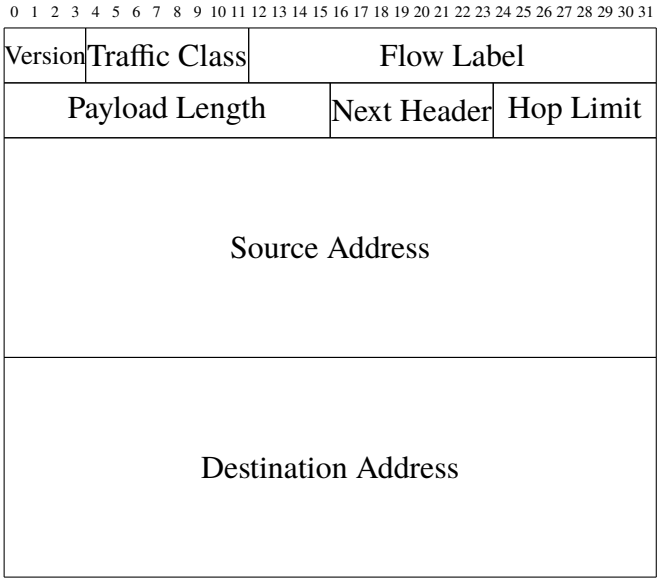

Figure 2.4: IPv6 datagram header

2.6 Major background area 2

Viktigt bakgrundsområde 2

...

2.7 Related work area

Relaterande arbeten

2.7.1 Major related work 1

Relaterande arbeten 1

Carrier clouds have been suggested as a way to reduce the delay between the users and the cloud server that is providing 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 [9].

2.7.2 Major related work

Relaterande arbeten

2.7.3 Minor related work 1

Mindre relaterat arbete 1

...

2.7.4 Minor related work n

Mindre relaterat arbete n

2.8 Summary

Sammanfattning

Det är trevligt att få 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 as 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.

Chapter 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 the degree project.

Give a theoretical description of the scientific or engineering methodology are you 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 consciousness 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 vetenskapliga eller ingenjörsmetodik ska du använda och varför har du valt den här metoden. Vilka andra metoder gjorde du överväga 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 ditt utvärdera den. Syftet med detta kapitel är att ge en översikt över forsknings metod som används i denna avhandling. Avsnitt 3.1 beskriver forskningsprocessen. Avsnitt 3.2 detaljer forskningen paradigm. Avsnitt 3.3 fokuserar på datainsamling tekniker 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 valts för att utvärdera xxx.

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

- Vilken process skall användas för konstruktion av lösningen och vilken process skall kopplas till denna för att svara på undersökningsfrågan?
- 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?).
- Vilken teori/teknik skall väljas och användas både för undersökningen (taxonomi, matematik, grafer, storheter mm) och problemlösning (UML, UseCases, Java mm) och varför?
- Vad behöver du som student leverera för att uppnå hög kvaliet (minimikrav) eller mycket hög kvalitet på examensarbetet? Frågorna kopplar till de följande underkapitlen.

  Resonemanget bygger på att studenter på hing-programmet ofta skall konstruera något åt problemägaren och att man till detta måste koppla en intressant ingenjörsfråga. Det finns hela tiden en dualism mellan dessa aspekter i exjobbet.

3.1 Research Process

Undersökningsrocess och utvecklingsprocess

Figure 3.1 shows the steps conducted in order 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

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

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

Datainsamling

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

3.3.1 Sampling

Stickprovsundersökning

3.3.2 Sample Size

Provstorleken

3.3.3 Target Population

Målgruppen

3.4 Experimental design/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

How will you know if your results are valid?

Giltigheten av metoder

Har dina metoder ge dig de rätta svaren och lösning? Var metoderna korrekt?

3.5.2 Reliability of method

How will you know if your results are reliable?

Tillförlitlighet av metoder

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

3.5.3 Data validity

Giltigheten av uppgifter

Hur vet du om dina resultat är giltiga? Har ditt resultat mäta rätta?

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

Dataanalys Teknik

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

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

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, designdokumnet, implementationsdokument, driftsdokument, testprotokoll mm.

Chapter 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? Vad designen beslut 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.

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

Konfigurationer testade

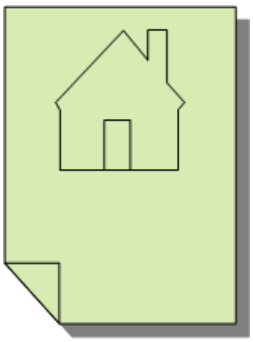

Figure 4.1: Homepage icon

Table 4.1: Configurations tested

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

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

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

4.2.1 Some examples of coding

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, world");
return 0;
}
```

In contrast, Listing 4.2 is an example of code in Python to get a list of all of the programs at KTH.

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: " + url)
    #
    r = requests.get(url)
    if Verbose_Flag:
        print("result of getting v1 programme: {}".format(r.text)
    #
    if r.status_code == requests.codes.ok:
        return r.text           # simply return the XML
    #
    return None
```

Chapter 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 resultatet 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 uppnå 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 mätningarna fördröjnings visas i Tabell 5.1. Förseningen har beräknats från den tidpunkt då begäran GET tas emot fram till svaret skickas.

Table 5.1: Delay measurement statistics

Configuration	Average delay (ns)	Median delay (ns)
1	467.35	450.10
2	1687.5	901.23

Fördröj mätstatistik

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

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

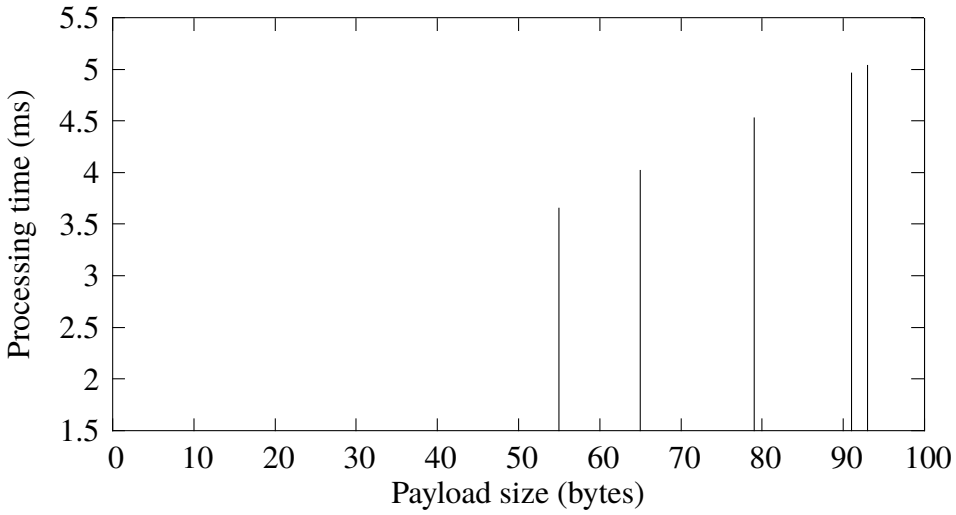

Figure 5.1: Processing time vs. payload length

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:

$$bitrate = \frac{1}{\frac{time_{byte}}{8}} = 20.03 \quad kb/s$$

5.2 Reliability Analysis

Analys av reabilitet

Reabilitet i metod och data

5.3 Validity Analysis

Analys av validitet

Validitet i metod och data

Chapter 6

Discussion

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

Diskussion

Förbättringsförslag?

Chapter 7

Conclusions and Future work

Slutsats och framtida arbete

Add text to introduce the subsections of this chapter.

7.1 Conclusions

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

Slutsatser

Discuss the positive effects and the drawbacks.
Describe the evaluation of the results of the degree project.
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?

Träffade du dina mål? Vilka insikter har du fått? Vilka förslag kan du ge till andra som arbetar inom detta område? Om du hade att göra igen, vad skulle du ha gjort annorlunda?

7.2 Limitations

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

Begränsande faktorer

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

7.3 Future work

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?

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?

Due to the breadth of the problem, only some of the initial goals have been met. In these section 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 requirment, i.e., a yearly unavailability of less than 3 minutes, this remains an open problem. ...

Cost analysis

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. ...

Security

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

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

Reflektioner

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

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.

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 opponents and examiner.
IEEE Editorial Style Manual: `https://www.ieee.org/content/dam/ieee-org/ieee/web/org/conferences/style_references_manual.pdf`

Låt Zotero eller annat verktyg fylla i det här för dig. Jag föreslår en utökad version av IEEE stil - att inkludera webbadresser, DOI, ISBN etc. - för att göra det lättare för läsaren att hitta dem. Detta kommer att göra livet lättare för dina motståndare och examinator.

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Appendix A

Something Extra

svensk: Extra Material som Bilaga

For DIVA


```
{
"Author1": {
            "Last name": "Liu",
            "First name": "John",
            "Local User Id": "u100001",
            "E-mail": "johnliu@kth.se",
            "organisation": {"L1": "School of Electrical Engineering and Computer Science ",
                             }
          },
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            "Subtitle": "Safety guarantee for reinforcement learning controllers with uncertain dynamics",
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            "Subtitle": "Säkerhetsgaranti för förstärkningsinlärning kontroller med okänd dynamik",
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},
"Supervisor1": {
                "Last name": "Proutiere",
                "First name": "Alexandre",
                "Local User Id": "u100003",
                "E-mail": "alepro@kth.se",
                "organisation": {"L1": "School of Electrical Engineering and Computer Science ",
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              },
"Examiner1": {
                "Last name": "Rojas",
                "First name": "Cristian",
                "Local User Id": "u100004",
                "E-mail": "crro@kth.se",
                "organisation": {"L1": "School of Electrical Engineering and Computer Science ",
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