THREE CASES OF VISUALIZED ALGORITHM ENGINEERING

ON

GRAPH PARTITIONING PROBLEMS

Approved by:

Dr. David W. Matula
Professor Emeritus of Computer Science

Dr. Ira Greenberg
Professor and Chair of Division of Art

Dr. Eli Olinick
Associate Professor of Engineering
Management, Information, and Systems

Dr. Jennifer Dworak
Associate Professor of Electrical and
Computer Engineering

Dr. Frank Coyle
Director of Software Engineering Program

THREE CASES OF VISUALIZED ALGORITHM ENGINEERING
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GRAPH PARTITIONING PROBLEMS

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Zizhen Chen

B.SE., Software Engineering, North China Electric Power University
M.S., Computer Science, Southern Methodist University

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Chen, Zizhen B.SE., Software Engineering, North China Electric Power University
M.S., Computer Science, Southern Methodist University

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visualization is an old method which has existed for thousands' years in human history. You must have impressions of old maps appearing in many fairytale adventure stories. An early example of using visualization in scientific research is Leonhard Euler who used a simple graph to study the problem of the Königsberg bridges in 1763 [2]. The study of this problem has been commonly recognized as the beginning of Graph Theory. Graphs are frequently used by computer scientists as abstractions when modeling an application problem. Cutting a graph into smaller pieces is one of the fundamental algorithmic operations. Current technology generates a massive amount of data ("Big Data") from business interactions and social exchanges (Facebook became the world's largest social networking site with more than 802 million active daily users on average for March 2014 [3]). Graph partitioning technics play a key role in classifying and clustering such huge amount of data. High-performance algorithms of partitioning graphs for specific applications are always pursued.

Nowadays visualization has ever-expanding applications in science, education and engineering especially after the rapid growing on computer graphic technologies. However, few researches use visualizations to study algorithms. Visualizations are normally treated as representations of results (data visualization), while algorithm visualization is more commonly used as a method for educational purpose. There also appeared several general purpose visual tools which can be used for graph theory research, but they are usually limited to their own platforms or lack abilities to be implemented in an efficient way for algorithm research.

This dissertation applied the methodology of algorithm engineering to three graph par-

titioning problems across different areas including computer networks, social networks and arithmetics. Not only visualizations indicate the performance of algorithm implementations of each work, but also help explore new algorithms to solve the problems. We term this research method as Visualized Algorithm Engineering since visualizations play a foundational role during the procedure.

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This is dedicated to my fiancee, Mengnan, who has been a constant source of support and encouragement during the challenges of graduation.

CHAPTER 1

INTRODUCTION

About 1/3 of the cerebral cortex is for visual processing in our brain [6], so humans are basically vision-driven species. That's why "What it looks like?" may be the most intuitive question pop out when humans try to know about a new thing. When people encountered a new problem, we usually try to find out what the problem looks like by modeling it then we can analyze the problem and solve it. There exists multiple ways of modeling a problem and this dissertation discusses modeling graph partitioning problems via visualization. Visualization answers the exact question: "What it looks like?".

This dissertation states three problems of three different areas: i) Partitioning Random Geometric Graphs (RGG's) into several bipartite backbone grids; II) Hierarchical Maximum Concurrent Flow Problems; iii) Precise and Concise Graphical Partitioning of Natural Numbers. These are all graph partitioning problems in three different areas. We use visualization to model the problem and developed new algorithms to solve them. Yet the techniques discussed here apply to a broader area of problems: computer networks, social networks, arithmetic, computer graphics and software engineering. Common terminologies accepted across the three areas have been used in this dissertation to guarantee people from all areas can understand concepts mentioned here.

Algorithms are a fascinating use case for visualization. To visualize an algorithm, we don't merely fit data to a chart; there is no primary dataset. Instead there are logical rules that describe behavior. This may be why algorithm visualizations are so unusual, as designers experiment with novel forms to better communicate. This is reason enough to study them.

But algorithms are also a reminder that visualization is more than a tool for finding patterns in data. Visualization leverages the human visual system to augment human intellect:

we can use it to better understand these important abstract processes, and perhaps other things, too.

Our research method builds the visual model of existing problem, adds available features to the model, then discovers new features by implementing existing algorithms and develops new algorithms to get close to our purpose and visualize the problem again. Finally, expand the problem to introduce new challenges. The whole procedure could be termed as Visualized Algorithm Engineering.

CHAPTER 2

VIRTUAL BACKBONE DETERMINATION IN WIRELESS SENSOR NETWORKS

2.1. Background

Sensor networks have a long history. The first obvious sensor network wa the Sound Surveillance System (SOSUS) which grew out of tasking in 1949 [5,16]. The SOSUS was made up of acoustic sensors that were interconnected by wired cables and were deployed by the US in deep ocean basins during the Cold War to detect and track Soviet submarines. The early development of sensor networks was mainly driven by military use, in which sensor nodes were wired together to provide battlefield surveillance. Advances in Microelectromechanical Systems (MEMS) technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that communicate untethered in short distances [1]. Such sensors can observe and respond to phenomena in the physical environment and they have driven sensor networks to the Wireless Sensor Networks (WSN's).

The WSN can be defined as a self-configured and infrastructure-less network composed of autonomous resource-limited electronic sensors geographically distributed across a region where the sensors communicate with each other wirelessly [4, 11]. WSN's have been the focus of intense research during the past few years because of their potential to facilitate data acquisition and scientific studies [15]. These inexpensive small miniaturized sensors can be embedded or scattered onto target environments in order to observe or monitor useful information in many situations. Wireless communication between sensors allows the formation of flexible sensor networks, which can be deployed rapidly over wide or inaccessible areas. Thus, WSN's greatly extend our ability to monitor and control the physical environment. Some of the main applications are habitat and ecosystem monitoring, seismic monitoring, civil structural health monitoring, volcano monitoring, groundwater contamination monitoring, outer space investigations and so on [7, 10, 12, 15, 17]. The communication in WSN's can be either ad hoc (multi-hop) or single-hop wireless transmission [1, 9, 13]. Although the latter is popular in short-range applications, such as home control and building automation, the former, ad hoc technique will be the focus of the engineering project of this chapter due to its high flexibility and ability to support long-range, large-scale, and highly distributed applications [13].

2.2. Problem Specification

In a WSN, after collecting information from the environment, sensors need to transmit aggregated data to sink nodes (gateways) or information collection nodes. Due to the small scale and limited communication capability of sensors, a packet sent from one sensor to another usually has to go through multiple hops, which makes routing a critical service required for WSN's. For sustenance of the network, one must have both energy efficient transmission and high overall network lifetime. The main goal is to minimize the energy consumed and maximize the network lifetime. Clustering and backbone formation are two contrasting schemes for efficient routing in wireless sensor network [14]. Basically every node will transfer its message to its cluster head and the cluster head would communicate to sink via many intermediate cluster head.

APPENDIX A

Works by Jack Handey

Deep Thoughts (1992)

Deeper Thoughts (1993)

Deepest Thoughts (1994)

Fuzzy Memories (1996)

What I'd Say to the Martians (2008)

The Stench of Honolulu: A Tropical Adventure (2013)

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