My Final College Paper

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I want to thank a few people.

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:

DMX	Digital Multiplex
sACN	Columbia Broadcasting System
Artnet	Center for Disease Control
CIA	Central Intelligence Agency
CLBR	Center for Life Beyond Reed
CUS	Computer User Services
FBI	Federal Bureau of Investigation
NBC	National Broadcasting Corporation

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Abstract

The preface pretty much says it all.

Dedication

You can have a dedication here if you wish.

Introduction

This thesis explores lighting control, specifically for live performance. It will take a look at how lighting was originally controlled manually, how the technology has advanced to today through the use of time coding, and proposes a system for control that is reactive to a performer. Lighting control has advanced at a breakneck speed over the past half-century as the world entered a digital age. Where lighting control rooms were packed with levers and room-scale dimming racks now sit lighting desks, or even just a laptop. As the technology for controlling lights has advanced, the lighting design for live performances has gotten more complicated, while being largely prerecorded. Thus, while a designer's vision is accomplished in collaboration with the director and performers, it stays static barring catastrophe, which introduces interesting problems. Consider the actor who moves in tandem to a moving light. This is usually accomplished through hours of rehearsal, and fine-tuning movements in order to keep pace with the light. However, if the actor in a particular showing wanted to modify a movement, either in the route or in the speed, they would be constrained by the lighting.

This thesis attempts to aleviate those constraints by creating a lighting control scheme that tracks a performer through a theatrical space. It is a reactive scheme that hopes to meet a few criteria: 1) The scheme must be lightweight; 2) The scheme must be able to run using off-the-shelf components and computing resources; 3) The scheme must be open source; 4) The scheme should run on top of existing theater infrastructure. It is worth mentioning that this concept is not revolutionary. There are numerous choices for high-end performer tracking offered by the likes of Cast Group's BLACKTRAX, Follow-Me, and zactrack. However, these systems are often closed-source, prohibitively expensive, hardware intensive, or otherwise difficult for small productions to access. The software developed during this thesis hopes to try to make it easier to access, which is why the scheme has criteria.

This thesis is spread across three(?) chapters. The first is a literature review of the theory and practice behind lighting control. It will start at the very beginning, mechanical ropes and pulleys, hiding and revealing gas lamps, all the way to the modern control systems that run live performance today. It will look at how the jump from analog to digital control marked a shift in the complexity of lighting design. It will explore how this technology differs over productions of different sizes with the theory that that technology often "trickles down" from high-end productions (concert tours, sporting events, Broadway, etc.) to low-end, and most technology is manufactured for the arenas, concert venues, and other performance spaces who can pay the premium.

The second chapter looks at this thesis with a different perspective, namely as a series of computational problems. It will be an exposition of the different computational problems that come with tracking a perfomer, what was done to solve them, and the juicy computer science theory that backs up the solutions. These problems are, including, but not limited to, tracking the performer, positioning the moving light, and communicating to the lights in question.

The third chapter will explore the culmination of the work done in the previous two chapters that will be presented in a lighting design for the Dance thesis of Beier (Belle) Li. Li's thesis (presented in February, 2025) explores the various topics of "mother" through three lenses: her own mother, her mother language, and her mother country (being Mandarin and China respectively). [More will be in this paragraph as I develop work alongside Belle.] It will also discuss the logical next steps, which largely remain with packaging the software for comsumer use, and other uses for this software.

Chapter 1

A History of Lighting Control

In this chapter, I present a comprehensive history of the technologies that controlled Lighting, and the theories posed by notable lighting designers when using the technology of the time. It is not a comprehensive history of Lighting Design as a whole, it is a history on the control technologies that evolved alongside the advancements in lighting. The first section will start out with the basic dousing technologies that obscured candles and oil lamps, and end with the transition into incandescent lighting (1500's-1885). The second will go from the room-sized analogue control, through the advent of the desk lighting console, to just beyond the inception of Digital Multiplex. The third section will jump forward to the modern lighting designer, and what options are in-store for them. It will also discuss the idea of liveness, especially given the toolkit of the designer and the cost of theatre.

1.1 From Gas to Electricity

The first instances of human-controlled lighting in the theatre was in the form of candle-light. Previously, theatre had relied on the whims of nature and the cycle of the day. However, in the 16th century, an Italian architect by the name of Sebastiano Serlio designed, and then constructed the one of the first theatres with artificial lighting. As this caught on, the equivalent of lighting technicians were tasked with trimming wicks and refilling lamps at the start, and throughout performances. Near the turn of the 17th century, Nicola Sabbattini, also an Italian architect, designed a rudimentary system of dimming light through tin cans suspended over candles or lamps. He describes it as follows: "When it is desired to darken the whole stage in a moment, this method is used: as many cans of soldered tin are made as there are lamps to be darkened. [This] done, you adjust each cylinder over its lamp [in] such a manner that by one motion on the side of the stage, the cylinders descend over the lamps and darken them." This marks the beginning of "lighting control". Oil lamps and candles were a major step up in depending on the day-night cycle, but they still had their issues. For starters, wax and oil was expensive, and in order to be able to see performers, many were needed. Sabbattini mentions this in his text also: "Every care must be taken to get this done as quickly as possible to avoid restlessness in the spectators who think this business is endless." Wicks needed to be trimmed, lamps refilled, and molten wax would sometimes fall upon the spectators. However, humanity had found a way to do theatre indoors. The next jumps in technology appeared in the 19th century when gas-light entered the theatrical scene in 1803. Quickly after, companies like Clémançon had created gas tables, or elaborate control schemes that could not only modify the intensity of a flame, but also allow color to be mixed within. These tables had pipes that would control sections of the theatre, like footlights, auditorium lights, proscenium lights, etc. As a quick aside, the term limelight comes from the process of heating quicklime under a gas flame, moderated by a supply of hydrogen and oxygen. The resulting–and blinding–light was a force of nature in the theatre world through the 1860s. Gas light, and quicklime was used in theatres until the 1880's. Following the invention of the incandescent light, large theatre venues were quick to adopt the technology, for a downside of the gas-light is the fact that it consumed oxygen, produced fumes, and lots of heat. Compared to gas, incandescent lamps produce little heat, and consume no oxygen creating a much nicer theatre going experience. The next hurdle to clear was how to control this newfangled electricity, and manufacturers were quick to respond. Operators that used to control gas valves could now flip switches, and dim lights using rheostat dimmers. The technology entering the early 20th century revolved around variable resistance dimmers. Multiple mediums were used: be it sand, water, or different amounts of copper. The gas tables turned into room scale operations, humming with electricity. Lighting control was dominated in the 1930's by systems such as the Bordoni and Salani control systems, which were variable rate transformers. This wasn't enough, however. Not 20 years later vacuum tubes were all the rage, and with it came the Thyratron control unit and the "light organ". These were consoles that controlled lighting at a single desk, not running about a room. This cut down on technicians, and allowed for presets and, shortly after, memory. Once memory was introduced, technicians no longer had to scramble to set each scene, and designers could just load scenes from memory. The console could recreate it. Technology still trudged on. In the 1980's, the US Institute for Theatre Technology (USITT) made the jump to digital with a signaling protocol called Digital Multiplex (DMX). With it, (and its revision in the 90's), lighting control devices could continue to shrink. Gone was the need to keep all the dimming capabilities in a single desk. Instead, keep the control part in one room and move the dimming part in a different one and link the two with cable. With the continued growth of LED technology, and the push to run more efficiently, some incandescent lighting is being phased out, replaced by LEDs which no longer require large dimming racks. The three decades following the genesis of DMX paved the way for new protocols, more advanced lanterns, and a full commitment to the world of saving and loading cues. MIDI (or Musical Instrument Digital Interface) was adapted as a control protocol to allow remote activation of lighting cues, often in time with sound or video cues. MIDI then had to contend with OSC (Open Stage Control), a control protocol that allowed specificity in control messages. DMX continued to be used widespread, with spaces taking multiple universes (or groupings of 512 addresses) as intelligent lights required more. The concept of timecoding is that there is a global clock running through a performance and certain lights activate after a set amount of time. Timecoding is a technique that often plays nice with sound and video cues, allowing lights to match a prerecorded video clip or sound file down to the millisecond. "A time based system is less forgiving to human performers. If, for example, the [cue was] triggered ar 4 minutes and 35 seconds into every performance, the performer would be out of luck if their performance varied much." Timecoding is effective as a synchronization technique, but can be a disservice to performers. So much so, that when it comes to lighting specific performers in major productions, oftentimes they are illuminated by a followspot. These are high-powered, massive instruments that require a human operator to direct. In large venues like stadiums, broadway theatres, and arenas, these can be found along the back walls, their beam easy to spot if there is any haze in the room. The issue with this is that followspots are expensive, and are only really useful in large spaces. More recently, some camera-operated followspots have been hitting the theatre market, but they require even more money. It's time to make this more portable. Lighting and other control software has evolved to a point where any designer can run a full show with a single laptop, it should be possible to track a performer with minimal equipment. There is a way to do this. The setup I am exploring is a stereo-vision system. Camera feeds take in a frame of the space, and search for an identifier. In my tests, I used a blue LED light. The cameras then perform some calculations to locate the performer in the space. Finally the position information is fed to an intelligent light (which is another word for a moving light), telling it where to move to point at the performer.

Chapter 2

Mathematics and Science

2.1 Math

TEX is the best way to typeset mathematics. Donald Knuth designed TEX when he got frustrated at how long it was taking the typesetters to finish his book, which contained a lot of mathematics.

If you are doing a thesis that will involve lots of math, you will want to read the following section which has been commented out. If you're not going to use math, skip over this next big red section. (It's red in the .tex file but does not show up in the .pdf.)

2.2 Chemistry 101: Symbols

Chemical formulas will look best if they are not italicized. Get around math mode's automatic italicizing by using the argument `$\mathrm{formula here}$`, with your formula inside the curly brackets.

So, $\mathrm{Fe_2^{2+}Cr_2O_4}$ is written `$\mathrm{Fe_2^{2+}Cr_2O_4}$`
Exponent or Superscript: $\mathrm{O^-}$
Subscript: $\mathrm{CH_4}$

To stack numbers or letters as in $\mathrm{Fe_2^{2+}}$, the subscript is defined first, and then the superscript is defined.
Angstrom: Å
Bullet: $\mathrm{CuCl \bullet 7H_2O}$
Double Dagger: ‡

Delta: Δ
Reaction Arrows: $\longrightarrow$ or $\xrightarrow{solution}$
Resonance Arrows: $\leftrightarrow$
Reversible Reaction Arrows: $\rightleftharpoons$ or $\xrightleftharpoons{solution}$ (the latter requires the chemarr package)

2.2.1 Typesetting reactions

You may wish to put your reaction in a figure environment, which means that LaTeX will place the reaction where it fits and you can have a figure legend if desired:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Figure 2.1: Combustion of glucose

2.2.2 Other examples of reactions

$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$
$MeCH_2Br + Mg \xrightarrow[below]{above} MeCH_2 \bullet Mg \bullet Br$

2.3 Physics

Many of the symbols you will need can be found on the math page (`http://web.reed.edu/cis/help/latex/math.html`) and the Comprehensive LaTeX Symbol Guide (enclosed in this template download). You may wish to create custom commands for commonly used symbols, phrases or equations, as described in Chapter **??**.

2.4 Biology

You will probably find the resources at `http://www.lecb.ncifcrf.gov/~toms/latex.html` helpful, particularly the links to bsts for various journals. You may also be interested in TeXShade for nucleotide typesetting (`http://homepages.uni-tuebingen.de/beitz/txe.html`). Be sure to read the proceeding chapter on graphics and tables, and remember that the thesis template has versions of Ecology and Science bsts which support webpage citation formats.

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

State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
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			
$z^7P_4^\circ$	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

State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
$y^5H_7^\circ$	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:

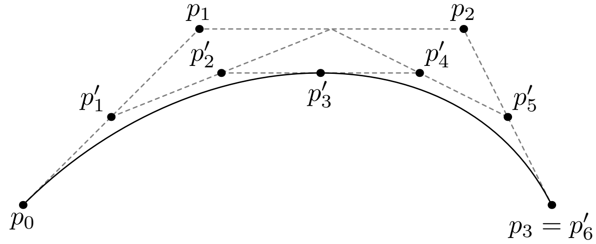

Figure 3.1: A Figure

3.3 More Figure Stuff

You can also scale and rotate figures.

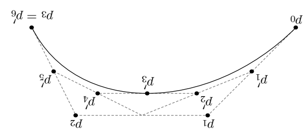

Figure 3.2: A Smaller Figure, Flipped Upside Down

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.

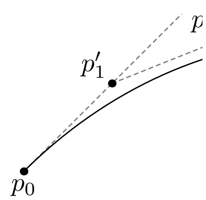

Figure 3.3: A Cropped Figure

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`.

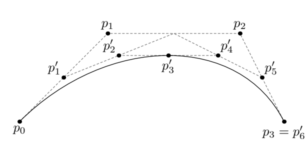

Figure 3.4: Subdivision of arc segments. You can see that $p_3 = p_6'$.

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

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