COLORADO MESA UNIVERSITY

# Algorithms Theory and Design CSCI480 Final Project

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Student Names: Your names here please
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## 1 Introduction, Task Objectives

1. To deepen your understanding of advanced data structures and algorithms: The primary goal of this project is for you to gain a deeper theoretical and practical understanding of advanced data structures and algorithms, such as Red-Black Trees and Max Flow algorithms, and their applications.

2. To implement and optimize selected data structures and algorithms: You aim to implement these data structures and algorithms in C++ and optimize them for efficient performance.

3. To apply these concepts to real-world problem-solving: You will select a real-world problem or case study and adapt your C++ implementations to solve this problem, demonstrating the practical application of the chosen topics.

4. To perform a comparative analysis: You will conduct a rigorous analysis of the performance of your implementations, comparing them with existing solutions or libraries. This will help you assess the strengths and weaknesses of your chosen data structures and algorithms.

5. To promote teamwork and collaboration: Through this project, your aim is to work collaboratively as a group, dividing responsibilities effectively and leveraging each member's strengths.

6. To enhance your presentation and reporting skills: You will prepare a final presentation and report summarizing your project findings, theoretical insights, and practical applications, thereby improving your communication skills.

# 2 Data Structures and Algorithms

## 2.1 Data Structure 1: Red-Black Trees

### 2.1.1 Theoretical Analysis

Discuss the theoretical aspects of Red-Black Trees, including time and space complexity, best/worst/average-case scenarios, and any important properties.

### 2.1.2 Practical Implementation

Explain the implementation details of Red-Black Trees in C++. Provide code snippets, data structures, and any unique features.

### 2.1.3 Real-World Application

Discuss how Red-Black Trees are applied in real-world scenarios. Provide examples and discuss their relevance.

### 2.1.4 Theoretical Questions

1. Prove that the height of a Red-Black Tree with 'n' nodes is guaranteed to be O(log n) in the worst-case scenario. Provide a rigorous mathematical proof.

2. Discuss how Red-Black Trees are used in modern databases and file systems to maintain balanced structures. Explain the trade-offs and advantages of using Red-Black Trees in these contexts.

## 2.2 Data Structure 2: Max Flow Algorithms

### 2.2.1 Theoretical Analysis

Discuss the theoretical aspects of Max Flow algorithms (e.g., Ford-Fulkerson and Edmonds-Karp), including the concept of augmenting paths and their role.

### 2.2.2 Practical Implementation

Explain the implementation details of Max Flow algorithms in C++. Provide code snippets and discuss the algorithm's inner workings.

### 2.2.3 Real-World Application

Explain how Max Flow algorithms are used in network flow problems. Discuss the Min-Cut Max-Flow Theorem and its significance.

### 2.2.4 Theoretical Questions

1. Describe the concept of augmenting paths and their role in the Ford-Fulkerson algorithm. Prove that the algorithm terminates and converges to the maximum flow in finite time, even for non-integer capacities.

2. Explain the Min-Cut Max-Flow Theorem and its significance in the context of network flows. How can this theorem be used to find a maximum flow and minimum cut in a flow network?

# 3 Real-World Problem Solving

Describe the real-world problem or case study you've chosen for this project. Explain how you've adapted and applied your C++ implementations to solve this problem.

# 4 Comparative Analysis and Reporting

Present the performance results of your implementations and compare them with existing solutions. Provide empirical data, analysis, and visualizations

to support your findings.

# 5 Conclusion

Summarize the project, its outcomes, and what you've learned. Reflect on the theoretical and practical aspects of the chosen data structures and algorithms.

# 6 References

List any sources and references you've used for your theoretical and practical work.