Graph Theory in Action: Solving Real-life Problems with Prim’s and Kruskal Algorithms

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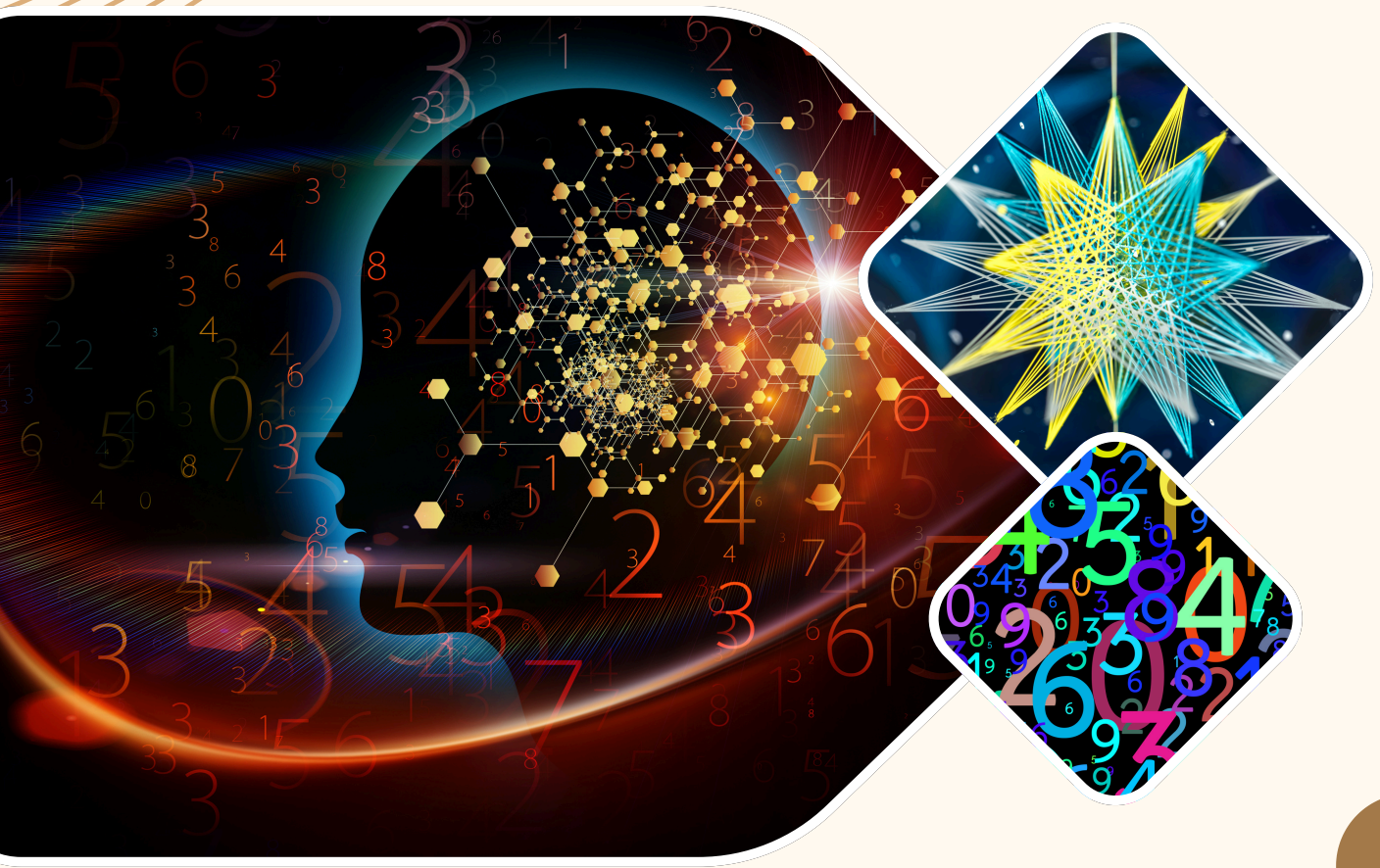
Abstract: Graphs are all around us, from the roads we navigate to the networks that link us. Graph Theory in Action: Solving Real- Life Problems with Algorithms brings this powerful mathematical tool to life, exploring how graphs and trees optimize real-world systems. This book delves into essential algorithms—Kruskal's and Prim's—and their applications in solving problems like finding the shortest routes, minimizing costs, and optimizing connections. Compiled from case studies by first-year IT diploma students, it showcases practical uses of Minimum Spanning Trees (MST) to tackle real-world challenges. Whether you're a student, educator, or professional in mathematics, computer science, or engineering, this book offers a hands-on understanding of graph theory and its farreaching impact. Unlock the potential of graph theory and see how it shapes the world we live in!

Keywords: Graph theory, algorithms, Minimum Spanning Trees (MST)

GRAPH THEORY

In action

SOLVING REAL-LIFE PROBLEMS WITH PRIM'S AND KRUSKAL ALGORITHMS



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PREFACE

Graph theory provides a powerful mathematical lens for addressing real-world problems across numerous disciplines, from network optimization and logistics to social network analysis. It uses graphs, composed of vertices (nodes) and edges, to model pairwise relationships. A key graph structure is the tree—an acyclic connected graph frequently employed in optimization, particularly for finding minimal paths or costs. Graph Theory in Action: Solving Real-Life Problems with Algorithms delves into fundamental graph algorithms, including Kruskal's and Prim's, and showcases their practical applications. This book is a collection of case studies developed by first-year Diploma in Information and Technology students in the DAT10203 Discrete Mathematics course, emphasizing the use of Minimum Spanning Trees (MST) for minimizing distance or cost. By connecting theory with real-world examples, it aims to foster an intuitive grasp of how graphs and trees can model and optimize real-life systems. This book will be a valuable tool for students, researchers, and practitioners in mathematics, computer science, and engineering, providing practical problem-solving skills and a deeper appreciation for the role of graph algorithms.

CHAPTER 1

MINIMIZING TRAVEL DISTANCE ACROSS SELANGOR

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1.0 INTRODUCTION

The Malaysian Department of Surveying and Mapping (JUPEM) is undertaking a project to determine the most efficient route to visit every region in Selangor exactly once, aiming to gather accurate distance data between all pairs of regions [1]. This task involves minimizing the total travel distance while ensuring complete coverage. In graph theory, such problems can be modelled using a spanning tree, which connects all vertices (regions) with the minimum number of edges [2].

A Minimum Spanning Tree (MST) is a spanning tree with the least possible total edge weight, representing the minimal travel distance required to connect all [3]. Two primary algorithms to find an MST are Prim's and Kruskal's algorithms. Prim's algorithm starts with a single vertex and expands the MST by adding the smallest edge connecting a vertex inside the tree to a vertex outside it, making it suitable for dense graphs [4]. In contrast, Kruskal's algorithm begins

CHAPTER 2

ALI AND HIS FAMILY'S NEW BEGINNING

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2.0 INTRODUCTION

Ali and his family recently moved to a new town and are eager to familiarize themselves with their new surroundings. Excited about their new home, they decide to spend the day exploring the town together. They plan to visit various landmarks, parks, and shopping areas to get a better sense of the community. Wanting to cover each location only once while minimizing their travel distance, they carefully map out their journey. To make their exploration more efficient, they consider using concepts from graph theory, such as the Minimum Spanning Tree (MST), which helps in finding the shortest path that connects all locations with minimum total distance [1]. MST is widely used in network optimization problems, including transportation and communication networks [2].

To determine the most efficient route, Ali and his family explore two well-known algorithms: Prim's and Kruskal's. Prim's algorithm builds the MST by starting from a single node and expanding by selecting the shortest edge at each step

CHAPTER 3

THE PERFECT PLAN FOR WEEKEND GETAWAYS

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3.0 INTRODUCTION

Five female students from Department of Information and Technology were tasked with planning weekend trips to several locations in Johor and Malacca, including Pagoh, Muar, Parit Sulong, Semerah, Tangkak, Jasin, Ayer Keroh, Taming Sari, and Merlimau. Their goal was to visit each location only once and minimize their total travel distance, a problem of optimizing routes. This scenario can be modelled as a *spanning tree* problem, where the aim is to connect all locations with the least total distance [1].

A *minimum spanning tree* (MST) approach is ideal for this and can be efficiently solved using either Prim's algorithm or Kruskal's algorithm [2,3]. Both algorithms help in constructing the MST by choosing the shortest possible connections between the locations, with Prim's algorithm gradually growing the tree from an initial location, while Kruskal's

CHAPTER 4

NETWORK CABLE INSTALLATION IN A UNIVERSITY COMPOUND

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4.0 INTRODUCTION

A university plans to connect several buildings, including the cafeteria, laboratory, library, and other facilities, using network cables while minimizing the total cable length. This problem can be modelled as a graph, where buildings represent vertices and the possible cable connections between them are edges [1]. To achieve an optimal solution, a spanning tree, which is a subset of the graph that connects all vertices without forming cycles, is required [2]. Specifically, the goal is to find a minimum spanning tree (MST), which ensures that all buildings are connected using the least possible total cable length [3]. Two well-known algorithms for finding the MST are Prim's algorithm and Kruskal's algorithm. Prim's algorithm starts from an arbitrary node and grows the tree by adding the smallest edge that connects a new vertex to the tree [4,5]. On the other hand, Kruskal's algorithm sorts all edges by weight and continuously adds the shortest edge that does not form a cycle until all vertices are connected [6].

CHAPTER 5

OPTIMIZING TRAVEL ROUTES IN MELAKA

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5.0 INTRODUCTION

Optimizing travel routes is a well-known application of graph theory, aimed at determining the most efficient path that connects multiple key locations while minimizing total travel distance. In urban areas, such as the city of Melaka, transportation networks consist of numerous interconnected roads, each with varying distances and travel times [1]. Identifying the optimal routes within these networks is essential for reducing travel costs, improving traffic flow, and enhancing overall accessibility [2].

One major advantage of utilizing Minimum Spanning Tree (MST) in transportation planning is its ability to minimize infrastructure costs while maintaining full connectivity. Unlike shortest path algorithms that focus on a single source-destination pair, MST ensures that all key locations are connected with minimal total road distance [3]. This is particularly beneficial for cities like Melaka, where tourism and

CHAPTER 6

COST-EFFECTIVE COMMUNICATION NETWORK DESIGN USING PRIM'S AND KRUSKAL'S ALGORITHMS

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6.0 INTRODUCTION

Constructing a Minimum Spanning Tree (MST) using Prim's and Kruskal's algorithms provides an effective solution for minimizing the total cost of connecting multiple houses. A telecommunication company seeks to interconnect nine houses at the lowest possible cost. Applying graph-based optimization techniques determines the most efficient and cost-effective way to establish the network [1].

Designing an efficient and cost-effective communication network is a fundamental problem in network optimization. A well-structured network can significantly reduce infrastructure costs while ensuring full connectivity [2]. The problem of network design has been extensively studied in operations

Graphs are all around us, from the roads we navigate to the networks that link us. Graph Theory in Action: Solving Real-Life Problems with Algorithms brings this powerful mathematical tool to life, exploring how graphs and trees optimize real-world systems. This book delves into essential algorithms—Kruskal's and Prim's—and their applications in solving problems like finding the shortest routes, minimizing costs, and optimizing connections. Compiled from case studies by first-year IT diploma students, it showcases practical uses of Minimum Spanning Trees (MST) to tackle real-world challenges. Whether you're a student, educator, or professional in mathematics, computer science, or engineering, this book offers a hands-on understanding of graph theory and its far-reaching impact. Unlock the potential of graph theory and see how it shapes the world we live in!

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