SANTA CLARA UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED

EMG-Based Vocal Translations

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN COMPUTER SCIENCE AND ENGINEERING
BACHELOR OF SCIENCE IN ELECTRICAL AND COMPUTER ENGINEERING

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EMG-Based Vocal Translations

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ABSTRACT

A good abstract is a concise summary (1–2 paragraphs) of the entire project: introduction, problem statement, work accomplished, results, conclusions, and recommendations. When you write the abstract, imagine that the reader will not read anything else, but that you must get your major point across immediately. This requires efficiency of words and phrases. An abstract is written to stand alone, without jargon or reference to figures and tables in the report body. (WIP)

Table of Contents

List of Figures

Chapter 1

Introduction

The introduction should be approximately 1–3 pages in length, and should contain the following information:

Problem statement: Make a concise statement of the problem, ideally in a few sentences, but no more than a paragraph. For example, try to complete this statement: “The sponsor desires that ... (insert goals of the project) ... subject to the following criteria: ... (insert numbered list).” These goals and criteria help to define the scope of work and the deliverables. Background or Related Work: State who else has worked on this problem or similar problems (you should do most of your citations here). For applied projects, provide information on other existing programs which will use your program. Objectives: The objectives are a battle plan for the project. They are a breakdown of steps or accomplishments that must be completed to achieve the project goals.

1.1 Problem Statement

Current methods of vocal communication relies on audible speech or text-based inputs. This creates barriers for individuals with speech disabilities and vocal impairments. Surface electromyography (sEMG) offers a way to capture muscle activity during vocalizations These signals can be translated into meaningful speech representations, such as the International Phonetic Alphabet (IPA), yet it remains a challenge.By developing a Silent Speech Interface [1] that accurately maps sEMG signals from facial and neck muscles groups involved in vocalization to IPA symbols we would be able to provide real-time vocal communication for non-speaking individuals or enhance existing silent speech technologies. The primary challenge lies in decoding complex muscle signal patterns, ensuring a consistent and high accuracy across a diverse set of users, and creating a system robust enough for real-world applications. This gap in accessibility and communication necessitates a need for an innovative solution combining biomechanics, linguistics, and machine learning.

1.2 Background or Related Work

State who else has worked on this problem or similar problems (you should do most of your citations here). For applied projects, provide information on other existing programs which will use your program.

Describe what systems already exist and why they are inadequate.

1.3 Objectives

The objectives are a battle plan for the project. They are a breakdown of steps or accomplishments that must be completed to achieve the project goals.

1.4 Our approach

Describe the team's approach for developing a system at a high level. Why will your work result in a system that is different / better than existing solutions?

Chapter 2

User Research - example middle chapter

2.1 Methods

Describe what methods you have used to identify user needs. This can include methods such as storyboards and interviews and surveys with target users. Describe how you analyze the data you collect. Include an example.

2.2 Stakeholder needs

Who are the stakeholders for this system? Provide a short description of what you know (so far) about each of the stakeholders and their needs. Highlight cases where their needs may differ. Personas could be appropriate here.

Describe whose needs your system will prioritize. It is ok to state that a potential stakeholder is out of scope for the project. For example, a virtual tour of the SCU campus might target prospective students, but choose *not* optimize for their parents (who are also potential stakeholders/viewers, but have different needs).

2.3 User stories

For each stakeholder that you choose to prioritize, describe one or more user stories that your system will support, e.g., ”As a prospective student, I want to find a social group at SCU so that I have friends to hang out with.”

Chapter 3

Design and Rationale - example middle chapter

3.1 Design

Describe the design of the system at a high-level. The system should support the use cases described in the previous chapter. —C4 system context and container diagrams go in this section. See: https://c4model.com/ (C4 Model Website) —

3.2 Functional requirements

Generally expressed in the form: ”system must do <requirement>.” These are similar to use cases (i.e, ”the user can do XYZ”), but written from the perspective of the system. For example: ”The landing page must introduce several different virtual tours and let the user choose one.”
See https://en.wikipedia.org/wiki/Functional_requirement

3.3 Non-functional requirements

Generally expressed in the form: ”system shall be <requirement>.” These are also known as quality requirements. For example: ”The virtual tour shall be fast-to-load. That is, the tour itself and any embedded media in it should load quickly enough that it is not a major annoyance for our target users.”
See https://en.wikipedia.org/wiki/Non-functional_requirement

3.4 Rationale

Describe why the system is designed this way. What alternatives did you consider, and why is design a good choice.

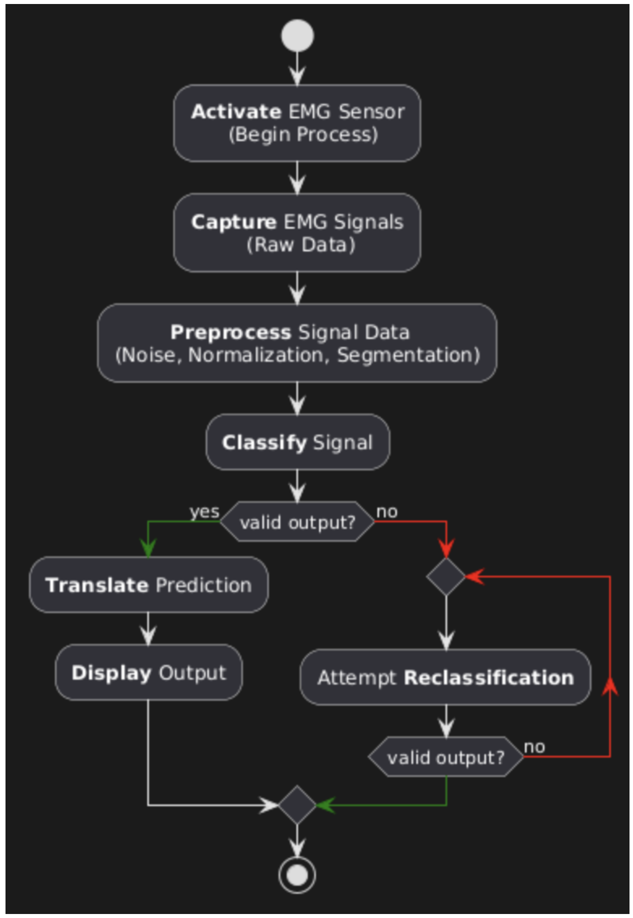

Figure 3.1: Activity Diagram

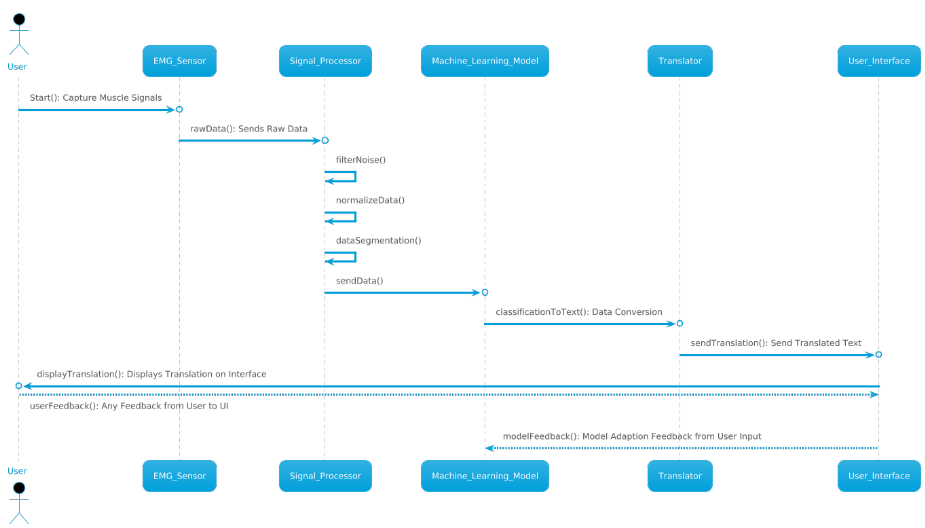

Figure 3.2: Sequence Diagram

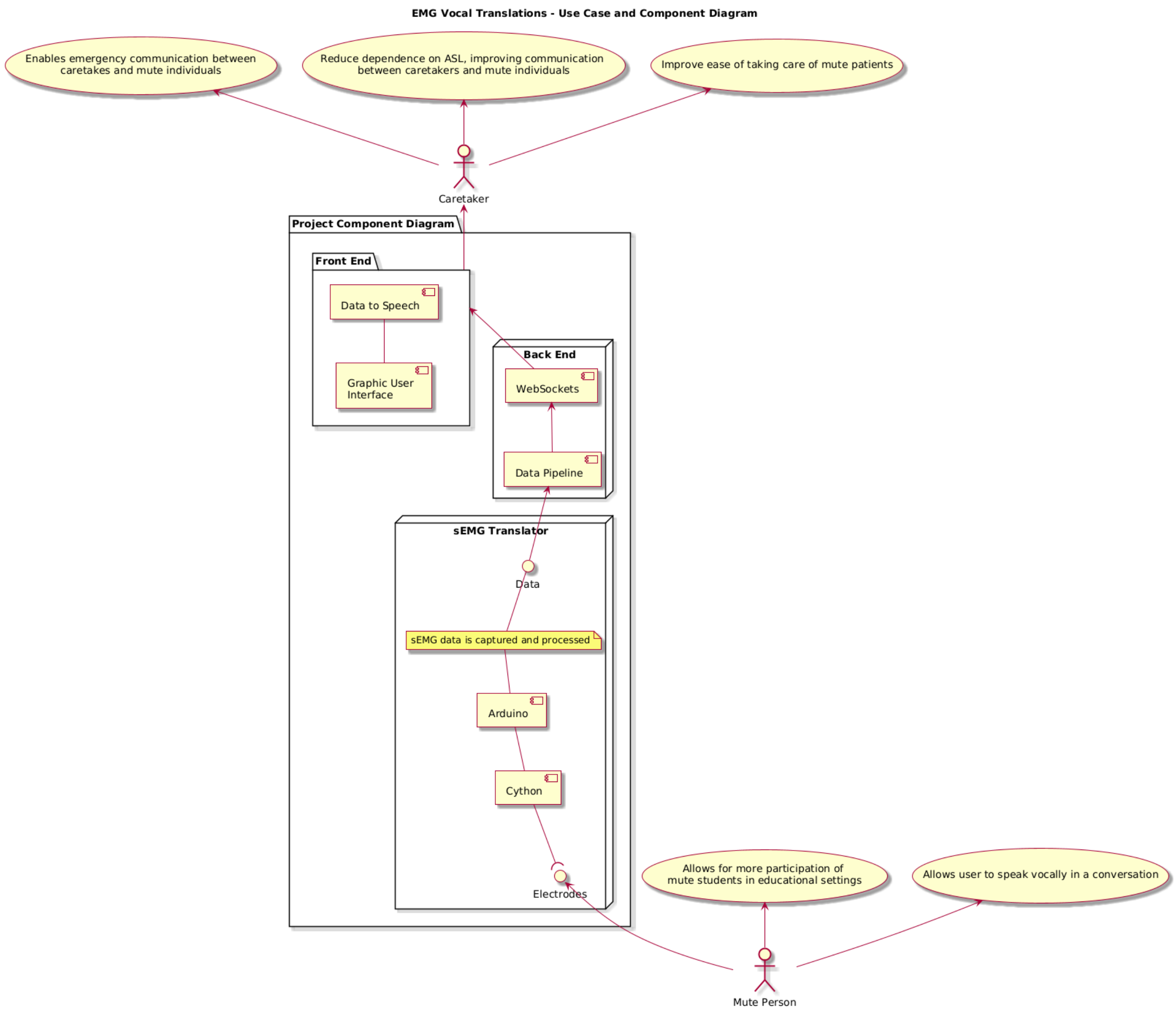

Figure 3.3: Use Case Diagram

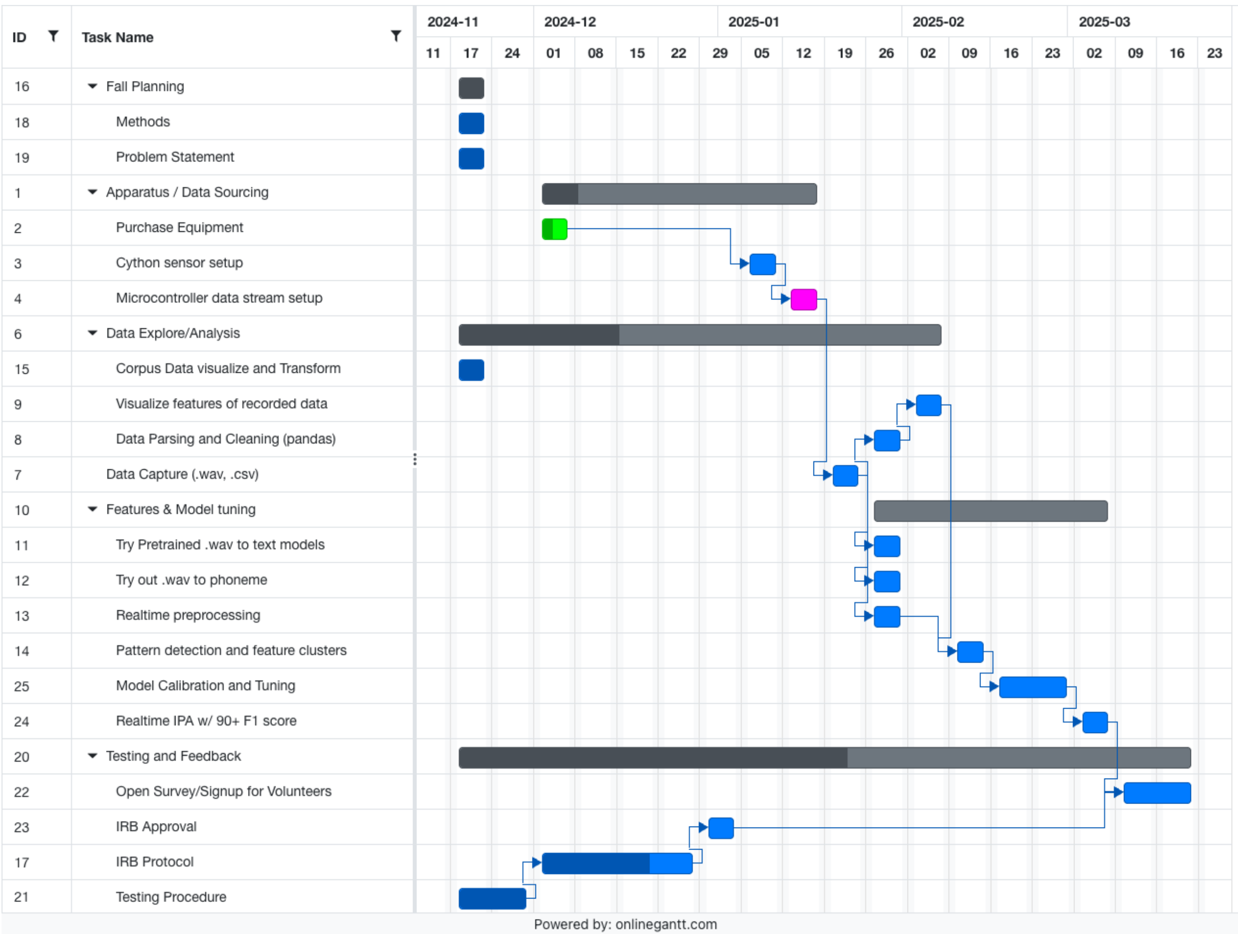

Figure 3.4: Gantt Timeline

Chapter 4

Technologies - example middle chapter

4.1 System Components

Describe the technologies you will use to build the system.

Chapter 5

System Evaluation - example middle chapter

Describe how you will evaluate the system you create. In particular, you need to have a plan for how to evaluate your functional and non-functional design requirements.

5.1 Internal Testing

How will test the system with internal users? That is, how will you and the team evaluate it yourselves? This is also called `https://en.wikipedia.org/wiki/Eating_your_own_dog_food`.

5.2 External Testing

How will test the system with external users? That is how will you get user feedback on your system. This can include methods such as usability testing, interviews with users, and analyzing log data from the product/service. How will you incorporate this user feedback into subsequent iterations of your system?

Chapter 6

Implementation Plan - example middle chapter

6.1 Timeline

Introduce the planned timeline for the work.

6.2 Agile software development

Repeat that we are using agile software development methods–the final system design will change in response to user feedback. Describe how in each two-week sprint, we work towards on one or more of the user stories. In the sprints, these are broken down into tasks that are assigned to specific team members. Show an example of what such tasks look like.

6.3 Project Risks

Briefly discuss any risks to the project and how you will mitigate them.

Chapter 7

Constraints and Standards

7.1 Constraints

Understanding and addressing the constraints of our project was critical for ensuring its successful and timely completion. We faced multiple constraints which included budgeting, legal and ethical constraints, post-deployment, and time.

7.1.1 Budget

Our project received a total of $1750 from the School of Engineering. This meant we were limited to purchasing 1 Cython Biosensing board, which limited our project's capabilities to accurately map sEMG signals into IPA symbols. However, we had enough budget to purchase other needed equipment, such as the electrodes, electrode cables, Li-Ion batteries, and an Arduino board.

7.1.2 Legal and Ethical

Legal and ethical considerations played a significant role in the project's constraints. One of our concerns was with user data privacy. Our project utilized biometric data collected from consenting individuals. This required upmost compliance to agreements by participants and the IRB protocol. Furthermore, ethical questions regarding the storage and use of sensitive biometric data, such as facial muscle signals, were also addressed through anonymization protocols and secure data handling practices.

7.1.3 Maintenance and Post-Deployment

Maintenance costs and post-deployment usability were also considered. The reliance on affordable components (such as the MyoWare sensors) meant that we were able to add in the aspect of ease of replacement to our project.

7.1.4 Time

Time constraints were experienced during the development, data collection, and testing phase of this project. Due to the time constraints, we had to focus our efforts to establish an MVP, developing a reliable machine learning model as soon as possible with the possible trade-off of user comfort and project scope (such as multilingual support).

7.2 Standards

This project considered the following standards:

7.2.1 ISO Standards

ISO norms and guidelines are vital for the protection of device reliability and usefulness, especially those manufactured to facilitate the disabled. They give assurance of quality and risk management standards widely accepted and appreciated internationally by users and stakeholders. In the scope of this project, we recognize multiple ISO standards such as ISO 14971, the risk management for medical devices. It is important to the EMG Vocal Translator since the standard recognizes and addresses the possible risks of device failure or incorrect speech. In so doing, we want to avoid any harm, boost user reassurance and trust, and provide the optimum safety and ethical practice levels for the technology used. ISO, ”Medical devices—Application of risk management to medical devices,” ISO 14971, 3rd ed., 2019.

7.2.2 IEEE Standards

A related factor in implementing the project is the capability of transferring user information either between devices or in a specific use such as in medical, and this comes under multiple IEEE standards. For example, IEEE 11073 which is a health device communication standard gives protocols on communication of medical and personal health devices. It defines communication protocols in data exchange and device commands allowing devices to interconnect and share data with other healthcare systems. This makes interoperability, reliability as well as security of handling sensitive health information assured. IEEE, ”Health informatics—Personal health device communication,” IEEE Standard 11073, 2022. [Online]. Available: https://standards.ieee.org

Chapter 8

Societal Issues

If you do not think an issue, such as ethics for example, has any relation to your project, you can say so, but you should justify this. SELECT AT LEAST FIVE OF THESE ISSUES TO ADDRESS IN AT LEAST ONE PARAGRAPH EACH:

8.1 Ethical

Our goal of developing a silent speech interface requires considerable thought into ethics. The resulting project targets a subset of people with an inability to speak. This means our project will be entrusted with sensitive health information and minimal risk to the user. Therefore, we must ensure that proper code of ethical conducts are followed. Some examples include physical risk, data handling, informed consent for data collection, data bias, and accessibility.

Physical risk includes discomfort, irritation, and potential misuse of our device. Users are advised about exposure to silver from the electrodes used to obtain the sEMG signals from facial muscle contraction. They are also informed about the possible discomfort from the application of the electrodes unto the skin. The users must be aware that application of the electrodes onto facial hair will both reduce the accuracy of our device and may result in damage to the facial hair itself.

The ethical constraints of our data handling and collection is a crucial point of discussion within this project. Data must be collected from a diverse set of users to avoid user bias. We must balance the transparency of the procedures of our data collection methods and the anonymized nature of the sensitive data we collect. This is to ensure the safety and privacy of our test group and ensure that our device remains accessible in nature.

We address and consider these ethical considerations heavily in our project. We ensure that data collected from participants are used solely for testing, and not training. They are informed of the risks of the study beforehand, and we provide as much transparency as possible regarding our anonymization protocols, ensuring the participants that no identifiable information is stored.

8.2 Social

Engineering is done within a social context, within a community of other people. Sometimes that community is defined very narrowly, sometimes very broadly. A focus on social issues allows us to consider the impact of our work on society. If we develop this product, or implement this system, what will be the effect? All of our human developments, in engineering and elsewhere, have unanticipated consequences, some good, some bad. We have an obligation to reflect on these consequences as well as we are able.

8.3 Economic

Economic considerations in engineering concern the costs of the various steps in the project. Such costs are usually dependent on the engineering decisions that are made during the design phase. Alternative approaches may offer cost options. We also need to consider the cost of money. How do we pay for the cost of a product development? If we must borrow significant amounts of money how do we account for the cost of the loan in the pricing of the product? What economic considerations arose in your project?

8.4 Health and Safety

Our device heavily leans towards the definition of a medical device. We are directly utilizing bioelectric signals in order to create a silent speech interface. The device must ensure minimal risk to the user, and it must secure any identifying health information obtained from the user. Some examples of Health and Safety standards can be found in the previous section on ISO/IEEE Standards, namely ISO 14971 and IEEE 11073.

8.5 Usability

Usability will be a deciding factor for the efficacy of our device for both short-term and long-term usage. Our device design aims to be simple to use and activate, with a comfort level in which a user would be able to utilize our device for long periods of time with minimal discomfort and no irritation. While our project may be bounded by constraints such as the generalization of musculosignals, we aim to utilize a calibration mechanic in order to individualize our device. The societal impact of a usable silent speech interface would improve the quality of life of those with vocal impairments.

8.6 Lifelong learning

Lifelong learning is a key aspect to our device's core design. The device provides an additional method for the vocally impaired community to interact and socialize with others. Not only does it allow such individuals to better fit into society, but it also spreads awareness of the challenges vocally impaired individuals face on a daily basis. We hope to empower our users and promote independence in their daily lives.

8.7 Compassion

One definition for compassion is an awareness of and sympathy for the suffering of another. Compassion means to recognize the suffering of another. But let's look at a broader definition. Let's define compassion as "the awareness of and sympathy for the suffering of another, and the desire to relieve that suffering." What does that have to do with engineering? Simple! One of the things that engineers can choose to do in life is to look for and try to relieve suffering where they find it. Perhaps it means replacing an ancient water supply system that is leading to disease in some tiny village, or designing a communication system to protect seniors with illnesses, or designing prosthetic devices for crippled children. Even if we do not decide to make the relieving of suffering the focus of our life's work, it is still critically important to our fullness as a human being that we feel compassion for the suffering. It is a part of the education that we hope you acquired at Santa Clara.

Chapter 9

Conclusion

State what you learned from your work. In this section:

- Summarize what you did. This can be viewed as the evidence.
- State what you learned (the actual conclusions that you are drawing), and relate them to the project objectives.
- List the advantages and disadvantages of your work. In what ways is your solution deficient or lacking? You are not divulging a weakness in your work when you state problems that still remain.
- State directions for future work and list any open problems.

Chapter 10

Acknowledgments

Acknowledge the contributions of the sponsor, university staff, other students, faculty, and other persons who were of assistance. This section is optional.

Chapter 11

References

You must include a list of references that you cite to support facts that are not common knowledge or expert opinions that you include in your report. In general, it is better not to use a bibliography of sources consulted for general background knowledge; instead, make a habit of citing the sources that you actually use. The format of the citations (which appear within the body of your report), and the format of the list of references (that appears near the end of the report, just before the appendices) should follow the guidelines described by the library.

Chapter 12

Appendices

Include complete source code listings, logic diagrams, parts lists, parts layout, data tables, background calculations, and other information needed for completeness, but would bog down the discussion in the body of the report.