SJSU SAN JOSÉ STATE UNIVERSITY
Department of Mathematics and Statistics

Math 298/299 Cover Page

Last Name: Cavallaro

Student ID Number : 008089835

First Name: Jeffery

Semester & Year: Fall 2019

E-mail: jeffery.cavallaro@sjsu.edu

Degree Program: MA Math

Which course are you taking? Math 298 or Math 299? 299

How did you fulfill the GWAR requirement? Math 100W

When are you planning to graduate? Fall 2019

List courses you need to complete your degree

All coursework completed

Create your application packet which consists of the following:

- This cover page.
- Final title and the name of your project supervisor and committee members
- A 1-2 page abstract including a rough timeline of project milestones and reading list for the semester.
- Unofficial SJSU transcript and other graduate level transcripts
- Proof that GWAR has been satisfied.
- Admission to candidacy form http://www.sjsu.edu/gape/forms/candidacy.pdf signed by the thesis/writing project advisor and graduate coordinator
- Create **one single** PDF with all documents

Submit the application packet to your thesis/project advisor in pdf format.

List the names of your faculty members on your committee (need a minimum of 3, including your thesis/writing project supervisor.)

1. Prof Sogol Jahanbekam
2. Prof Wasin So
3. Prof Jordan Schettler

Student Signature ____________

Date 8/13/2019

Two Graph Vertex Partitioning Algorithms for Part Consolidation in Axiomatic Design

Jeffery Cavallaro

15 August 2019

Abstract

In traditional manufacturing, parts are designed and manufactured separately so that the parts can be combined into subassemblies, which are then combined into final assemblies. Indeed, the standardization of parts was one of the key developments that fueled the explosive growth of manufacturing during the 19^{th} and 20^{th} centuries. Now, in the 21^{st} century, a new technique, referred to as *additive manufacturing*, promises a new leap forward in manufacturing capability: instead of manufacturing the parts for subassemblies separately, the subassemblies are constructed directly through the additive application of layers of material, commonly referred to as *3-D printing*.

But what is the best way to allocate parts into subassemblies in order to minimize the number of subassemblies? One possible answer is to represent the problem by a graph, where the nodes are the parts and the edges represent the need to separate incident parts into different subassemblies. The answer then becomes the solution to a vertex partitioning problem. This research will investigate two such vertex partitioning algorithms that were initially developed as part of an NSF grant working with two mechanical engineer researchers at NYU Buffalo and presented at IDETC conferences in 2018 and 2019.

The first algorithm accepts a simple graph with edge weights as input, where the edge weights indicate a penalty for consolidating the endpoint parts. Non-adjacent vertices are assumed to be connected with an edge of infinite weight, and thus can never be consolidated together. The output is a partitioning scheme with the smallest penalty.

The second algorithm accepts a simple graph where the presence of an edge indicates that the two endpoint parts can never be consolidated together; only non-adjacent vertices can be consolidated together. The problem then becomes a standard chromatic coloring problem.

In both cases, what is needed is a rationale for determining the presence of an edge. A good way to determine the separation of two parts into different subassemblies is through the use of so-called *axiomatic design*, where a set of *design parameters* (DPs) are translated into a set of *functional requirements* (FRs) via a *design matrix* (A) of common and problem-specific design goals: $[FR] = [A][DP]$.

The primary goal of this research project is finalize the two algorithms, complete with theoretical support for their steps and a good comparison of runtime complexity to the standard exhaustive NP-complete algorithm for vertex partitioning. Since previous work has relied on manual execution of the algorithms under study, an additional goal is to develop software solutions that can extend the ability to try and compare various examples. The availability of a good software tool will provide the ability to run the algorithms on sets of random graphs in order to empirically demonstrate the theoretical results.

297 Summary

This work was begun as a Math-297 project that concentrated on learning the basics of axiomatic design and improving the second algorithm. Highlights includes:

1. A good understanding of the theoretical basis of axiomatic design.
2. A strong algorithm with a sound theoretical basis.
3. Software support for the algorithm.
4. A paper that will be presented at the IDETC conference in Anaheim on 19 August 2019.
5. Best conference paper award.

Timeline

Note: Some tasks to run concurrently.

Topic	weeks
Reading on axiomatic design	3
Reading on the Zykov exhaustive approach	1
Reading on solutions for special-case graphs	2
Reading on recursion relationships	1
Existing algorithm analysis and improvement	4
Algorithm software development and statistical investigation	4

Reading List

[1] G. Agnarsson and R. Greenlaw, *Graph theory: Modeling, applications, and algorithms*, Prentice Hall, Upper Saddle River, NJ, 2007.

[2] S. Behdad, P.K. Gopalakrishnan, S. Jahanbekam, and H. Kain, *Graph partitioning technique to identify physically integrated design concepts*, Proceedings of the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (2018), no. DETC2018-85646, 1–13.

[3] R. Beigel and D. Eppstein, *3-coloring in time $\mathcal{O}(1.3289^n)$*, Journal of Algorithms **54** (2005), 168–204.

[4] D. Chartrand and P. Zhang, *A first course in graph theory*, Dover Publications, Inc., Mineola, NY, 2012.

[5] R.C. Reed (ed.), *Graph theory and computing*, Academic Press, New York and London, 1972.

[6] C. Smyth, *Functional design for 3d printing*, third revised ed., 2017.

[7] N.P. Suh, *Axiomatic design theory for systems*, Research in Engineering Design **10** (1998), no. 4, 189–209.

[8] D.B. West, *Introduction to graph theory*, 2^{nd} ed., Prentice Hall, Upper Saddle River, NJ, 2001.

SJSU SAN JOSÉ STATE UNIVERSITY

Petition for Advancement to Graduate Candidacy

09.2016

Student Information

Completed form should be emailed to the appropriate GAPE evaluator (see www.sjsu.edu/gape/about_us/staff), submitted to Window G in the Student Services Center, or sent through interoffice mail to extended zip 0017.

Last Name: Cavallaro   First Name: Jeffery

Student ID: 008089835   Previous Name (if any):

Current Address: 38712 Almaden Place   City: Fremont   State: CA   Zip: 94536

Daytime Phone: 510-797-7712   Email Address: jeffery.cavallaro@sjsu.edu

Degree Information

Degree Sought, *e.g.*, MBA: MA   Major: Mathematics   Concentration, if applicable:

Means of satisfying Graduation Writing Assessment Requirement: Course Prefix, Catalog No.: Math 100W

University where taken: SJSU   Semester/Year GWAR Completed: Fall/2013   Plan ☒ A ◯ B ◯ C

Proposed Graduate Degree Program

A. Courses (include all SJSU courses taken and those that will be taken for degree credit; leave Grade section blank for current and future classes.)

Course Prefix/No.	Title	Semester Units	Grade	Semester/Year Completed
Math 179	Intro to Graph Theory	3	A	Spring/2015
Math 279A	Graph Theory	3	A-	Fall/2015
Math 231A	Real Analysis	3	A	Spring/2016
Math 279B	Advanced Graph Theory	3	A	Spring/2016
Math 221A	Higher Algebra I	3	A+	Fall/2016
Math 238	Advanced Complex Variables	3	A+	Fall/2016
Math 221B	Higher Algebra II	3	A+	Spring/2017
Math 229	Advanced Matrix Theory	3	A-	Spring/2017
Math 231B	Functional Analysis	3	A	Fall/2017
Math 297A	Preparation for Thesis	3		Spring/2019

B. Culminating Experience

Check box if applicable and then fill out corresponding row

	Course Prefix/Catalog No. (*e.g.*, MAS 203)	Total Units	Grade	Semester/Year Completed
☒ 299 Thesis (Plan A)/Creative Work (Plan C)	Math 299	3		Fall/2019
☐ Last completed project or comprehensive exam-preparation course (plan B)				

☐ Other Culminating Experiences

	Type	Semester/Year Completed
1) Other culminating experience		
2) Other culminating experience		

	Course Prefix/Catalog No. (*e.g.*, MAS 203)	Total Units	Grade	Semester/Year Completed
☐ 599 Dissertation				

C. Transfer Courses

University	Course Prefix/No.	Title	Semester Units	Grade	Semester/Year Completed
Sub. for SJSU Course					
Sub. for SJSU Course					
Sub. for SJSU Course					

	Units
A	
B	
C	
Total	

Required Signatures

Student: Jeffery Cavallaro   Date: 1/21/2019

Signature (certifies accuracy of the information provided)

For Official Use Only

The signatures below indicate approval.

Project or Thesis Advisor (if required by your department)

Name: ______ Signature: ______ Date: ______

Department Grad Advisor (Grad Coordinator)

Name: ______ Signature: ______ Date: ______

GAPE Evaluator

◯ Approved ◯ Denied Name: ______ Date: ______