My Final College Paper

A Thesis
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The Division of History and Social Sciences
Reed College

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Arts

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The cat, Grindle.

Preface

This is an example of a thesis setup to use the reed thesis document class.

List of Abbreviations

You can always change the way your abbreviations are formatted. Play around with it yourself, use tables, or come to CUS if you'd like to change the way it looks. You can also completely remove this chapter if you have no need for a list of abbreviations. Here is an example of what this could look like:

AI	Artificial Intelligence
MAS	Multi-Agent System
MDP	Markov Decision Processes
ML	Machine Learning

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Abstract

The preface pretty much says it all.

Dedication

You can have a dedication here if you wish.

Introduction

Welcome to the LaTeX thesis template. If you've never used TeX or LaTeX before, you'll have an initial learning period to go through, but the results of a nicely formatted thesis are worth it for more than the aesthetic benefit: markup like LaTeX is more consistent than the output of a word processor, much less prone to corruption or crashing and the resulting file is smaller than a Word file. While you may have never had problems using Word in the past, your thesis is going to be about twice as large and complex as anything you've written before, taxing Word's capabilities. If you're still on the fence about using LaTeX, read the Introduction to LaTeX on the CUS site as well as skim the following template and give it a few weeks. Pretty soon all the markup gibberish will become second nature.

0.1 Why use it?

LaTeX does a great job of formatting tables and paragraphs. Its line-breaking algorithm was the subject of a PhD. thesis. It does a fine job of automatically inserting ligatures, and to top it all off it is the only way to typeset good-looking mathematics.

0.2 Who should use it?

Anyone who needs to use math, tables, a lot of figures, complex cross-references, IPA or who just cares about the final appearance of their document should use LaTeX. At Reed, math majors are required to use it, most physics majors will want to use it, and many other science majors may want it also.

Chapter 1

Agent Systems

This chapter lays out the background material of multi-agent systems–what they are, how they work, and why economists might be interested in them–that drives the rest of the thesis.

1.1 Agents

An **agent** is something that acts. This comes from the Latin word agere, to do. In general, anything might be considered an agent so long as it can perceive the environment and act upon it. A **rational agents** is something that acts to achieve the best outcome or with uncertainty, the best expected outcome in a given situation. For example we are agents, we have the ability to take an action and effect the world. We even might be considered rational since we are generally trying to navigate the world around us so as to try and lead to our preferred outcome. People are not the only agents, animals and machines are also agents capable of acting on the world around them.

1.1.1 In Economics

In economics many of the models are constructed with utility maximizing agents in line with Decision Theory and Rational Choice Theory. Because economics seeks to understand the outcomes of peoples interactions, and perhaps how these outcomes could be improved, if people can be modeled as utility maximizers, it is then possible to analytically solve for this solution and see what the results are.

The primary purpose of constructing agents in economics is to see how their interactions play out in an economic setting that can not be solved analytically.

1.1.2 In Artificial Intelligence

In artificial intelligence, the primary purpose of understanding agents is to try and create the most effective artificial agents possible. This discipline cares deeply about how good the agents they are able to make are able to solve problems, either general or specific. To do this, they use much of the theory of agents with a deep emphasis on how a constructed agent can be taught or learn from its environment to achieve its goals.

1.2 Formal Model of Agents

This section lays out a more formal definition of agents, specifically geared towards constructed or artificial agents such as we will be constructing. An **agent** is anything that can be viewed as perceiving its environment through sensors and acting upon its environment through actuators. A **precept** is a perceptual input to an agent, and a **precept sequence** is the complete history of everything the agent has ever perceived. The agent then has an **agent function** that maps these precepts to an action. In the case of an artificial agent this is done with an **agent program** that is the physical implementation of the agent function. In the case of an agent simulated on a computer, this will be the computer code that decides what action to take. The agents actions will then cause the environment to go through a series of states and the agent will measure the outcome with some **performance measure**.

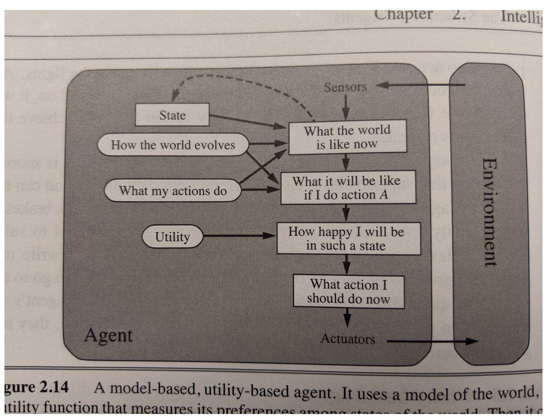

Figure 1.1: Utility Based Agent

For our purposes we focus on what are called **utility based agents**, where the agent has a utility function as an internalized performance measure and is able to numerically assign values of "goodness" to the outcome from the agents perspective. A rational agent will always try to maximize average expected utility over its lifetime as explained by decision theory.

1.2.1 Task Environment

The environment that an agent exists in and their relationship to it is critical for understanding the system as a whole. For example the environment can fully observable with the agent's sensors able to see the entire environment, or only partially observable to the agent. There can also be multiple agents within the system, each trying to maximize their own performance measure. This is called a **multi-agent system** and it will be a key aspect of all of the simulations we construct. It is important to note that the agents in the multi-agent system share no internal state and must communicate (if they so wish to do so) through the environment. The environment can also be deterministic or stochastic, either depending entirely upon its current state and the agents actions or contains randomness.

1.2.2 Agents Who Learn

Learning is a critical part of being a rational agent. We expect that as agents interact with their environment, they should be able to adapt and change in order to continue to maximize their utility. The general model of an artificial agent who learns is as follows.

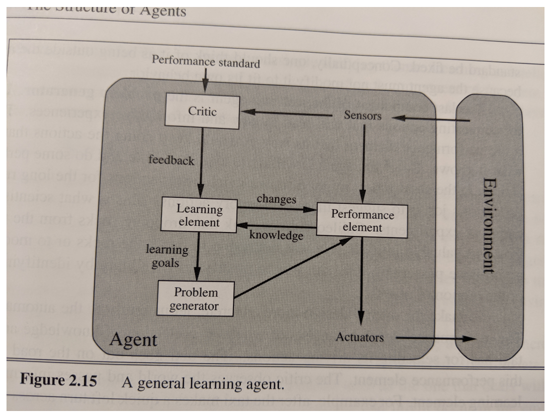

Figure 1.2: Model of Agent that Learns

First, the agent reprieves its environment and sends that information to the performance function that determines what it will do. There is now a critic that gives feedback for how the agent is doing based on aprori information and the observed state that sends feedback to a learning element that can change the behavior of the performance element. Based on what the learning element is trying improve, there is also a problem generator that suggests actions to the performance element so that different actions can be tested and evaluated.

Chapter 2

Reinforcement Learning

Reinforcement learning has become a popular way of teaching agents how to play games and interact with each other in Machine Learning (ML). Because the dynamics and behavior of a final simulation are determined by the learning algorithm used for its composing agents, we spend some time developing the ideas of reinforcement learning in both a single agent and multi-agent setting.

2.1 Single Agent Learning

Reinforcement learning is the area of machine learning where agents learn through repeated interactions with their dynamic environment. This section gives a brief overview of learning algorithms used by single agents with a focus on deep reinforcement learning. In general, reiforcment learning formalizes the interaction of agents and environment using a Markov decision process (MDP).

Definition: Markov Decision Process
A Markov decision process is 5-tuple $\langle \mathcal{S}, \mathcal{A}, R, T, \gamma \rangle$ where,
1. $\mathcal{S}$ represents a finite set of states
2. $\mathcal{A}$ represents a finite set of actions
3. T is a transition function $T : \mathcal{S} \times \mathcal{A} \times \mathcal{S} \to [0, 1]$ that determines the probability of transitioning from any state $s \in \mathcal{S}$ to any state $s^{'} \in \mathcal{S}$ given any possible action $a \in A$
4. R is the reward function $R : \mathcal{S} \times \mathcal{A} \times \mathcal{S} \to \mathbb{R}$
5. $\gamma \in [0, 1]$ is the discount factor that balances immediate and future rewards

2.1.1 Q-Learning

Q-Learning is an an algorithm that has been developed for single-agent, fully observable environments with discrete actions. Q learning involves creating a table of expected payoffs for each action a available at a state s denoted $\hat{Q}(s, a)$. Each time the agent transitions from a state s to a state $s^{'}$ taking an action a and recieving payoff r, the Q table is updated according to the following assignment:

$$\hat{Q}(s,a) \leftarrow \hat{Q}(s,a) + \alpha[(r + \gamma max_{a^1}\hat{Q}(s^{'},a^{'})) - \hat{Q}(s,a)]$$

2.2 Chemistry 101: Symbols

2.2.1 Typesetting reactions

2.3 Physics

2.4 Biology

Chapter 3

Tables and Graphics

3.1 Tables

The following section contains examples of tables, most of which have been commented out for brevity. (They will show up in the .tex document in red, but not at all in the .pdf). For more help in constructing a table (or anything else in this document), please see the LaTeX pages on the CUS site.

Table 3.1: Correlation of Inheritance Factors between Parents and Child

Factors	Correlation between Parents & Child	Inherited
Education	-0.49	Yes
Socio-Economic Status	0.28	Slight
Income	0.08	No
Family Size	0.19	Slight
Occupational Prestige	0.21	Slight

If you want to make a table that is longer than a page, you will want to use the longtable environment. Uncomment the table below to see an example, or see our online documentation.

Table 3.2: Chromium Hexacarbonyl Data Collected in 1998–1999

Chromium Hexacarbonyl			
State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
$z^7P_4^\circ$	266 nm	Argon	1.5
$z^7P_2^\circ$	355 nm	Argon	0.57
$y^7P_3^\circ$	266 nm	Argon	1
$y^7P_3^\circ$	355 nm	Argon	0.14
$y^7P_2^\circ$	355 nm	Argon	0.14
$z^5P_3^\circ$	266 nm	Argon	1.2
$z^5P_3^\circ$	355 nm	Argon	0.04
$z^5P_3^\circ$	355 nm	Helium	0.02
$z^5P_2^\circ$	355 nm	Argon	0.07
$z^5P_1^\circ$	355 nm	Argon	0.05
$y^5P_3^\circ$	355 nm	Argon	0.05, 0.4
$y^5P_3^\circ$	355 nm	Helium	0.25
$z^5F_4^\circ$	266 nm	Argon	1.4
$z^5F_4^\circ$	355 nm	Argon	0.29
$z^5F_4^\circ$	355 nm	Helium	1.02
$z^5D_4^\circ$	355 nm	Argon	0.3
$z^5D_4^\circ$	355 nm	Helium	0.65
$y^5H_7^\circ$	266 nm	Argon	0.17
$y^5H_7^\circ$	355 nm	Argon	0.13
$y^5H_7^\circ$	355 nm	Helium	0.11
a^5D_3	266 nm	Argon	0.71
a^5D_2	266 nm	Argon	0.77
a^5D_2	355 nm	Argon	0.63
a^3D_3	355 nm	Argon	0.05
a^5S_2	266 nm	Argon	2
a^5S_2	355 nm	Argon	1.5
a^5G_6	355 nm	Argon	0.91
a^3G_4	355 nm	Argon	0.08
e^7D_5	355 nm	Helium	3.5
e^7D_3	355 nm	Helium	3
f^7D_5	355 nm	Helium	0.25
f^7D_5	355 nm	Argon	0.25
f^7D_4	355 nm	Argon	0.2
f^7D_4	355 nm	Helium	0.3
Propyl-ACT			

State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
$z^7P_4^\circ$	355 nm	Argon	1.5
$z^7P_3^\circ$	355 nm	Argon	1.5
$z^7P_2^\circ$	355 nm	Argon	1.25
$z^7F_5^\circ$	355 nm	Argon	2.85
$y^7P_4^\circ$	355 nm	Argon	0.07
$y^7P_3^\circ$	355 nm	Argon	0.06
$z^5P_3^\circ$	355 nm	Argon	0.12
$z^5P_2^\circ$	355 nm	Argon	0.13
$z^5P_1^\circ$	355 nm	Argon	0.14
Methyl-ACT			
$z^7P_4^\circ$	355 nm	Argon	1.6, 2.5
$z^7P_4^\circ$	355 nm	Helium	3
$z^7P_4^\circ$	266 nm	Argon	1.33
$z^7P_3^\circ$	355 nm	Argon	1.5
$z^7P_2^\circ$	355 nm	Argon	1.25, 1.3
$z^7F_5^\circ$	355 nm	Argon	3
$y^7P_4^\circ$	355 nm	Argon	0.07, 0.08
$y^7P_4^\circ$	355 nm	Helium	0.2
$y^7P_3^\circ$	266 nm	Argon	1.22
$y^7P_3^\circ$	355 nm	Argon	0.08
$y^7P_2^\circ$	355 nm	Argon	0.1
$z^5P_3^\circ$	266 nm	Argon	0.67
$z^5P_3^\circ$	355 nm	Argon	0.08, 0.17
$z^5P_3^\circ$	355 nm	Helium	0.12
$z^5P_2^\circ$	355 nm	Argon	0.13
$z^5P_1^\circ$	355 nm	Argon	0.09
$y^5H_7^\circ$	355 nm	Argon	0.06, 0.05
a^5D_3	266 nm	Argon	2.5
a^5D_2	266 nm	Argon	1.9
a^5D_2	355 nm	Argon	1.17
a^5S_2	266 nm	Argon	2.3
a^5S_2	355 nm	Argon	1.11
a^5G_6	355 nm	Argon	1.6
e^7D_5	355 nm	Argon	1

3.2 Figures

If your thesis has a lot of figures, LaTeX might behave better for you than that other word processor. One thing that may be annoying is the way it handles "floats" like tables and figures. LaTeX will try to find the best place to put your object based on the text around it and until you're really, truly done writing you should just leave it where it lies. There are some optional arguments to the figure and table environments to specify where you want it to appear; see the comments in the first figure.

If you need a graphic or tabular material to be part of the text, you can just put it inline. If you need it to appear in the list of figures or tables, it should be placed in the floating environment.

To get a figure from StatView, JMP, SPSS or other statistics program into a figure, you can print to pdf or save the image as a jpg or png. Precisely how you will do this depends on the program: you may need to copy-paste figures into Photoshop or other graphic program, then save in the appropriate format.

Below we have put a few examples of figures. For more help using graphics and the float environment, see our online documentation.

And this is how you add a figure with a graphic:

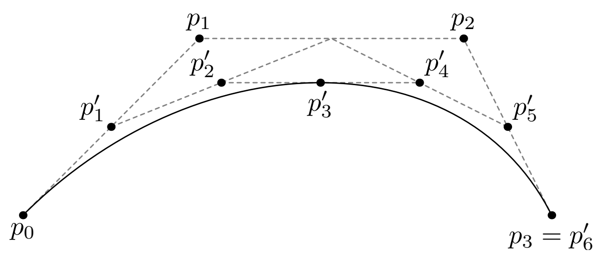

Figure 3.1: A Figure

3.3 More Figure Stuff

You can also scale and rotate figures.

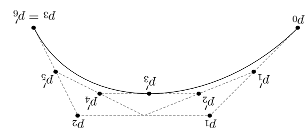

Figure 3.2: A Smaller Figure, Flipped Upside Down

3.4 Even More Figure Stuff

With some clever work you can crop a figure, which is handy if (for instance) your EPS or PDF is a little graphic on a whole sheet of paper. The viewport arguments are the lower-left and upper-right coordinates for the area you want to crop.

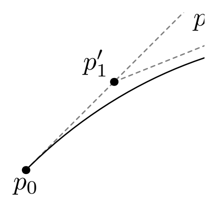

Figure 3.3: A Cropped Figure

3.4.1 Common Modifications

The following figure features the more popular changes thesis students want to their figures. This information is also on the web at `web.reed.edu/cis/help/latex/graphics.html`.

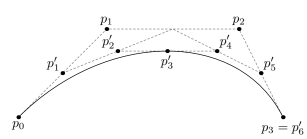

Figure 3.4: Subdivision of arc segments. You can see that $p_3 = p_6'$.

Conclusion

Here's a conclusion, demonstrating the use of all that manual incrementing and table of contents adding that has to happen if you use the starred form of the chapter command. The deal is, the chapter command in LaTeX does a lot of things: it increments the chapter counter, it resets the section counter to zero, it puts the name of the chapter into the table of contents and the running headers, and probably some other stuff.

So, if you remove all that stuff because you don't like it to say "Chapter 4: Conclusion", then you have to manually add all the things LaTeX would normally do for you. Maybe someday we'll write a new chapter macro that doesn't add "Chapter X" to the beginning of every chapter title.

4.1 More info

And here's some other random info: the first paragraph after a chapter title or section head *shouldn't be* indented, because indents are to tell the reader that you're starting a new paragraph. Since that's obvious after a chapter or section title, proper typesetting doesn't add an indent there.

Appendix A

The First Appendix

Appendix B

The Second Appendix, for Fun

References

Angel, E. (2000). *Interactive Computer Graphics : A Top-Down Approach with OpenGL*. Boston, MA: Addison Wesley Longman.

Angel, E. (2001a). *Batch-file Computer Graphics : A Bottom-Up Approach with QuickTime*. Boston, MA: Wesley Addison Longman.

Angel, E. (2001b). *test second book by angel*. Boston, MA: Wesley Addison Longman.

Deussen, O., & Strothotte, T. (2000). Computer-generated pen-and-ink illustration of trees. *"Proceedings of" SIGGRAPH 2000*, (pp. 13–18).

Fisher, R., Perkins, S., Walker, A., & Wolfart, E. (1997). *Hypermedia Image Processing Reference*. New York, NY: John Wiley & Sons.

Gooch, B., & Gooch, A. (2001a). *Non-Photorealistic Rendering*. Natick, Massachusetts: A K Peters.

Gooch, B., & Gooch, A. (2001b). *Test second book by gooches*. Natick, Massachusetts: A K Peters.

Hertzmann, A., & Zorin, D. (2000). Illustrating smooth surfaces. *Proceedings of SIGGRAPH 2000*, *5*(17), 517–526.

Jain, A. K. (1989). *Fundamentals of Digital Image Processing*. Englewood Cliffs, New Jersey: Prentice-Hall.

Molina, S. T., & Borkovec, T. D. (1994). The Penn State worry questionnaire: Psychometric properties and associated characteristics. In G. C. L. Davey, & F. Tallis (Eds.), *Worrying: Perspectives on theory, assessment and treatment*, (pp. 265–283). New York: Wiley.

Noble, S. G. (2002). *Turning images into simple line-art*. Undergraduate thesis, Reed College.

Reed College (2007). Latex your document. `http://web.reed.edu/cis/help/LaTeX/index.html`

Russ, J. C. (1995). *The Image Processing Handbook, Second Edition*. Boca Raton, Florida: CRC Press.

Salisbury, M. P., Wong, M. T., Hughes, J. F., & Salesin, D. H. (1997). Orientable textures for image-based pen-and-ink illustration. *"Proceedings of" SIGGRAPH 97*, (pp. 401–406).

Savitch, W. (2001). *JAVA: An Introduction to Computer Science & Programming*. Upper Saddle River, New Jersey: Prentice Hall.

Wong, E. (1999). *Artistic Rendering of Portrait Photographs*. Master's thesis, Cornell University.