

# **A rule-based geospatial reasoning system for trip price calculations**



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This dissertation is submitted for the degree of  
*Bachelor Software Engineering*

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## Acknowledgements

Before you lies the graduation report that displays all the accomplishments and research conducted during the final phase of my Bachelor Software Engineering study at the Amsterdam University of Applied Sciences, written to fulfill the graduation requirements. The moment I was introduced to my assignment reminded me of a chapter in a book called Clean Code, in which this exact pursuit is used as a common example for which the book would provide solutions; "Now the two teams are in a race. The tiger team must build a new system that does everything that the old system does. Not only that, they have to keep up with the changes that are continuously being made to the old system. Management will not replace the old system until the new system can do everything that the old system does." [6]. This challenge, I could not have accomplished without the help of my colleagues, therefore I would like to thank Dan Stefancu, Marco Strijker and Martin Zwaneveld for their insightful criticism that has led to the most useful lessons during my internship.

Stefan Schenk

Andijk, 01-05-2018



## **Abstract**

A purely geometrical interpretation of user-defined locations would allow taxi-companies around the world to set up rules so that trip prices could be calculated without depending on distinct postal code systems. Geolocation datatypes provide part of the solution, but the benefits of geometrical definitions are lost when areas intersect. A precedence hierarchy of rules that are tied to reusable locations would eliminate these competing rule matches.

A solution is proposed to implement a microservice with a single responsibility of calculating trip prices that is accessible to existing systems and portals in which users can define the pricing rules. The company for which this system is realized requires customers to be able to migrate to the new system without downtime, while keeping the existing rules that determine the prices of taxi trips.

The core system manages user and company data, this complicates identity management in the microservice. A JSON Web Token would allow user identity to be stored in the payload of the token, thereby delegating authentication to the core system, maintaining the single responsibility of the microservice.





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# Chapter 1

## Introduction

Automatic fare estimations and calculations are one of many common features to go hand in hand with taxi dispatch systems. A potential passenger wants to book a ride using a mobile app. The passenger selects the pickup and drop off locations, upon which a list of available vehicles and corresponding prices is displayed. The passenger selects the desired vehicle from the list, and a taxi arrives to take the passenger to the selected destination. When the destination is reached, the system calculates the final price, with or without discounts, including taxes, and additional costs added by the driver. Based on whether the passenger ordered a ride from the center of Amsterdam, or a desolate hard to reach location, the directors of a taxi company want to make a profit. For this reason, companies must be able to define prices based on locations. The project for which this thesis is written aims to improve the process of defining prices based on various factors, one of which is geographical locations.

### 1.1 Context

The company for which the project is realised is taxiID, an Amsterdam based company providing end-to-end cloud solutions for taxi companies. Founded as a startup that successfully introduced smartphone taxi booking in The Netherlands, and offers a wide range of IT solutions to serve the taxi market, including a passenger app, a driver app, administrative panels, and track and trace hardware. taxiID solutions have proven to be a reliable set of tools for all size businesses. For independent taxi companies with 2 cars or a companies with large fleets, affordable solutions are available. taxiID's goal is to deliver affordable, time-saving solutions for taxi companies to allow for convenient planning and dispatching without requiring local installation. Though based in Amsterdam, the development team is located in Medemblik, consisting of two mobile developers, two backend developers, a de-

signer and two project managers. Clients are located across the globe, introducing challenges when developing applications that rely on clearly defined locations and infrastructures that vastly differ between countries. YourDriverApp (YDA) is a light version of the original solution that is offered by taxiID more focussed on smaller taxi companies. Currently this label depends on services within taxiID to operate, which has to change in the near future.

## 1.2 Assignment

YDA requires its own pricing calculation functionality that is similar to the existing taxiID implementation. All functionalities within the current system align with the clients demands, but some features introduce difficulties, for example: region names are too vague for specific database queries. A system must be implemented in which group admins can define pricing rules based on user defined locations and time schedules, that can be used for calculating a passengers trip price, or show prices of different products based on the trip the passenger is about to make. In the current system, locations are uploaded by taxi company group admins as excel sheets with departure and destination zip codes in conjunction with prices. This process works in countries with an unambiguous, explicit, well-defined postal code infrastructure. Postal codes are matched in efficient database queries, leaving less room for improvement in terms of performance. Interpretability is an issue however. Sheets may contain thousands of rows, making it hard to interpret and maintain. On top of that, countries without such systems are not covered by the functionality. There are two more types of pricing rules that cover the rest of trip pricing cases. A tier price system, that calculates fixed prices based cascading thresholds, and a dynamic pricing system that calculates prices per distance unit and minute. The term 'distance unit' is used on purpose, as distances are measured using different metrics in various countries. Pricing rules should be constrained by time frames, making rules available only for some hours a day, or only on christmas for example. Rules should be specifiable per product as different vehicle types have different prices, but are included in the same pricing rules. Discounts may be calculated with the trip price, and VAT should be displayed in the price breakdown. Some additional requirements to the system may be added in later phases, as Scrum will be used to manage work iterations (this fact will be covered later in this chapter). The system should be accessible to other systems, meaning that applications that currently rely on the old system should be able to migrate to the new system. As the old system shouldn't be used for new applications, as it was not designed for this use case. The system should have a single responsibility, and should be atonomous in that regard.



## 1.3 Research

Three main challenges that construct the assignment can be identified. Research must be done to attain the best possible way of mapping locations to pricing rules. What this means is that locations must be storable, comparable, and interpretable. The database must be able to store locations in an efficient manner, to which queries can be made as efficiently in order to find out whether a pricing rule applies to a given ride. For this to be the case, the stored locations must be comparable to the location of the passenger, or the destination. The user must be able to reason about his pricing rules, from which an understanding of his defined locations logically follows. But edge cases must be covered completely. For example, a rule in the current system dictates that a user traveling to Schiphol should receive a discount. But how would the system detect that this is the case? Or what if hotel guests receive discounts, but the neighbour shouldn't be allowed to use these discounts? Secondly, a system has to be developed that encapsulates the solution that is the result of the conducted research. It is helpful to extend the research of the problem to finding out how to incorporate the answers into a working system, where architecture has a major influence in the tools that are available. For example: if a solution to the main problem requires a database system capable of handling high quantities of geospatial queries, this requirement has to be satisfied in order to proceed in finding the final solution. Finally, a user interface has to be created that enables users to define the pricing rules. The complexity of the interface depends on how straight forward the price calculation system is put together. The user interface should also be available in multiple portals. The best way of making the systems capabilities available to the user through the UI in the portal, must be investigated.

### 1.3.1 Research Questions

From the description of the problem, one main important research question can be derived: *How can a generic location-based price calculation system be implemented that is usable around the globe?*

This question encapsulates the three important challenges that have to be dealt with before the project can successfully be implemented. In order to give a clear direction to the research, sub-questions are separated into three groups; location mapping, architecture and user interface.

1. In what way can locations be represented to be universally interpretable?
  - (a) Which types of locations should be distinguished?

- (b) What are the main differences between postal systems used around the globe?
  - (c) Can postal codes be abstracted to geospatial data while retaining the same usefulness in the system?
  - (d) How can different types of locations be effectively stored in a database?
2. Which architectural pattern is best suited for implementing the pricing system?
- (a) Which architectural patterns fit in with the existing architecture?
  - (b) How will authentication be handled?
  - (c) Which database will be suited for this project?
3. How can the task of defining rules be as insightful as possible to the user?
- (a) Which views should exist, does a logical hierarchy exist among views?
  - (b) How should locations be defined and managed by the user?
  - (c) How should timeframes be handled in the interface?

## 1.4 Process

The first group of questions will be answered in the chapter Theory. The second and third will be answered in the chapter Proposed Approach. At that point, enough knowledge is available to implement a solution. Scrum will be used to iteratively implement the solution. This project is taxiID's first project to make use of Scrum and Jira for project management.

# **Chapter 2**

## **Theory**

Additional to investigating solutions for the challenges, a concise literature review may be conducted to discover potential existing solutions that are comparable to the current implemented solution at taxiID. But definitions of what must be achieved should be explicit and according to the goals set by the product owner.

### **2.1 Defining a Location**

### **2.2 Literature Review**



# **Chapter 3**

## **Proposed Approach**

### **3.1 Methods and Techniques**



# Chapter 4

## Realization

### 4.1 What is loren ipsum? Title with math $\sigma$

Lorem Ipsum is simply dummy text of the printing and typesetting industry (see Section 4.3). Lorem Ipsum [3] has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum [1, 4, 5].

The most famous equation in the world:  $E^2 = (m_0c^2)^2 + (pc)^2$ , which is known as the **energy-mass-momentum** relation as an in-line equation.

A *LaTeX class file* is a file, which holds style information for a particular *LaTeX*.

$$CIF : \quad F_0^j(a) = \frac{1}{2\pi i} \oint_{\gamma} \frac{F_0^j(z)}{z-a} dz \quad (4.1)$$

### 4.2 Why do we use loren ipsum?

It is a long established fact that a reader will be distracted by the readable content of a page when looking at its layout. The point of using Lorem Ipsum is that it has a more-or-less normal distribution of letters, as opposed to using 'Content here, content here', making it look like readable English. Many desktop publishing packages and web page editors now use Lorem Ipsum as their default model text, and a search for 'lorem ipsum' will uncover many

web sites still in their infancy. Various versions have evolved over the years, sometimes by accident, sometimes on purpose (injected humour and the like).

### 4.3 Where does it come from?

Contrary to popular belief, Lorem Ipsum is not simply random text. It has roots in a piece of classical Latin literature from 45 BC, making it over 2000 years old. Richard McClintock, a Latin professor at Hampden-Sydney College in Virginia, looked up one of the more obscure Latin words, *consectetur*, from a Lorem Ipsum passage, and going through the cites of the word in classical literature, discovered the undoubtable source. Lorem Ipsum comes from sections 1.10.32 and 1.10.33 of "de Finibus Bonorum et Malorum" (The Extremes of Good and Evil) by Cicero, written in 45 BC. This book is a treatise on the theory of ethics, very popular during the Renaissance. The first line of Lorem Ipsum, "Lorem ipsum dolor sit amet..", comes from a line in section 1.10.32.

The standard chunk of Lorem Ipsum used since the 1500s is reproduced below for those interested. Sections 1.10.32 and 1.10.33 from "de Finibus Bonorum et Malorum" by Cicero are also reproduced in their exact original form, accompanied by English versions from the 1914 translation by H. Rackham

"Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum."

Section 1.10.32 of "de Finibus Bonorum et Malorum", written by Cicero in 45 BC: "Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo. Nemo enim ipsam voluptatem quia voluptas sit aspernatur aut odit aut fugit, sed quia consequuntur magni dolores eos qui ratione voluptatem sequi nesciunt. Neque porro quisquam est, qui dolorem ipsum quia dolor sit amet, consectetur, adipisci velit, sed quia non numquam eius modi tempora incidunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur?"

1914 translation by H. Rackham: "But I must explain to you how all this mistaken idea of denouncing pleasure and praising pain was born and I will give you a complete



account of the system, and expound the actual teachings of the great explorer of the truth, the master-builder of human happiness. No one rejects, dislikes, or avoids pleasure itself, because it is pleasure, but because those who do not know how to pursue pleasure rationally encounter consequences that are extremely painful. Nor again is there anyone who loves or pursues or desires to obtain pain of itself, because it is pain, but because occasionally circumstances occur in which toil and pain can procure him some great pleasure. To take a trivial example, which of us ever undertakes laborious physical exercise, except to obtain some advantage from it? But who has any right to find fault with a man who chooses to enjoy a pleasure that has no annoying consequences, or one who avoids a pain that produces no resultant pleasure?"

Section 1.10.33 of "de Finibus Bonorum et Malorum", written by Cicero in 45 BC: "At vero eos et accusamus et iusto odio dignissimos ducimus qui blanditiis praesentium voluptatum deleniti atque corrupti quos dolores et quas molestias excepturi sint occaecati cupiditate non provident, similique sunt in culpa qui officia deserunt mollitia animi, id est laborum et dolorum fuga. Et harum quidem rerum facilis est et expedita distinctio. Nam libero tempore, cum soluta nobis est eligendi optio cumque nihil impedit quo minus id quod maxime placeat facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et aut officiis debitis aut rerum necessitatibus saepe eveniet ut et voluptates repudiandae sint et molestiae non recusandae. Itaque earum rerum hic tenetur a sapiente delectus, ut aut reiciendis voluptatibus maiores alias consequatur aut perferendis doloribus asperiores repellat."

1914 translation by H. Rackham: "On the other hand, we denounce with righteous indignation and dislike men who are so beguiled and demoralized by the charms of pleasure of the moment, so blinded by desire, that they cannot foresee the pain and trouble that are bound to ensue; and equal blame belongs to those who fail in their duty through weakness of will, which is the same as saying through shrinking from toil and pain. These cases are perfectly simple and easy to distinguish. In a free hour, when our power of choice is untrammelled and when nothing prevents our being able to do what we like best, every pleasure is to be welcomed and every pain avoided. But in certain circumstances and owing to the claims of duty or the obligations of business it will frequently occur that pleasures have to be repudiated and annoyances accepted. The wise man therefore always holds in these matters to this principle of selection: he rejects pleasures to secure other greater pleasures, or else he endures pains to avoid worse pains."



# Chapter 5

## Conclusion

### 5.1 Reasonably long section title

I'm going to randomly include a picture Figure 5.1.

If you have trouble viewing this document contact Krishna at: [kks32@cam.ac.uk](mailto:kks32@cam.ac.uk) or raise an issue at <https://github.com/kks32/phd-thesis-template/>

### Enumeration

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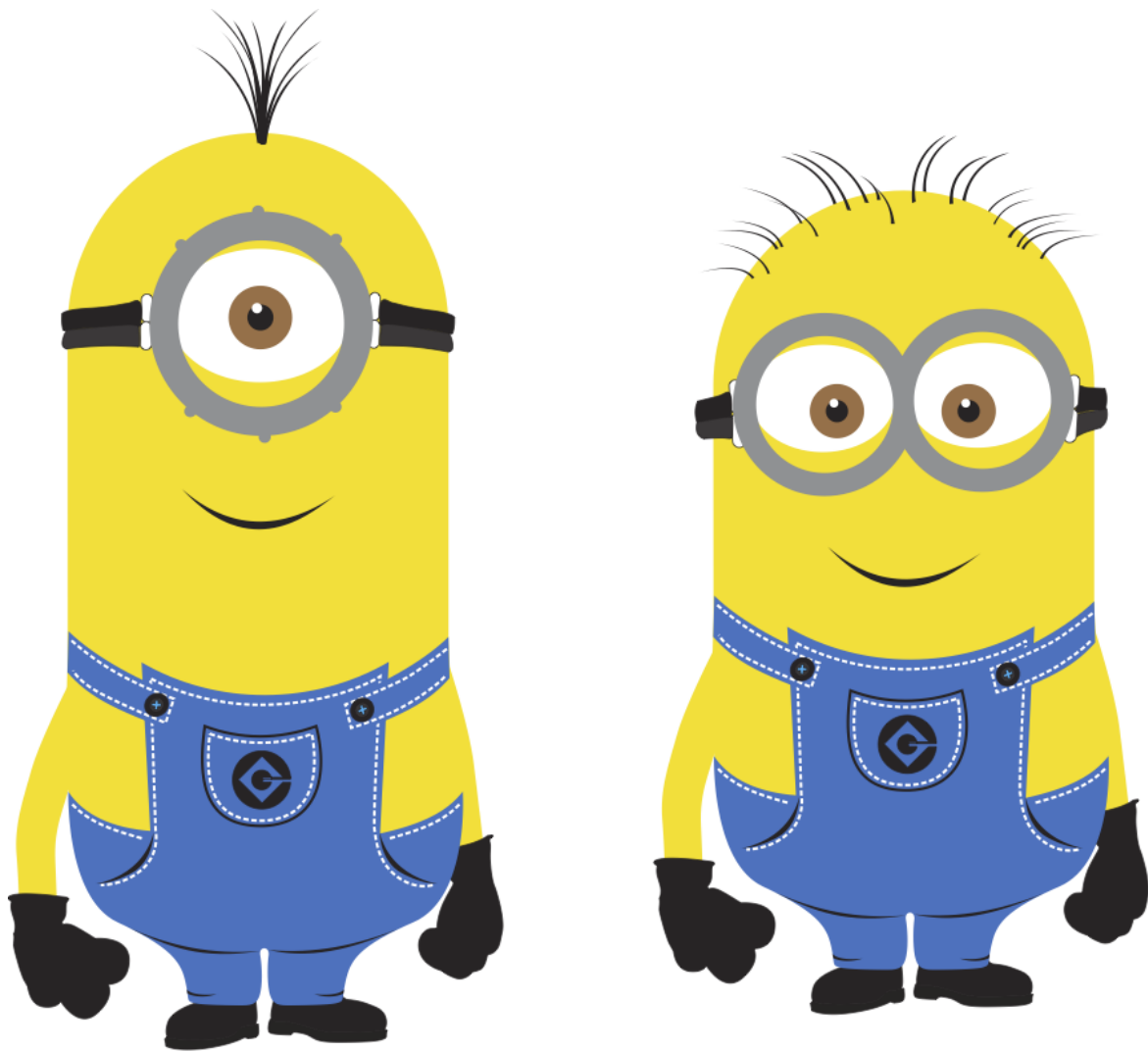


Fig. 5.1 This is just a long figure caption for the minion in Despicable Me from Pixar

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1. The first topic is dull
2. The second topic is duller
  - (a) The first subtopic is silly
  - (b) The second subtopic is stupid
3. The third topic is the dullest

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## Itemize

- The first topic is dull
- The second topic is duller
  - The first subtopic is silly
  - The second subtopic is stupid
- The third topic is the dullest

## Description

**The first topic** is dull

**The second topic** is duller

**The first subtopic** is silly

**The second subtopic** is stupid

**The third topic** is the dullest

## 5.2 Hidden section

**Lorem ipsum dolor sit amet, consectetur adipiscing elit.** In magna nisi, aliquam id blandit id, congue ac est. Fusce porta consequat leo. Proin feugiat at felis vel consectetur. Ut tempus ipsum sit amet congue posuere. Nulla varius rutrum quam. Donec sed purus luctus, faucibus velit id, ultrices sapien. Cras diam purus, tincidunt eget tristique ut, egestas quis nulla. Curabitur vel iaculis lectus. Nunc nulla urna, ultrices et eleifend in, accumsan ut erat. In ut ante leo. Aenean a lacinia nisl, sit amet ullamcorper dolor. Maecenas blandit, tortor ut scelerisque congue, velit diam volutpat metus, sed vestibulum eros justo ut nulla. Etiam nec ipsum non enim luctus porta in in massa. Cras arcu urna, malesuada ut tellus ut, pellentesque mollis risus. Morbi vel tortor imperdiet arcu auctor mattis sit amet eu nisi. Nulla gravida urna vel nisl egestas varius. Aliquam posuere ante quis malesuada dignissim. Mauris ultrices tristique eros, a dignissim nisl iaculis nec. Praesent dapibus tincidunt mauris nec tempor. Curabitur et consequat nisi. Quisque viverra egestas risus, ut sodales enim blandit at. Mauris quis odio nulla. Cras euismod turpis magna, in facilisis diam congue non. Mauris faucibus nisl a orci dictum, et tempus mi cursus.

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<sup>1</sup>My footnote goes blah blah blah! ...



Fig. 5.2 Best Animations

Subplots

I can cite Wall-E (see Fig. 5.2b) and Minions in despicable me (Fig. 5.2c) or I can cite the whole figure as Fig. 5.2



# Chapter 6

## Recommendations

### 6.1 First section of the third chapter

And now I begin my third chapter here ...

And now to cite some more people Read [7], Ancey et al. [2]

#### 6.1.1 First subsection in the first section

...and some more

#### 6.1.2 Second subsection in the first section

...and some more ...

##### First subsub section in the second subsection

...and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

#### 6.1.3 Third subsection in the first section

...and some more ...

##### First subsub section in the third subsection

...and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it and some more and some more and some more and some more and some more and some more and some more ...

### Second subsub section in the third subsection

... and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

## 6.2 Second section of the third chapter

and here I write more ...

## 6.3 The layout of formal tables

This section has been modified from “Publication quality tables in L<sup>A</sup>T<sub>E</sub>X<sup>\*</sup>” by Simon Fear.

The layout of a table has been established over centuries of experience and should only be altered in extraordinary circumstances.

When formatting a table, remember two simple guidelines at all times:

1. Never, ever use vertical rules (lines).
2. Never use double rules.

These guidelines may seem extreme but I have never found a good argument in favour of breaking them. For example, if you feel that the information in the left half of a table is so different from that on the right that it needs to be separated by a vertical line, then you should use two tables instead. Not everyone follows the second guideline:

There are three further guidelines worth mentioning here as they are generally not known outside the circle of professional typesetters and subeditors:

3. Put the units in the column heading (not in the body of the table).
4. Always precede a decimal point by a digit; thus 0.1 *not* just .1.
5. Do not use ‘ditto’ signs or any other such convention to repeat a previous value. In many circumstances a blank will serve just as well. If it won't, then repeat the value.

A frequently seen mistake is to use ‘`\begin{center}`’ ... ‘`\end{center}`’ inside a figure or table environment. This center environment can cause additional vertical space. If you want to avoid that just use ‘`\centering`’

Table 6.1 A badly formatted table

|                    | Species I |      | Species II |      |
|--------------------|-----------|------|------------|------|
| Dental measurement | mean      | SD   | mean       | SD   |
| I1MD               | 6.23      | 0.91 | 5.2        | 0.7  |
| I1LL               | 7.48      | 0.56 | 8.7        | 0.71 |
| I2MD               | 3.99      | 0.63 | 4.22       | 0.54 |
| I2LL               | 6.81      | 0.02 | 6.66       | 0.01 |
| CMD                | 13.47     | 0.09 | 10.55      | 0.05 |
| CBL                | 11.88     | 0.05 | 13.11      | 0.04 |

Table 6.2 A nice looking table

| Dental measurement | Species I |      | Species II |      |
|--------------------|-----------|------|------------|------|
|                    | mean      | SD   | mean       | SD   |
| I1MD               | 6.23      | 0.91 | 5.2        | 0.7  |
| I1LL               | 7.48      | 0.56 | 8.7        | 0.71 |
| I2MD               | 3.99      | 0.63 | 4.22       | 0.54 |
| I2LL               | 6.81      | 0.02 | 6.66       | 0.01 |
| CMD                | 13.47     | 0.09 | 10.55      | 0.05 |
| CBL                | 11.88     | 0.05 | 13.11      | 0.04 |

Table 6.3 Even better looking table using booktabs

| Dental measurement | Species I |      | Species II |      |
|--------------------|-----------|------|------------|------|
|                    | mean      | SD   | mean       | SD   |
| I1MD               | 6.23      | 0.91 | 5.2        | 0.7  |
| I1LL               | 7.48      | 0.56 | 8.7        | 0.71 |
| I2MD               | 3.99      | 0.63 | 4.22       | 0.54 |
| I2LL               | 6.81      | 0.02 | 6.66       | 0.01 |
| CMD                | 13.47     | 0.09 | 10.55      | 0.05 |
| CBL                | 11.88     | 0.05 | 13.11      | 0.04 |



# References

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- [3] Aupetit, B. (1991). *A Primer on Spectral Theory*. Springer-Verlag, New York.
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- [6] Martin, R. C. (2008). *Clean Code*. Prentice Hall.
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# Appendix A

## How to install L<sup>A</sup>T<sub>E</sub>X

### Windows OS

#### TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from  
<https://www.tug.org/texlive/>
2. Download WinCDEmu (if you don't have a virtual drive) from  
<http://wincdemu.sysprogs.org/download/>
3. To install Windows CD Emulator follow the instructions at  
<http://wincdemu.sysprogs.org/tutorials/install/>
4. Right click the iso and mount it using the WinCDEmu as shown in  
<http://wincdemu.sysprogs.org/tutorials/mount/>
5. Open your virtual drive and run setup.pl

or

#### Basic MikTeX - T<sub>E</sub>X distribution

1. Download Basic-MiK<sub>T</sub>E<sub>X</sub>(32bit or 64bit) from  
<http://miktex.org/download>
2. Run the installer
3. To add a new package go to Start » All Programs » MikTeX » Maintenance (Admin)  
and choose Package Manager

4. Select or search for packages to install

## **TexStudio - T<sub>E</sub>X editor**

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Run the installer

## **Mac OS X**

### **MacTeX - T<sub>E</sub>X distribution**

1. Download the file from  
<https://www.tug.org/mactex/>
2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

### **TexStudio - T<sub>E</sub>X editor**

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Extract and Start

## **Unix/Linux**

### **TeXLive - T<sub>E</sub>X distribution**

#### **Getting the distribution:**

1. TeXLive can be downloaded from  
<http://www.tug.org/texlive/acquire-netinstall.html>.
2. TeXLive is provided by most operating system you can use (rpm,apt-get or yum) to get TeXLive distributions



## Installation

1. Mount the ISO file in the mnt directory

```
mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
```

2. Install wget on your OS (use rpm, apt-get or yum install)
3. Run the installer script install-tl.

```
cd /your/download/directory
./install-tl
```

4. Enter command 'i' for installation
5. Post-Installation configuration:  
<http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1>
6. Set the path for the directory of TexLive binaries in your .bashrc file

### For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

### For 64bit OS

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
```

```
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;  
export INFOPATH
```

**Fedora/RedHat/CentOS:**

```
sudo yum install texlive  
sudo yum install psutils
```

**SUSE:**

```
sudo zypper install texlive
```

**Debian/Ubuntu:**

```
sudo apt-get install texlive texlive-latex-extra  
sudo apt-get install psutils
```

# Appendix B

## Installing the CUED class file

$\text{\LaTeX}$ .cls files can be accessed system-wide when they are placed in the  $\langle\text{texmf}\rangle/\text{tex}/\text{latex}$  directory, where  $\langle\text{texmf}\rangle$  is the root directory of the user's  $\text{\TeX}$  installation. On systems that have a local  $\text{texmf}$  tree ( $\langle\text{texmflocal}\rangle$ ), which may be named “ $\text{texmf-local}$ ” or “ $\text{localtexmf}$ ”, it may be advisable to install packages in  $\langle\text{texmflocal}\rangle$ , rather than  $\langle\text{texmf}\rangle$  as the contents of the former, unlike that of the latter, are preserved after the  $\text{\LaTeX}$  system is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory  $\langle\text{texmf}\rangle/\text{tex}/\text{latex}/\text{CUED}$  for all CUED related  $\text{\LaTeX}$  class and package files. On some  $\text{\LaTeX}$  systems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For  $\text{\TeX}$ Live systems this is accomplished via executing “ $\text{texhash}$ ” as root.  $\text{MikTeX}$  users can run “ $\text{initexmf -u}$ ” to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in  $\text{\LaTeX}$ .



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