Master of Science Thesis in Electrical Engineering
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# Artificial Neural Networks for Image Improvement

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# Sammanfattning

Abstrakt på svenska

# Abstract

If your thesis is written in English, the primary abstract would go here while the Swedish abstract would be optional.

# Acknowledgments

Acknowledgements

*Linköping, Januari 2020*
*Benjamin Lind*

# Contents

# Notation

### Några mängder

| Notation | Betydelse |
|---|---|
| $\mathbb{N}$ | Mängden av naturliga tal |
| $\mathbb{R}$ | Mängden av reella tal |
| $\mathbb{C}$ | Mängden av komplexa tal |

### Förkortningar

| Förkortning | Betydelse |
|---|---|
| ARMA | Auto-regressive moving average |
| PID | Proportional, integral, differential (regulator) |

# 1

# Introduction

Back in the days when all photographies were analogue, several hours were usually put into the development of the photo after the camera button was clicked. Images were rare then, and in some sense more precious.

As cameras became cheaper, more people could afford them and more images were produced. Today, images are in abundance, and spending hours on post-production on images is practised exclusively by professionals photographers or the rare enthusiast.

Many images are taken by amateurs, with cheap gear which comes included in their mobile phone. We all want to take good pictures, but don't feel like learning the details about how to make the best use your our cameras. The

But the need for quickly enhancing the quality of an image is not reserved to the for the amateur; Even professionals find a need for a swift edit of their digital photos.

Instagram, snapchat, and similar services put a lot of effort into developing post-processing techniques for helping their users to make the most out of their digital photos. Within such an application, a single touch on the screen is often enough to give the image a substantial improvement.

In this thesis, automatic image improvement will be explored with limitations to colorization and super-resolution. Artificial neural networks are an interesting sub-field within machine-learning and artificial intelligence, concepts which are of great importance today, and will probably be much, much more in the future.

Artificial neural networks recently received an upswing in popularity because they have been shown to be able to learn how to perform well on a range of certain tasks, including image improvement. The ultimate goal of this thesis is to find a neural network which "understands" how we humans like images to look, and given an image it has never seen before, produce a better version of it. One could say that we train an AI to make educated guesses on how enhance image quality.

# 2

# Background and Context

In this chapter, the background and context to this thesis will be explained. After reading this chapter, the reader will be up to date with some of the recent developments in deep neural networks and other methods that have been used to enhance images.

Some interesting techniques in neural networks regarding convergence of the networks, faster training, higher accuracy and other tricks and optimizations will be presented as well.

The text presented here is supposed to be of use to the reader to go from a knowledge-level in machine-learning and neural networks acquired from a basic university course, to a more up to date understanding of what is currently going on in the sub field which this thesis is studying.

To start off, other fields of use for neural networks will be briefly listed. Then the background and context more directly applicable to this thesis will be explained in more details.

## 2.1 A two page crash course in neural networks

Neural networks are studied for a variety of tasks. The most prominent achievement is the classification accuracy on huge data sets, the best networks are able to get a top-5 error of just a few percentages on several thousands of images the net has never seen before. When a neural net is used for classification of objects in an image, the aim is for the network to be able so "say", or indicate, what object is found in the image. For the network to be able to say that the image contains, let's say a fish, the network need to know beforehand that "fish" is an option.

If we want to build a network to be able to detect fishes, frogs, barnacles, and turtles, we provide the network with the ability to express four different "words". That is the reasoning of how we communicate with the artificial intelligence.

However, we are not on the level of AI as in the Asimov novels, and we still understand how they are built on the very smallest of details in our computer programs.

How it works in practice is that the network has these different "words" which it will utter by different strengths of its "voice" when it is shown a picture. The output (what the network "says") is encoded like this: [fish, frog, barnacle, turtle]. For each object, there is a separate position in a list. Neural networks speak in numbers, which we translate to words, and are thus able to understand what they say. If the network is given an image and it responds by [1, 0 0 0], then that would mean that the network is sure that there is a fish in the image, and none of the other objects. If the output is given like [0, 1, 0, 0] with the position of the frog being a 1 and the rest 0, it tells us that a frog was found in the image.

The networks are usually trained to classify only one object in an image, and the correct answer is on the form with one 1 and the rest as zeros. This is called 1-hot encoding.

The classification works in the way that the object is the one where the number is the largest. If the output is [0.35, 0.30, 0.15, 0.20] the network believes that the image contains a fish, since 0.35 is the largest number in the list. It is quite uncertain however, since it was a close call to "frog" whose number is only slightly smaller than the output number for "fish".

If the correct answer in this last case indeed was "frog", the network would've made a mistake. In the large networks, there are not 4 classes (objects), but hundreds or thousands. To make the game fairer to the networks and their researchers, the networks is said to be correct if one of the five most likely objects is the correct one. This is called top-5 score, or top-5 result in the literature.

An image is a collection of numbers, and there is one number per pixel and per color. The most commonly used color space is the RGB color space, which stands for Red, Green, and Blue. There are several other color spaces, and one which will be used later in this thesis is the LAB color space. What the network does with the image is that it performs mathematical operations such as multiplication and addition to the numbers in the image. The output of the resulting operations are fed to some linear function, then that result is modified in some additional way, and the process repeats until the final output is given.

The different steps described above are performed in what is called "layers" of the network. The different kinds of layers are heavily experimented with as of today, and new layers and combinations of them show better and better results in some way for each paper published.

There is always an input layer and an output layer, and the rest are called "hidden layers". The input layer is where the signal (often images, but could also be data from audio files, statistical measurements from finance or weather, and many other types of "signals"). A new method for better training and understanding of the networks is a technique called "deep visualisation", where the output from the hidden layers are exposed, and not just fed to the next layer as conventionally done.

So how do they learn?

The numbers in the input image is multiplied with another number which is

in the network, called a weight. Weight is another word for number, or numerical value in neural networks. The weights are the numbers which are changed, often ever so slightly, to make the network perform better on its task. If the network is supposed to find animals in an image and produces an output like [0.2, 0.2, 0.2, 0.2] and the correct answer is [1, 0, 0, 0], we can tune the weights to direct the output closer to the desired output, the correct answer. After the weights are changed slightly in their correct direction (which makes them larger or smaller), the produced the next time the network sees the same image [0.3, 0.1, 0.1, 0.1].

Note that there are usually a lot of weights in a large neural network, (millions or billions) and that they are all individually updated. A neural network with many layers is some times called a deep neural network, or DNN.

Different kinds of loss-functions are used to be able to know how to change the weights in the network, and also to get a measurement of how well it performed on its task. One kind of loss function could be the sum of the difference between the elements in the actual output and the desired output.

$$error = loss\_function(image, weights) = \sum_i (output(i) - desired\_output(i))^2 \tag{2.1}$$

The differences are squared in the equation since there are not supposed to be any "negative" errors. Taking the absolute value would also work, but the square has another favourable property...

One can then take the derivative of the error with respect to a weight. If the derivative is positive, that means that the error will increase if the weight is increases, and if the derivative is negative the error will decrease if the weight increases. With help of this, we update all weights by increasing or decreasing them accordingly. A small step length is used, so that we carefully tune the network. If a too large step length is used, the optimum value for a weight might be overshot. Also, changing one weight will change what is a good modification of other weights in the neural network, so caution is a virtue.

The gradients for the weights in the last layer can be calculated easiest since those weights are the closest to the analytic loss function. The derivative of the error with respect to the weights in the preceding layers is dependent on the weights in the layer closer to the end of the network. The derivative can thus be split up and calculated with help of the chain rule.

That is the basics and some intuition about how the neural networks work.

## 2.2 Advances in Images Enhancement

In this section we change gears and move into more advanced details of neural networks with their and other methods for advances in image enhancement during the recent years.

Quite a few concepts will be explained here, with references to further reading or the original papers from which these concepts or methods emerged. In the literature, the problem of improving images may be divided into two main

categories: color improvement, and resolution improvement. In both categories, methods which does not include any kind of machine learning has been used previously, but seem to swiftly being phased out by learning algorithms. Since neural networks is such a new field, it is to no surprise that many researchers want to explore them. It is like a newly found mine with promise of gold and opportunities. Neural networks are showing a great deal of promise and are already performing very well on both color improvement tasks and resolution improvement.

### 2.2.1 Color improvement

In color improvement, several sub-fields are being researched, each with different views on how the image is interpreted as "better". Some recent articles have explored the task of colorizing black and white photos. This has been done with and without neural networks, some times in an end-to-end fashion and some times not. In some works, example images of similar scenes and colors to the one that shall be colorized is used in the algorithm. In some cases, a deep neural network is trained on hundreds, thousands, or a million of images to learn how to colorize black and white images. Colorization of a black and white image can also lead to higher classification accuracy performance by nerual networks, as shown in the "Colorful Colorization" paper.

On reddit (reddit.com/r/colorization), people colorize black and white images by hand.

Apart from colorizing images which has no color, another interesting topic is to improve on image where color is already present. Such methods are of great interest to the consumer markets, image editing applications, and to companies which are working with various kinds of cameras where a subjective measure of image quality is belongs, for example video streams.

The last and perhaps most artistic concept in color improvement are the neural networks which are trained to morph one image so that it fits a style of another.

**Colorization of black and white images** The first paper to propose a deep neural network for colorization of black and white images is named "Deep Colorization" [1] **Improving on already present colors**

**Style transfer**

### 2.2.2 Super resolution

When trying to improve the resolution in an image, an up sampling is what happens. The standard ways of performing up sampling are still strong benchmarks against the newly developing techniques. The bilinear up sampling method does not produce high quality up sampling, but is good for visualising a low resolution image on a screen. The bicubic interpolation method produces blurred compared to the bilinear method, but more details become present.

In recent papers, the developed methods still usually compare their results to the bicubic method along with other researchers' methods.

## 2.3 Tricks of the trade

In this section, a collection of interesting methods regarding the trade of neural networks will be presented. Neural networks has been given a reputation of being black boxes, which receives inputs and gives an output; but nobody understands how and why the cogs are turning on the inside. Some of the tricks of the trade discussed in this section were developed with aims to make the training and understanding of the neural networks more transparent; they aim at opening up the black box and put a flash light to it. Others aim at speeding up the training, which can be excruciatingly slow for large models and large data sets. During training, the networks may get stuck in local optima for their loss functions; the aim of some tricks are to improve on convergence during training. Others aim at achieving higher classification accuracy.

Despite that one trick might be developed with classification in mind, it might show beneficial to use within other sub-genres of neural networks as well, like image segmentation, super-resolution and others.

### 2.3.1 Deep supervision

The technique called *Deep Supervision* was presented in the paper *Deeply-Supervised Nets* [3].

# 3

# Results

Det här är kapitlet där resultaten presenteras.

## 3.1 Section 1

## 3.2 Section 2

# Appendix

## 3.A Chapter-Appendix

Det här är en appendix-del av det aktuella kapitlet.

# 4

# Avslutande kommentarer

Sätt av ett kort kapitel sist i rapporten till att avrunda och föreslå rikningar för framtida utveckling av arbetet.

# Appendix

# A

# Trista saker

Detta är ett appendix-kapitel. Jämför med appendixet i kapitel 3.

## A.1 Appendix stuff 1

## A.2 Appendix stuff 2

# B

# *rtthesis* documentation and LaTeX tips

This document is not only an example that you can use to get started with the *rtthesis* class, it also contains written instructions for how to use the class, and some general tips on how to use LaTeX to produce a beautiful thesis. As we do so in this chapter, we also get the opportunity to look at some theorem-like environments, which you can alter the look of by changing the options given to the *rtthesis* class.

## B.1 Basic setup

You must decide on an input encoding from start, and select the corresponding class option from tabell B.12 on sida 34. You must also tell *rtthesis* whether you intend to use part sectioning or not, see tabell B.1. There are many more class options, but they will be mentioned below where there is room for a more detailed discussion for the corresponding features.

Information about the thesis, which is needed to produce the thesis itself as well as the thesis cover and the "spikblad", is passed to *rtthesis* using the command `\setupThesis`. The command is called in the following way, where the most common key-value pairs are listed in tabell B.2 (the remaining key-value pairs concern master's theses, see avsnitt B.22)):

```
\setupThesis{
  key1=value1,
  key2=value2,
  ...
}
```

If a PhD thesis has an interesting illustration on the cover, it is customary to provide a caption for the illustration. The caption will be printed on the back of the title page, and is set up by redefining the command `\rtcoverinfo`. For instance, it may look like this:

***Table B.1:*** *Class options that inform* rtthesis *whether part sectioning will be used or not.*

| Class option | Meaning |
|---|---|
| `parts` | Prepare for `\part` as the topmost sectioning command. |
| `noparts` | Prepare for `\chapter` as the topmost sectioning command. |

***Table B.2:*** *Key-value pairs recognized by* `\setupThesis`*. Note that values that include white space are surrounded by braces.*

| **Key** = **Example value** | Comment |
|---|---|
| `author = {My Name}` | |
| `title = {Thesis title}` | |
| `subtitle = {Good stuff}` | Optional. |
| `city = Norrköping` | Default: *Linköping* |
| `year = 2010` | |
| `isbn = isbn-isbn-isbn-isbn` | |
| `type = phd` | Must be either *phd*, *lic*, or *msc*. |
| `thesisNo = 9999` | Number in series (the series is determined by the choice of thesis type). |
| `localID = 11` | Only used for licentiate's theses. It is the last part of the local identifier *LIU-TEK-LIC-2010:11* in this case. |
| `username = isyusername` | Used to generate the author's email address. |
| `dedication = {To my parents!}` | |

```
\renewcommand{\rtcoverinfo}{\textbf{Cover illustration:} Block
diagram showing the structure of the control scheme proposed in
\chapterref{cha:cool-control}}
```

## B.2 Page layout and related options

Theses are restricted to the S5 paper size. How the S5 page is organized is up to you, but *rtthesis* only allows you to choose from two predefined layouts, and only one of them is recommended. To get your own layout you should make a copy of *rtthesis.cls* and modify the code for one of the existing class options for layout. The class options for page layout are given in tabell B.3.

At the time of writing, the printers used by LiU-Tryck print on A4 paper (physical size), which is then cropped to S5 (logical size). Similarly, when you print draft versions of your thesis on your office printer, it is very likely that the used physical paper size will be A4. Hence, it makes sense to let *rtthesis* control how

***Table B.3:*** *Class options related to page layout. The most important one to remember is* `crop` *(since* `S5` *and* `pdf` *are default).*

| Class option | Meaning |
|---|---|
| `S5` | Recommended layout. Margin paragraphs are tiny (see avsnitt 3.1 for examples), and should only be used for comments that will be removed in the final version of the thesis. Default. |
| `S5MP` | Layout to use if you are serious about margin paragraphs. Not recommended, since the S5 format is too narrow to really fit margin paragraphs of reasonable width. |
| `nailing` | Layout for the "spikblad". Not for theses! |
| `pdf` | Produce pages in the S5 format. Default. |
| `onA4` | Logical S5 page on a PDF page of size A4. |
| `info` | Write information about each page above the logical S5 page. |
| `crop` | Same as `onA4` with `info` and crop marks. |
| `noInfo` | Turn off the effect of `info`. |
| `draft` | Same as `onA4`, but pictures are blank and overfull `hbox`es stand out. |

the S5 logical page is placed on the A4 physical paper. In this case, *rtthesis* will produce a PDF with pages in the A4 format, with content restricted to the S5 format. On the other hand, when you produce a PDF that is meant to be read on a computer screen, the page size should be exactly S5. When targeting the A4 physical format, it is possible to get crop marks for the S5 box, and to put some information about each page outside the S5 box. The related class options are given in tabell B.3.

To ensure that you really get the page layout you think when you send your thesis file to the printer's, the best option *should* be to use the `crop` option. However, they will tell you differently, since they think it's *their* job to position the logical page on A4 and add crop marks. Unfortunately, there is a lot of manual work in the process, so there is a (substantial?!) risk that the content of your pages will be shifted with respect to the S5 box of your layout...

Although only weakly related to page layout, this section ends with a tip for how to change the size of the chapter numbers (some users find them much too big). The font is controlled using the sectsty package, and it follows that it can be redefined by, for instance,

```
\chapternumberfont{\fontsize{60mm}{63mm}\selectfont}
```

***Table B.4:*** *Legal option values to the* `notation` *environment. The options control the look of the* `notationtabular` *environments used inside the* `notation` *environment. The initial definition of* `notationtabular` *is the same as that obtained by passing the option* `new`*.*

| Option | Meaning |
|---|---|
| *emty* | Do not redefine `notationtabular`. Default. |
| `old` | Make `notationtabular` produce a plain LaTeX table with double horizontal lines under the table headings, and a vertical line separating the two columns. |
| `new` | Make `notationtabular` produce a table according to the guidelines in Mori [4] using the ctable package. |

## B.3 Front-matter environments

There are environments defined for typical sections in the front-matter[1]. The most important purpose of providing these environments is that they take care of the table of contents and the PDF bookmarks for you. The environments are `abstract`, `preface`, `acknowledgments`, and `notation`.

The environment `abstract` accepts the language used inside the environment as an optional argument (which defaults to `english`). If the language is set to `swedish`, the title of the abstract will be *Populärvetenskaplig sammanfattning*, in accordance with the Linköping University requirements on theses written in English.

Inside the `notation` environment, you can put anything you like, and maybe the `notationtabular` environment provided by *rtthesis* suits your needs. In order to define this environment, *rtthesis* loads the two packages array and ctable, and also defines the command `\otoprule` to mean the same as `\toprule`. See tabell B.4 regarding how to change the look of `notationtabular`.

There is a class option called `noextras`, which was intended to inhibit the effect of the `\maketitle` command, and redefine the front-matter environments to not produce any output. However, the option is not working well at the moment. On the other hand, as the time it takes to compile a thesis on a modern computer is very short, it is rather unclear why someone would like to use this feature anyway.

[1] The *front-matter* is everything that goes in the beginning of the thesis, before the page numbered *1*.

## B.4 Abbreviations

Automatic control is a LaTeX-friendly community. This means that everything you produce is expected to look good. We begin with a basic result.

**Theorem B.1.** *Abbreviations, such as ARMA, look best in small caps.*

**Proof:** Just compare with "ARMA". □

However, it is important that the small caps match the sorrounding text, compare the statement in the theorem above with the following variation of it, in italics instead of slanted text:

> *Abbreviations, such as* arma[2] *or* ARMA, *will stick out in a terrible way if you don't watch out!*

This is why the *rtthesis* class uses slanted text rather than italics in theorems rather when slanted small caps are available.

Unfortunately, *rtthesis* does currently not provide a way to make small caps look good in italics, which leads to the following corollary to teorem B.1.

**Corollary B.2.** *One has to make a choice between*

- *Beautiful abbreviations using small caps (instead of ordinary upper case).*
- *Pretty text typeset in italics (instead of slanted text).*

## B.5 Definitions

Let us discuss another theorem-like environment while we have some examples of similar environments to compare with in the previous section. That is, let us discuss the `definition` environment (and the similar environments `assumption` and `remark`). All the theorem-like environments are defined in a separate package, rtthesis-theorems, so that they can be used with other document classes as well. The definition below is an example of a definition with a title.

**Definition B.3 (Definition).** A *definition* is a precise explanation of the meaning of a word or concept. It may be tempting to include examples in a definition, but a good definition should not depend on examples as part of the definition. However, examples are often useful to clarify a definition, and should appear near the definition.

A short definition may require just a single paragraph, while a more complex definition may require a few paragraphs. Some definitions will also make use of displayed math.

One problem one has to consider if definitions are not restricted to just one paragraph, is how to show the reader where the definition ends. In theorems, it is common to use italics or slanted text (for brevity, we will not mention italics

[2] This will cause a LaTeX warning.

from here on) to show where the theorem statement ends, but for definitions it may be desirable to use the slanted text to emphasize the word or concept being defined. (It is arguably more clear to highlight the new word or concept using slanted text with upright surrounding text, than vice versa.) To use an upright font for the definitions may also be a way of avoiding to heavy use of slanted text.

Various options related to the appearance of theorem-like things (in LaTeX, a definition is a kind of theorem) are described in tabell B.5. Tabell B.8 (used also to illustrate tables) contains some suggestions regarding combinations of options for the `definition` environment and options for paragraph breaks.

Sometimes, a definition may be given without a title. The next definition is an example of this, even though it is questionable whether it was a good idea to omit the title in this particular case.

**Definition B.4.** An *environment* in LaTeX is a construct that is entered with the command `\begin{...}` and exited with the command `\end{...}`, where "..." should be the name of the environment.

In tabell B.5, there are three options related particularly to how `definition`, `assumption`, and `remark` are typeset.

- With `definition=naked` (default) the definitions are typeset in upright font, and there is nothing on the page that marks the end of the definition.
- With `definition=theorem` the definitions are typeset in the same style as theorems. Since theorems are supposed to be typeset in slanted text, this will make it clear where the definition ends.
- With `definition=marks` the beginning and end of definitions will be indicated with small marks. Compare how the end of a proof is marked with a square box! The current implementation has some problems with placing the marks if the definition ends with a displayed equation, but this can be compensated for by manual insertion of a `\vspace` command.

You may judge from the following example whether manual insertion of a `\vspace` command is necessary to make the definition ending with a displayed equation look alright.

**Definition B.5.** The factorial (denoted by the postfix operator !), defined for natural numbers, is given by

$$n! = \begin{cases} 1, & \text{if } n = 0 \\ n \cdot (n-1) \cdot \ldots \cdot 1, & \text{otherwise} \end{cases}$$

This paragraph only serves to highlight the vertical white space below the definition ending with a displayed equation. Note that one way to avoid problems with this kind of definitions is to rewrite them so that they don't end with displayed equations.

All definitions in this section have been entered as isolated paragraphs; that is, there is an empty line in the source code of the document before and after each

***Table B.5:*** *Class options related appearance of theorem-like environments. The* theorem-like environments *defined by* rtthesis *are* `theorem`*,* `proposition`*,* `lemma`*,* `corollary`*,* `definition`*,* `assumption`*, and* `remark`*. The* definition-like environments *are a subset of the* theorem-like environments*, consisting of the environments* `definition`*,* `assumption`*, and* `remark`*. See also tabell B.10 regarding the fonts used in theorems.*

| Class option | Meaning |
|---|---|
| `break` | Put line breaks after the titles of the environments `theorem`, `proposition`, `lemma`, and `corollary`. |
| `nobreak` | Never put line breaks after titles of theorem-like environments. Default. |
| `definition=naked` | Definition-like environments look like the surrounding text, and are only isolated by some vertical white space. Default. |
| `definition=theorem` | Definition-like environments use same font as the `theorem` environment, and are isolated by some vertical white space. |
| `definition=marks` | Definition-like environments look like the surrounding text, and are isolated by small marks. Strongly recommended if `parskip` is used. |
| `nosharecounter` | Use separate numbering sequences for each theorem-like environment and the `example` environment. |
| `sharecounter` | Use one numbering sequence for theorem-like environments, and the `example` environment. |

`definition` environment. Although not recommended, *rtthesis* supports definitions that are connected with the preceding paragraph, in which case the usual vertical space (if any) between paragraphs will not be inserted. *Be careful so that you don't omit the paragraph breaks by mistakes, since it makes a difference that may be hard for proofreaders to spot!* As an example of a definition written in the same paragraph as the preceding text,

**Definition B.6.** A *paragraph* (according to Oxford American Dictionaries) is a distinct section of a piece of writing, usually dealing with a single theme and indicated by a new line, indentation, or numbering.

There is no paragraph break in the source code between the definition above and this text, but currently this cannot be seen in the typeset document. If you know how to solve this, let the *rtthesis* maintainer know! If you want to learn about the TeX mechanisms involved, see Ryćko and Jackowski [6].

## B.6 Theorem titles

The class lets you control the white space that separates a theorem title from the theorem statement. The options appear in tabell B.5. With the class option `break` (default), you will get a line break. With `nobreak`, you will just get horizontal space. Not all types of theorem-like environments will be affected by the `break` option, so to get things exactly they way you want, you may have to make your own modified copy of the *rtthesis* class. Try to recompile the document with the two different options and compare the result!

## B.7 To share or not to share counters

Other things to think about regarding style include whether to use the same counter for all sorts of theorem-like things. Again, the options appear in tabell B.5. Some like to make the number of important theorems to stand out by having a separate counter (as in Khalil [2]), while other prefer to use as few counters as possible in order to make it easy to locate referenced items (as in Rugh [5]). The two alternatives are supported in *rtthesis*, via the options `sharecounter` and `nosharecounter`.

## B.8 Completely customized theorem-like environments

If you don't like the way *rtthesis* sets up theorem-like environments (listed in the caption of tabell B.5) for you, you may pass the class option `notheorems`. Then amsthm will not be loaded, none of the theorem-like environments will be defined, and it is up to you to define your own environments. If you decide to do so, using the amsthm package will be a good idea.

***Table B.6:*** *The lengths used to control the appearance of the* `example` *environment. Note that the environment tries to compensate for the current value of* `\parskip`*, so you may not always get exactly what you'd expect. Also, the meaning of the distance between the upper stroke and the text is somewhat arbitrary in order to allocate space for the example title.*

| Length | Default | Purpose |
|---|---|---|
| `\exampleLineWidth` | 0.6 pt | Thickness of the strokes. |
| `\exampleTopBotInnerMargin` | 2 ex | Vertical space between strokes and contents of the example. |
| `\exampleTopBotOuterMargin` | 1 em `plus` 1 ex `minus` 1 ex | Vertical space surrounding the example. |

## B.9 The `example` environment

The `example` environment defined by the *rtthesis* class is *not* a floating environment, but is simply used to highlight that the text inside the environment is just an example of something more general that you have explained before. Just as with the theorem-like environments, the environment is defined in a separate package, rtthesis-example, so that it can be used with other document classes as well.

**Example B.7**

As an example of the `example` environment, we include a little example here. You can use this example to see how the options described in avsnitt B.7 affects the numbering of the environment.

Depending on where this example ends up in the typeset document, you may also have the chance to see the ugly stretched vertical space that sometimes appears at the top and bottom of the environment.

There are three lengths you may play with the fine tune the appearance of examples, explained in tabell B.6. Clearly, it would be possible to introduce additional parameters, but currently the corresponding aspects of the environment are hard-coded into *rtthesis*.

As is mentioned in the example above, there is sometimes problem with vertical space at the top and bottom of the `example` environment. During the page breaking process (see avsnitt B.17) you could consider to add something like

```
\vspace{-1\baselineskip}
```

to reduce such artifacts. Even better, if you know how to correct this in the definition of the environment, let the *rtthesis* maintainer know! The paper Ryćko

and Jackowski [6] is recommended for anyone interested in the lesser known details of TeX that one has to grasp in order to really solve the problem.

## B.10 Captions

The *rtthesis* class loads the captions package to obtain good-looking captions. Captions are set up assuming that table captions will be placed above the table they belong to. Many authors find this confusing since figure captions are always placed below the figure they belong to. If you want to put table captions below the table you need to adjust the spacing around the caption by putting the following line in your personal style file:

```
\captionsetup[table]{position=bottom}
```

Note that the command above only changes the spacing around the caption. You still have to put the code for each caption relative to the tabular itself consistently with the captions setup. Two tables are included in this document for illustration. Tabell B.8 indicates the many combinations of options that the `definition` environment has been designed to work with. The next one, tabell B.7 is just a stupid table telling where the different chapters in this document begin. For comparison, a typical automatic control block diagram has been included in figur B.1.

Some nice guidelines for table creation in LaTeX are given in Mori [4] (it is just two clicks away!).

## B.11 Hyperlinks

For readers our the electronically published version of your thesis, as well as yourself while your are working on it, it is very convenient to have working hyperlinks in the document.

### B.11.1 Basic setup

Basically, hyperlinks are obtained by using the hypreref package. However, this package has quite a lot of compatibility issues with other packages, and knowledge about how to deal with these issues is coded into the *rtthesis* class. That is, all you should have to do to get hyperlinks in your document is to specify the `hyperref` option to *rtthesis*. The class options related to the linking infrastructure of the document are listed in tabell B.9.

At the time of writing *rtthesis* does not call `\hypersetup` with information about document title, keywords, and other information provided to `\setupThesis` (see tabell B.2). If someone wants this, it shouldn't be hard to do.

### B.11.2 Hyperlinks and electronic publishing

To make your dear hyperlinks survive all the way to the electronic publishing system, you may have to replace the file that is sent to e-press by LiU-tryck. The

***Table B.7:*** *Different combinations of class options that affects the* `definition` *environment. The code for this caption appears at the beginning of the* `table` *environment. It would have had the desired distance to the tabular if the default caption setup of* rtthesis *was used, but this document has been set up for table captions below the corresponding tabular.*

| Chapter | Title | Page |
|---|---|---|
| 1 | Introduction | 1 |
| 3 | Results | 9 |
| B | *rtthesis* documentation and LaTeX tips | 17 |
| A | Trista saker | 15 |

***Table B.8:*** *Different combinations of class options that affects the* `definition` *environment. The code for this caption appears at the end of the* `table` *environment. It will be too close to the tabular using the default settings of* rtthesis *(but note that this document has been setup differently, see avsnitt B.10).*

| | `definition=` | | |
|---|---|---|---|
| | **naked** | **theorem** | **marks** |
| **noparskip** | OK | Avoid | OK |
| **parskip** | Bad | Avoid | OK |

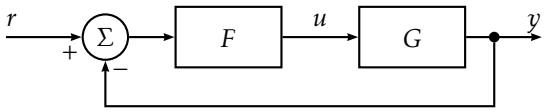


***Figure B.1:*** *A simple illustration in a floating* `figure` *environment. Note that figure captions are always placed under the corresponding figure, and hence that the caption code should always appear at the end of the* `figure` *environment.*

***Table B.9:*** *Class options related to (hyper) linking infrastructure.*

| Class option | Meaning |
|---|---|
| `hyperref` | Turn on hyperlinks using the hyperref package. Default. |
| `nohyperref` | Turn off hyperlinks, and compensate for commands no longer provided by the hyperref package. |
| `backref` | Turn on bibliography back references. Default. |
| `nobackref` | Turn off bibliography back references. (Currently required if you plan to use the features of bibunits.) |

problem is that LiU-tryck creates a compressed version of the file that is used in the printer, and the compression will remove nice features such as page numbers, hyperlinks, and bookmarks. Fortunately, the guys at e-press seem to be understanding and will accept to publish a file that they receive directly from you.

### B.11.3 Page number formatting in the index

If you use an index in your thesis, you will often want to change the formatting of certain page numbers in the index. Without hyperref, this could look like

```
hyperlinks\index{hyperlinks|textit}
```

to get the page number for this occurrence of *hyperlinks* to be typeset in italics. The problem with this is that this page number will not be a hyperlink, while other page numbers will be hyperlinks to the correct page. To get both italics and a hyperlink you need to define a special index formatting commands like the following.

```
\newcommand{\hyperpageit}[1]{\textit{\hyperpage{#1}}}
\newcommand{\hyperpagebf}[1]{\textbf{\hyperpage{#1}}}
\newcommand{\hyperpagefootnote}[1]{\hyperpage{#1}n}
```

Now, you can write

```
hyperlinks\index{hyperlinks|hyperpageit}
```

to get both italics and a hyperlink. The *rtthesis* class will provide a trivial definition of `\chapter` in case hyperref is not loaded, so you may safely start to use the above definitions even if you are not sure whether you will use hyperlinks in the end.

### B.11.4 Friendlier hyperlinks

The default mechanism for references in LaTeX, being the command `\ref`, is modified as expected by the hyperref package. For instance, the number in “chapter B”

is linked to the beginning of the current chapter (if you click it, be sure to just the *jump back* function of your PDF viewer to get back to here!). However, all of "this" is also a link to the same place. That is, it is possible to other things than the number itself as links. We could also make a reference that will never be linked, like in "chapter B".

So, what's so friendly about this? What I'm aiming at is that you can say "chapter B". The code for this link is

```
\hyperref[cha:rtthesis]{chapter~\ref*{cha:rtthesis}}
```

Of course, it is very annoying to repeat the key twice; first to point the hyperlink to the correct place, second to show the number of the chapter. With the `\autoref` command from the hyperref bundle, we get "Appendix B". This is almost perfect. The problem is that one cannot get an uppercase initial at the beginning of a sentence without redefining "chapter" to "Chapter",

```
\renewcommand{\Chaptername}{Chapter}
```

but then we will not get the nice lower case initial in the middle of a sentence. Many authors don't bother about this and use uppercase initials irrespectively of where in a sentence the reference appears.

The only solution I (Henrik Tidefelt) knows of, is to define special commands for each type of reference. A basic solution might look as follows.

```
\newcommand{\chapterref}[1]{\hyperref[#1]{chapter~\ref*{#1}}}
\newcommand{\Chapterref}[1]{\hyperref[#1]{Chapter~\ref*{#1}}}
```

You should then use `\chapterref` in the middle of a sentence, and `\Chapterref` at the beginning of a sentence. I you later decide that you want to have upper case initials everywhere, you just have to change your definitions to

```
\newcommand{\chapterref}[1]{\hyperref[#1]{Chapter~\ref*{#1}}}
\newcommand{\Chapterref}[1]{\hyperref[#1]{Chapter~\ref*{#1}}}
```

A more complete solution will also provide commands for the plural forms "chapters" and "Chapters".

It is also nice to use a similar technique for page references. For instance, this chapter starts on page 17, and such links can be created easily using a command like

```
\newcommand{\pagepageref}[1]{\hyperref[#1]{page~\pageref*{#1}}}
```

Because of the many possible preferences for how to handle labels and references within documents, *rtthesis* does not define any related commands. The current section should give you some ideas of what can be achieved, and now it is up to you to design your own solution or borrow a solution from someone else (or simply stick with `\autoref` or the 1980's way of doing things)!

## B.12 Backreferences from the bibliography

By default, *rtthesis* uses the backref package to put references from the bibliography back into the text. The options for turning this feature on and off are listed in tabell B.9.

By controlling this feature via the class, the choice whether to use it or not can be made orthogonal to the choice of whether to use hyperref or not.

In addition to just loading backref, *rtthesis* will do a basic setup of the commands used to typeset the list of page numbers for each reference. This behavior can easily be redefined without modifying the *rtthesis* class file. See the backref documentation for details on how to do this!

## B.13 Using the bibentry package

The bibentry package makes it possible to use the information in the bibliography to present your publications at any place in the document. In order to work independently of whether you use back references from the bibliography or not, you need to follow the pattern below each time you use the `\bibentry` command, where `KEY` is the same key to you publication that you would with use with any other citation command.

```
\begin{quotation}
  \nocite{KEY}\noindent
  \backrefparscanfalse\bibentry{KEY}.\backrefparscantrue
\end{quotation}
```

To use the `quotation` environment is just a suggestion — it will make the reference stand out by using a some what shorter text line width. Note the period that follows the `\bibentry` command — the command leaves it up to you how to terminate the entry. The `\nocite` command ensures that the reference appears in the bibliography, which is necessary to produce the entry. The `\noindent` commands simply prevents the first line in the `quotation` from being indented. The commands `\backrefparscanfalse` and `\backrefparscantrue` are related to the backref package used to produce back references from the bibliography, and should always surround the `\bibentry` command. In case you have turned back references off using the `nobackref`, *rtthesis* will provide substitutes for these two commands.

## B.14 Fonts

Though basically not a task for a LaTeX class, *rtthesis* will assist in loading some font packages. There are some class options that control this behavior, described below, and if these options are not good enough for you, you may have to make your own copy of the class and replace the font packages you don't like. Options for font selection are listed in tabell B.10.

One reason, however, for letting *rtthesis* handle the font selection is that this makes it possible for the class to do some things more intelligently. At the mo-

***Table B.10:*** *Class options related to fonts. When slanted small caps are activated, theorem-like environments will use slanted text instead of italics. The lower part of the table are examples of options that will be understood by the kpfonts package, and are only meaningful in combination with the* `kp` *option. (Note that options passed to* rtthesis*, but that are not understood by* rtthesis *will be passed on automatically by LaTeX to loaded packages.)*

| Class option | Meaning |
|---|---|
| `kp` | Use KpFonts (Kepler) and activate slanted small caps. Default. |
| `times` | Use Times and deactivate slanted small caps. |
| `lm` | Use Latin Modern and deactivate slanted small caps. |
| `largesmallcaps` | Let the small caps be slightly higher than an *x*. See the KpFonts documentation! |
| `intlimits` | Placement of integration limits. See the KpFonts documentation! |
| `widermath` | Put just a little more horizontal space between entities in math mode. See the KpFonts documentation! |

ment, *rtthesis* will help you make use of some of the goodies of KpFonts, if you choose to use that font.

## B.15 Hanging punctuation

The *rtthesis* class automatically loads the pdfcprot package with its default settings. It uses a pdfTeX feature to make punctuation hang into the right margin. If you don't like it, make your own copy of the class and comment out the line that loads the package. One reason not to use it would be if your document will be (perhaps only occasionally) typeset using the old TeX program, since this will lead to noticeable differences in the line breaks compared to when pdfTeX is used. No matter what you choose, make your choice *before* you start working with the page breaks in your document!

## B.16 Paragraph breaks

There are two common ways of visualizing paragraph breaks in a document, illustrated by the two examples below. The look of paragraph breaks is controlled using the class options listed in tabell B.11.

***Table B.11:*** *Class options related to formatting of paragraph breaks.*

| Class option | Meaning |
|---|---|
| `noparskip` | US style, see exempel B.8. Default. |
| `parskip` | European style, see exempel B.9. |

**Example B.8: Indented first line**

This style is still the most common. It is particularly dominant in text written in the US.

It is a matter of style whether to omit the indentation of the first line after a sectioning command such as `\chapter` or `\subsection`. The omission is typically automated, but can also be enforced using the `\noindent` command.

One drawback of not having vertical space between paragraphs is that it will be harder for pdfTeX to find good places for page breaks, compared to the option shown below. If you like compact documents, however, this is the option for you!

For testing purposes, this example ends with a paragraph break, so that TeX is in *vmode* at the end. You should always avoid this, but the class will try to compensate for your mistakes...

**Example B.9: Vertical white space**

This style is still increasing in popularity. It is rather common in modern texts written in Europe, and the style has received special attention from the Netherlands TeX user group *Nederlandstalige TeX Gebruikersgroep, NTG*. Their efforts can be used through their variants of the standard LaTeX classes.

Unfortunately, the NTG classes are not compatible with *rtthesis*, and the solution provided by the parskip package is only part of the solution. Hence, *rtthesis* will do more than just loading the parskip package for you if you specify the `parskip` option.

A good reason to put code related paragraph breaks in the class file is that all the small adjustments that different people come up with can be put in one placed so that they are accessible to future users of the class.

## B.17 Page breaks

There is a whole lot to say about how to obtain nice page breaks. You will find some recommendations below, but do not use this document as your ultimate reference on this topic! (This document itself contains some really nasty page breaks — at least at the time of writing this — as a result of not paying any attention at all to the problem. It would simply bee too time-consuming to keep adjusting the page breaks each time the document is edited.)

- Take no consideration of page breaks until page breaking is the only aspect of your thesis that remains to be taken care of! Page breaking involves a lot of manual intervention of the automatic mechanisms in pdfTEX, and as soon as you have started to intervene, any further changes to the text will risk to ruin your page breaking fixes, and may even lead to worse results than before since the automatic page breaking has been tampered with.

- First thing to try is to make changes to the text to help the automatic page breaking mechanism. Try to make sentences longer or shorter depending on the situation. Since this will not tamper with the automatic page breaking mechanism, this option will incur the least loss of maintainability of your document.

- Can the location of floats be changed to improve page breaks? Play around with exactly where in your source files the code for the floating environments appears!

- You may also try to force early page breaks using the `\Needspace*` command. For instance, putting

  ```
  \Needspace*{2\baselineskip}
  ```

  before a paragraph will cause a page break if there is not enough vertical space on the page to hold two lines of text. The good thing about this option is that your intervention will cause no harm if the `\Needspace*` command appears in the middle of a page. The bad thing about this option is that it may cause remaining vertical space on the broken page to be stretched quite badly. You should always check that the resulting page looks OK!

  For more information, and related commands, see the documentation for the needspace package!

- The last option is to play with the vertical size of individual pages. For instance, putting

  ```
  \enlargethispage{2\baselineskip}
  ```

  before a paragraph you would like to fit into the current page will make space for two extra lines of text. This avoids the bad stretching of vertical space that the `\Needspace*` option may cause. However, if you would make other changes that makes tampering with the page size unnecessary, it will be very time-consuming to detect this and remove the no longer needed `\enlargethispage` command.

Note that manual page breaking is a time-consuming task. Make sure to have at least one full day allocated to page breaking before you submit your thesis for print!

***Table B.12:*** *Class options related to input encodings. Note that there is no default;* rtthesis *requires one of these options to be passed explicitly.*

| Class option | Meaning |
|---|---|
| `latin1` | Simply use inputenc with option `latin1`. |
| `utf8` | Use inputenc with option `utf8`, and define some additional characters. |

## B.18 Input encoding

Two input encodings are supported, being latin-1 and UTF-8. The choice of input encoding should be made via the *rtthesis* class, so that the class can use the correct encoding to define certain global strings. The input encoding options are listed in tabell B.12.

Choose latin-1 if you depend on lots of files using this encoding, and do not want to change the encoding of these files. Changing the encoding of a file is easy both in Emacs and using the *iconv* command line utility. The latin-1 encoding is the default in *rtthesis*, but the choice can be made explicit by passing the `latin1` option to the class.

Choose UTF-8 to be able to type many more characters directly in your LaTeX sources compared to latin-1. For instance, names of foreign authors often use characters that cannot be entered directly using latin-1. In UTF-8, most of these as well as special punctuation characters such as double quotes and various dashes can be entered directly in the source. Use the `utf8` class option if your files are encoded in UTF-8.

The current implementation of UTF-8 in the inputenc package only defines the input encoding for characters that have corresponding glyphs in active fonts (see the inputenc documentation for details). This means that some characters that TeX would build by combining several glyphs will not be defined by inputenc. If the `utf8` is given, *rtthesis* will define a list of additional characters by inclusion of the package rtthesis-utf8-ext. If you need additional characters, you should make your own package similar to rtthesis-utf8-ext, and then let the maintainer of *rtthesis* know, so that the additional characters may be added to rtthesis-utf8-ext so that others can use them in the future. Note that rtthesis-utf8-ext may be a useful package also when you are not using the *rtthesis* class.

It is easy to set up Emacs so that it uses the UTF-8 encoding for your TeX files, but it is out of the scope of the current document to give further explanations here.

## B.19 *rtthesis* and natbib

Interoperability with different bibliography packages is a tricky issue. It has been a design decision to try to support at least natbib, at the cost of loosing compatibility with other packages such as jurabib. The core of the problem is package loading

***Table B.13:*** *Class options related to the natbib package. Note that options can be passed to natbib by passing them as global class options to* rtthesis. *See the natbib documentation for more useful options.*

| Class option | Meaning |
|---|---|
| `authoryear` | Default option of natbib — no need to specify. |
| `round` | Default option of natbib — no need to specify. |
| `colon` | Default option of natbib — no need to specify. |
| `square` | Example of option that natbib will pick up (alternative to `round`). |
| `comma` | Example of option that natbib will pick up (alternative to `colon`). |
| `numbers` | Conflicting natbib option — forbidden in combination with `usebibunits`, see `forcenumbers` below. |
| `forcenumbers` | Enforce option `numbers` to be passed to natbib (alternative to `authoryear`) — it's up to you to resolve the conflict. |

order, requiring natbib to be loaded very early on in the class. To pass options to natbib, pass them as global class options to *rtthesis*. Note that the default options for natbib are quite reasonable, and see tabell B.13 for examples of other options that natbib will pick up. If you know how to resolve the conflict with the natbib option `usebibunits`, let the *rtthesis* maintainer know!

## B.20 The lists of previous theses

The lists of previous licentiate's and PhD theses can be found in *liclist.tex* and *phdlist.tex*, respectively, and the appropriate one of the is automatically included at the end of your thesis. Both files are found in the directory *$TEXMFGROUPLOCAL/tex/latex/rt/rtthesis* .

Note that it is *your responsibility* to make sure that your thesis is added to the appropriate list after you have sent it to print but before the next thesis of the same kind is printed. If other people are writing theses at the same time as you, you will have to coordinate your moves in order to make sure that the lists get updated in the correct order. To get your thesis added to the appropriate list, you simply send an email with information about your thesis to the *rtthesis* maintainer. The information shall be in one of the following formats:

```
\licitem{J.~Doe}{Title}{Thesis No}{YYYY}
```

or

```
\phditem{J.~Doe}{Title}{Theis No}{YYYY}{ISBN}
```

It is a good idea to make a copy of the file you need when it is time to print. If you don't make a copy, and then compile your thesis again at a later time, the list will be wrong because it will include at least one thesis that wasn't prior to yours — namely your own!

## B.21 Compilation theses

The *rtthesis* class aims to support the production of both monographs and compilation theses. There is a compilation thesis example included with *rtthesis*. Please have a look at that while reading the sections below!

### B.21.1 Including publications in your thesis

It is assumed that included publications shall be compiled together with the rest of your thesis, as opposed to being included as exactly the way the look where published. Under this assumption, it is reasonable to expect things such as a suitable chapter numbering, and that the global table of contents includes the sections withing publications. Note that it would be rather difficult to get things such as the table of contents and other infrastructure right if publications were to be included by direct PDF inclusion.

The `papers` environment provided by *rtthesis* will redefine commands and set up some additional commands to support the inclusion of LaTeX sources of your publication. It is recommended that the environment is placed in a second part of the thesis. Inside the environment, the `\chapter` command is redefined to both start a new chapter and set up the title of the publication to be included in the same chapter. Chapters will be labeled with letters instead of numbers, so it is up to you to make a clear distinction between referencing an appendix chapter and a publication chapter.

If the title of a publication is too long to fit in the page header, you may follow the `\chaptermark` command by a `\chaptermark` command. Since the `\chaptermark` command takes an optional argument to be used in the table of contents, there are three different variations of the publication title that can be defined.

The word for publications used by *rtthesis* is *paper*; it will appear both on the chapter title page and in page headers. To change this to something else, you simply have to redefine `\chaptername` to something else inside the `papers` environment.

After setting up the publication title, the `\author` command should be used to set up the list of authors. It works as usual, but sports two special *rtthesis* commands that should be used when there are two author affiliations; put `\authorleft` immediately after author names who's affiliation should appear to the left below

the list of authors, and put `\authorright` after the other authors. There is currently no support for more than two different affiliations.

In case there is only one affiliation, that affiliation is given by `\paperaffiliation` (which should be set once and for all to your own affiliation), and you use the `\email` command to specify the list of email addresses to the authors.

In case of two affiliations, you call the commands `\affilblockleft`,`\affilblockrig` `\emailleft`, and `\emailright` with the appropriate arguments. Note that one of the two affiliation block arguments should simply be `\paperaffiliation`.

Additional information about the publication is given in after `\item` commands inside the `paperinfo` environment. In addition to the items given, the environment automatically starts with one item displaying the author information (without any marks related to affiliation blocks). Three commands are defined by *rtthesis* to simplify consistent formatting of additional information.

- `\paperedited`*`bib-key`* — For ordinary publications. The extent to which the publication has been edited should be state clearly. The bibliography entry will be formatted using the technique described in avsnitt B.13.

- `\paperprelver`*`ISY-report-number`* — For publications for which there is only a preliminary version available. The preliminary version should be published as a technical report at the department, and as no bibliography keys are involved, the technical report will not be listed in any the bibliography.

- `\papertechrep`*`ISY-report-number`* — For publications that are not yet even preliminary versions of something. These too should be published as technical reports at the department, and will not appear in the bibliography.

At this point the chapter title page will be finished. The next step is to make a nice title and abstract for your publication on the following odd page. Use `\maketitle` or `\maketitletwoaffil` depending on whether you set up one or two affiliation blocks. Then put the publication abstract inside the `abstract` environment.

After this point, you should just be able to include the source of your publication, with `\section` as the topmost sectioning command (since the publication itself is a chapter of your thesis).

Finally, you must decide where your references should go. Should there be one global bibliography for the whole thesis, or should there be one bibliography for each publication. This is the topic of the next section.

### B.21.2 Compilation theses and bibliographies

If you are fine with having just one global bibliography for the whole thesis, everything should work out of the box. Hence, this section will try to describe how to do in order to get one bibliography for the background part of your thesis, and one for each publication.

The *rtthesis* class only supports this by relying on the bibunits package. Due to package loading order issues, it should always be loaded by passing `usebibunits` to *rtthesis*. Note that some of the bibunits commands appears to be incompatible with bibliography back references, so you need to pass the `nobackref` to *rtthesis* if you plan to use the bibunits features.

*Remark B.10.* There is a very interesting package called biblatex which is currently in beta version. Hopefully, it will let us drop the messy packages bibunits and backref. You are invited to try this package, and if you find it to work satisfactory it should probably be incorporated in *rtthesis*. Future maintainers of *rtthesis* are strongly encouraged to find out what biblatex can do for us!

Use the command `\defaultbibliography` to specify the bibliography files to use for all of the per-publication bibliographies, and use `\defaultbibliographystyle` to select the bibliography style, see the bibunits documentation for details.

To get an individual bibliography for a publication, you should just have to include that chapter in a `bibunit` environment, and call `\putbib` where you want the bibliography to appear. Here, the `\putbib` command will be redefined by *rtthesis* in order to make the bibliography appear in the table of contents.

A bibliography for references that appear in the background part of your thesis are produced as usual with the `\bibliography` command. (It might be good to know that *rtthesis* will automatically issue the `\nobibliography*` command in order to make the bibentry package work as you would expect.)

## B.22 Master's theses

The liuthesis class by Gustaf Hendeby was developed for the production of master's theses at Linköping University. The class knows how to create the special pages required by several departments, and in the summer of 2011 this capability was merged into *rtthesis*. This makes it convenient to produce a master's thesis at Linköping University using *rtthesis* instead of liuthesis, allowing a wider audience to benefit from the more active development of *rtthesis*.[3]

This section describes how to use *rtthesis* to produce a master's thesis. To begin, pass *msc* as the value for the key *type* in the call to `\setupThesis`, and select your department using the key *department*. More details are given below, and the reader is encouraged to study the bundled example in order to get a better overall picture.

### B.22.1 Master's thesis setup

In addition to the pieces of information given to `\setupThesis` for licentiate's and PhD theses (see tabell B.2), there are some that only apply to master's theses. These are listed in tabell B.14.

[3] The LaTeX class files tend to be maintained by PhD students, and PhD students have a tendency to be more interested in maintaining the class files for writing licentiate's and PhD theses than class files for master's theses.

***Table B.14:*** *`\setupThesis` key-value pairs for master's theses, in addition to those listed in tabell B.2. Note that values that include white space are surrounded by braces.*

| Key = Example value | Comment |
|---|---|
| swetitle = {Svensk titel} | Title in Swedish |
| swesubtitle = {Bra grejer} | Optional Swedish subtitle |
| month = 4 | |
| day = 9 | |
| subject = reglerteknik | |
| site = {Bosses AB i Linkan} | |
| division = {Avdelningenrt...} | |
| department = isy | See tabell B.15 |
| examiner = {Lena Lärare...} | Details given below |
| supervisor = {Doktorand Si} | Details given below |
| keywords = {this, that} | Appears on library page |
| isrn = LiTH-ISY-EX... | See below |
| url = {http://...} | Thesis download URL, see below |

The value for the key *department* must be one of the special values listed in tabell B.15. This setting controls both the department name and address, as well as how the special pages of the thesis are formatted. Please help the *rtthesis* maintainer to keep the special pages for your department up to date.

In the values for the keys *examiner* and *supervisor*, multiple persons should be separated using `\AND`, and the affiliation of a person should appear after `\AT`, like this:

```
supervisor={Doktorand Si \AT \textsc{isy}, Linköpings universitet
       \AND Ingenjör Så \AT Företaget},
```

The ISRN[4] should be something like

```
isrn=LITH-ISY-EX-{}-YY/NNNN-{}-SE
```

but the format varies between different departments. Note that if the report identifier contains two or three consecutive dashes, they have to be separated by empty braces in the input to prevent LaTeX from interpreting them as one character. The thesis download URL should be something like

```
url={http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-XXXXX}
```

The exact details regarding the report number and URL will be given to you by the librarian when you register your thesis.

[4] The ISO standard for ISRN was withdrawn in 2007, but the report numbering system is still in use at Linköping University.

***Table B.15:*** *Recognized values for the key* department *in tabell B.14.*

| department | Department of... | Updated |
|---|---|---|
| ida | Computer and Information Science | Not after 2008-08-01 |
| ifm | Physics, Chemistry and Biology | 2011-07-03 |
| iei | Management and Engineering | *Out of date!* |
| isy | Electrical Engineering | 2011-07-03 |
| itn | Science and Technology | 2011-07-03 |
| mai | Mathematics | 2011-07-03 |

### B.22.2 Special pages

The requirements on a master's thesis include that certain information go on the front page and title page of the thesis. Further, a library page for cataloging purposes is required at the beginning of the thesis, and a page with copyright information is required at the end. The copyright page is automatically added at the end. The other special pages can be produced using the macros `\makeFrontPage`, `\maketitle` (as usual), and `\makeLibraryPage`. These macros are meant to be invoked more or less immediately after `\begin{document}`, see the bundled example for details. Note that in the printed report, the front page should be replaced by the cover, and the library page is *probably* meant to be on a loose piece of paper inserted between the cover and the title page.

There is no magic that puts the correct abstract on the library page, but the abstract must be given as an argument to `\makeLibraryPage`. To make sure that this is exactly the same as the abstract in the thesis, it is recommended that you write the abstract text without any surrounding `abstract` environment in a separate file, say *svensk-sammanfattning.tex*. Then you can use this file twice, like this:

```
\makeLibraryPage{\input{svensk-sammanfattning}}

\begin{abstract}[swedish]
  \input{svensk-sammanfattning}
\end{abstract}
```

(The bundled example uses this technique.)

### B.22.3 Choice of language

If your main report language will be Swedish, put

```
\selectlanguage{swedish}
```

right after

```
\begin{document}
```

Also make sure to provide the thesis title (and possibly subtitle) in Swedish via the keys *swetitle* and *swesubtitle* to `\setupThesis`. You may then omit writing an abstract in English.

If your main report language will be English you don't need to change the default choice of language. However, you must provide a thesis title both in English and Swedish, and the thesis should contain abstracts in both English and Swedish.

## B.23 Compiling the document

Using all the current features of *rtthesis*, the following sequence of steps is usually sufficient to compile your document. Let us assume your main file is named *main.tex*.

- First run

  ```
  pdflatex main
  ```

  to scan your document for references, labels, and index items.

- Then run

  ```
  bibtex main
  ```

  to extract relevant references from your bibliography file(s). If you are using the bibunits package, you also have to process some additional files;

  ```
  bibtex bu1; bibtex bu2; ...; bibtex bun
  ```

- If you have an index in your document, run

  ```
  makeindex main
  ```

  to format it.

- Then run

  ```
  pdflatex main
  ```

  to insert references in the typeset document. This will typically move things around, and your page references will be invalidated.

- Hopefully, it is enough to run

  ```
  pdflatex main
  ```

  once more now to get the page references right. You will get a warning if you need to repeat this step.

In addition to the steps above, certain auxiliary files must be deleted when certain features of the class are turned on or off. In particular, turning hyperlinks on or off requires the following.

```
rm main.aux main.toc main.ind
```

***Table B.16:*** *Files with logotype graphics used by* rtthesis. *Use the command* `kpsewhich` *to find where the files are located!*

| Filename | Use |
|---|---|
| *LinkUniv_sigill_sv.pdf* | For the cover and the first page in PhD theses. |
| *LiTH_staende_eng_sv.pdf* | For the cover of both licentiate's and PhD theses. |
| *rtlogo_tall.pdf* | For the first page in licentiate's theses. |

## B.24 Generating a thesis cover and the "spikblad"

A thesis cover can be created by making a file that contains the `\makecover` command. For example, given that *mythesis.sty* invokes the `\setupThesis` command with the necessary information (see tabell B.2), a PhD thesis cover can be made as follows.

```
\documentclass[utf8,phd]{rtthesis}
\usepackage{mythesis}

\makecover
```

Note that while all licentiate's theses should have the same cover, there is no standard (but many rules set by the university!) for the PhD theses. The `\makecover` command gives a "classic" cover that quite a few people have used over the years. This cover might also be useful as a means to compile the information needed when LiU-Tryck (or some other printing company) designs a more artistic cover.

For a dissertation, there should always be a "spikblad" (literally, *nailing sheet*). Such an information sheet can be generated easily if the English abstract is put in a separate file. In this case, the same abstract can be included both in the thesis and in a separate file that defines the "spikblad". For a licentiate's thesis presentation, a similar information sheet should be produced. The monograph example demonstrates how to created these, see the files *spikblad.tex* (for dissertations) and *licinfo.tex* (for licentiate's thesis presentations).

## B.25 Required logotypes (not included with *rtthesis*)

Tabell B.16 lists files with logotype graphics that are needed by *rtthesis*. They are not part of the *rtthesis* bundle since they are used in many other contexts as well. Users at the Division of Automatic Control should have access to these files via the group's common texmf tree, but in order to be able to work at home you will have to make sure one way or another that the files are installed.

Beware that the university changes logos quite often. Make sure that there are no new versions of the logos you use. If the logos are old, please, let the *rtthesis* maintainer know so that the files get updated at the central location.

## B.26 Compatibility with standard packages

Incompatibilities between different packages is a problem that quickly becomes quite an issue when the list of packages used in a document grows beyond just a few. It may sound strange, but it is because of compatibility problems that *rtthesis* includes a rather long list of packages for you. The reason is that this allows knowledge about package loading order requirements and various workarounds, to be encoded in the class file.

No list of packages included by *rtthesis* will be presented here, but you should check the class file directly to be sure that you always get the correct answer to whether a package is included or not (or you can just read the compilation output).

Packages with no known compatibility issues will generally not be included by *rtthesis* unless needed by the class itself. The following list contains some examples of useful packages that are not included by *rtthesis*. They *should* be compatible with *rtthesis*. Please let the *rtthesis* maintainer know if any of these are no longer compatible, or if you have suggestions for other packages that should be mentioned here.

- nextpage — page break control
- algorithm — code listings
- listings — code listings
- SIunits — physical dimensions
- pmat — partitioned matrices
- bm — bold math
- footmisc — extras for footnotes
- dcolumn — decimal point alignment in tables (the already included array can also do this)
- lettrine — start chapter with fancy letter
- supertabular — multi-page tables
- longtable — multi-page tables
- multirow — tabular entries occupying more than one row

# Bibliography


[1] Z. Cheng, Q. Yang, and B. Sheng. Deep Colorization. *ArXiv e-prints*, April 2016. Cited on page 6.

[2] Hassan K. Khalil. *Nonlinear systems*. Prentice Hall, Inc., third edition, 2002. Cited on page 24.

[3] C.-Y. Lee, S. Xie, P. Gallagher, Z. Zhang, and Z. Tu. Deeply-Supervised Nets. *ArXiv e-prints*, September 2014. Cited on page 7.

[4] Lapo Filippo Mori. Tables in LaTeX $2_\varepsilon$: Packages and methods. *The PracTeX Journal*, 2007(1), 2007. URL `http://tug.org/pracjourn/2007-1/mori`. Cited on pages 20 and 26.

[5] Wilson J. Rugh. *Linear system theory*. Prentice-Hall, Inc., second edition, 1996. Cited on page 24.

[6] Marek Ryćko and Bugosław Jackowski. TeX from \indent to \par. *TUGboat*, 14(3), 1993. URL `http://www.tug.org/TUGboat/Articles/tb14-3/tb40rycko.pdf`. Cited on pages 24 and 26.