Automatic Protoboard Layout

by

Michael Mekonnen

B.S. EECS, Massachusetts Institute of Technology (2013)
B.S. Mathematics, Massachusetts Institute of Technology (2013)

Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degree of

Masters of Engineering in Electrical Engineering and Computer Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 2014

Author . . . .
Department of Electrical Engineering and Computer Science
September 18, 2013

Certified by . . . .
Dennis M. Freeman
Professor
Thesis Supervisor

Accepted by . . . .
Professor Albert R. Meyer
Chairman, Department Committee on Graduate Theses

Automatic Protoboard Layout

by

Michael Mekonnen

Submitted to the Department of Electrical Engineering and Computer Science
on September 18, 2013, in partial fulfillment of the
requirements for the degree of
Masters of Engineering in Electrical Engineering and Computer Science

Abstract

Abstract.

Thesis Supervisor: Dennis M. Freeman
Title: *Professor*

Acknowledgments

Acknowledgments.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Problem Statement

What problem are we solving?

1.2 Motivation

Why is this an interesting problem?

1.3 Goal

Precisely state the goal of this project. In particular, explain that we ultimately want to make a teaching tool for 6.01.

1.4 Outline

How is the Thesis organized?

Chapter 2

Background

2.1 Technical Background

What is a circuit schematic? What is a protoboard? What circuit components are we working with in this project?

2.2 Previous Work

2.2.1 Current tools in 6.01

Discuss CMax and its capabilities.

2.2.2 Current work in automatic protoboard layout

What similar work has been done before?

Chapter 3

Evaluation

How are we going to evaluate a particular solution to the problem?

Chapter 4

Methods

In this Section, I discuss my solution to the problem and various alternatives I considered along the way.

4.1 Overview

I solved this problem by formulating it as a search problem. By this I mean, given a schematic of a circuit, I start from an empty protoboard, and I consider the space of all possible protoboard layouts to find the protoboard corresponding to the schematic at hand. The space of all possible protoboards is very large (?), so I utilize various heuristics to facilitate the search.

I broke down the problem into two parts. The first task is finding a placement of all the circuit pieces on the protoboard. The second task is wiring them up appropriately.

4.2 Part 1: Piece Placement

Let us first consider how to place a set of circuit pieces on the protoboard for a given circuit schematic.

Figure 4-1: Placement of the pieces on the protoboard.

4.2.1 The Pieces

Any given circuit may contain resistors, Op Amps, pots, motors, head connector parts, or robot connector parts. For each of these components, we must put down a corresponding piece on the circuit.

Resistors

For the sake of simplicity, and to significantly reduce the search space (?), for every resistor in the schematic, I use one resistor piece on the protoboard placed in the middle strip of the protoboard as shown in Figure 4.2.1. This choice, i.e. allowing the resistor pieces to only reside in the middle strip of the protoboard is critical as the resistor pieces generally be placed at numerous places on the protoboard. With this restriction, there are 63 slots available for one resistor. Without this restriction, there are a total of 763 slots available. The restirction is good when we consider the reduction in the search space size. On the other hand, the restriction is bad when we consider the size of circuits the algorithm can layout. Given that the number of circuits in the typical 6.01 circuit is very small, this restriction proves to be very useful, but we will consider the alternative in Section 4.4.1.

n	$f(n)$
1	1
2	1
3	7
4	25
5	81
6	331
7	1303
8	5937
9	26785
10	133651

Table 4.1: Number of ways of packaging together n Op Amps for various values of n.

Op Amps

Op Amps are the trickiest components to handle because each Op Amp package put on the protoboard contains two Op Amps within it. Thus, we face the task of packaging the Op Amps in the schematic in the "best" possible way, i.e. so as to require as little work as possible when wiring the pieces together. Equation 4.1 presents an expression for the value $f(n)$, the number of different ways to package together n Op Amps. To get a sense of how many different packagings are possible, Table 4.2.1 gives the values of $f(n)$ for various n.

$$f(n) = \sum_{k=0}^{\lfloor \frac{n}{2} \rfloor} \frac{n!}{n!(n-2k)!} \tag{4.1}$$

Pots

Head, Motor, and Robot Connectors

4.2.2 Choosing a Placement

Random Placement

Minimal Heuristic Cost

Small Heuristic Cost

4.3 Part 2: Wiring

4.3.1 What do we need to wire together?

4.3.2 Search Infrastructure

4.3.3 Wire all pairs at once

4.3.4 Wire one pair at a time

4.4 Why breakdown problem into two parts?

4.4.1 Treating Resistors as Wires

Chapter 5

Results

Quantitatively compare the various methods discussed in the previous section.

Chapter 6

Discussion

6.1 Explaining the Results

Give plausible explanation for the observed results.

6.2 Remarks

Why are these results encouraging? What are their implications? Relate back to Introduction to Thesis. What could have been done differently?

Appendix A

Schematic Drawing GUI

Discuss the features and capabilities of the GUI.