

# Garbage Collection Routing Based on Traveling Salesman Problem

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# Outline

## Introduction

- Garbage Collection Routing
- Traveling Salesman Problem
- Problem Formulation

## Motivation

## Related Work

## Our Approach

- Dynamic Programming
- Christofide's Heuristic

## Comparison

## Proposal

## Future Work

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# Garbage Collection Routing

- ▶ Route garbage trucks to optimal tour
- ▶ Similar to Traveling Salesman Problem (TSP)

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# Traveling Salesman Problem

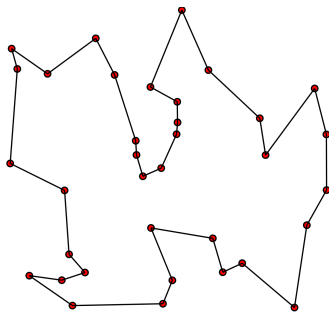


Figure: *An example tour*

- ▶ A salesman needs to visit some number of cities to sell his goods

# Traveling Salesman Problem

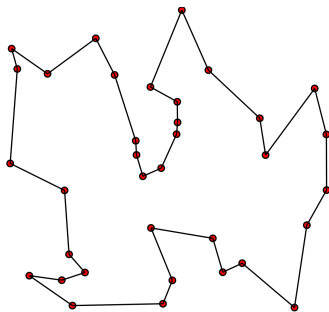


Figure: *An example tour*

- ▶ A salesman needs to visit some number of cities to sell his goods
- ▶ He wants to visit each city exactly once

# Traveling Salesman Problem

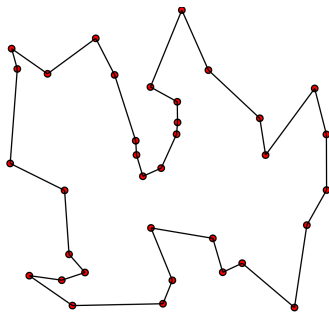


Figure: *An example tour*

- ▶ A salesman needs to visit some number of cities to sell his goods
- ▶ He wants to visit each city exactly once
- ▶ And come back to starting city



# Traveling Salesman Problem

- ▶ Finding shortest route for the salesman is *NP-hard*
- ▶ No polynomial-time solution
- ▶ Approximation or heuristic based solutions

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# Problem Formulation

- ▶ Garbage bins are cities
- ▶ Edges are the path between any two bins
- ▶ Each edge has some cost
- ▶ We want optimal tour for each truck

# Motivation

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- ▶ 7 billion people producing wastes, *every single day*
- ▶ 1.65 million metric ton of strong waste in Dhaka per year
- ▶ Small improvement in collection implies large contribution to the whole system

## Related Work

- ▶ Approach with objective function - simulation

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- ▶ Minimum Spanning Tree



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- ▶ Approach with objective function - simulation
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- ▶ Chinese Postman Problem

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- ▶ Approach with objective function - simulation
- ▶ Minimum Spanning Tree
- ▶ Chinese Postman Problem
- ▶ Genetic Algorithms

# Our Approach

- ▶ Dynamic Programming (DP)

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# Dynamic Programming

- ▶ A well known DP technique - DP with bitmasks

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- ▶ Optimal for small cases - roughly for 20-22 nodes

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- ▶ A well known DP technique - DP with bitmasks
- ▶ Optimal for small cases - roughly for 20-22 nodes
- ▶ Still exponential -  $\mathcal{O}(2^n n^2)$



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- ▶ Reconstruct input graph

# Christofide's Heuristic

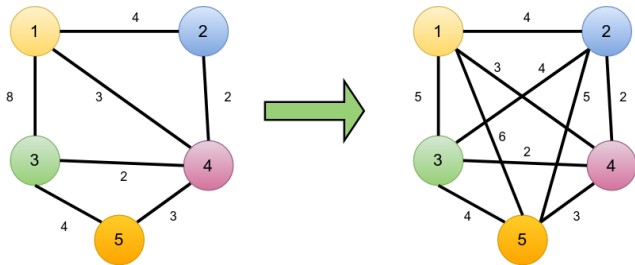


Figure: Reconstruction of input graph based on APSP algorithm.

# Christofide's Heuristic

- ▶ Prerequisite - *triangle inequality*
- ▶ Reconstruct input graph
- ▶ Build *Minimum Spanning Tree*

# Christofide's Heuristic

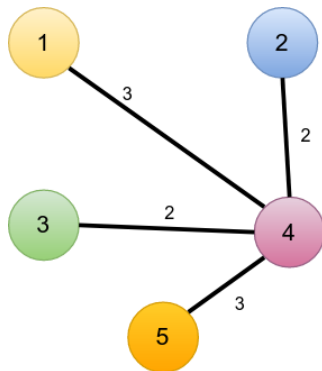


Figure: *MST of the reconstructed graph.*

# Christofide's Heuristic

- ▶ Prerequisite - *triangle inequality*
- ▶ Reconstruct input graph
- ▶ Build *Minimum Spanning Tree*
- ▶ *Minimum Weight Matching* using odd degree nodes and combine with MST

# Christofide's Heuristic

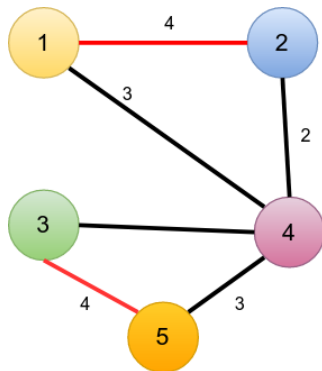


Figure: Combined graph



# Christofide's Heuristic

- ▶  $1.5 \cdot \text{OPT}$  heuristic
- ▶ Complexity -  $\mathcal{O}(n^3)$

# Comparison of Output

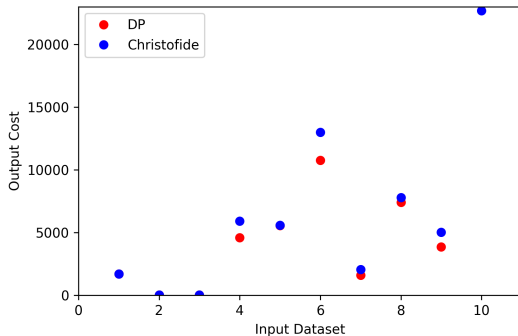


Figure: Comparison based on the output cost.

# Comparison of Execution Time

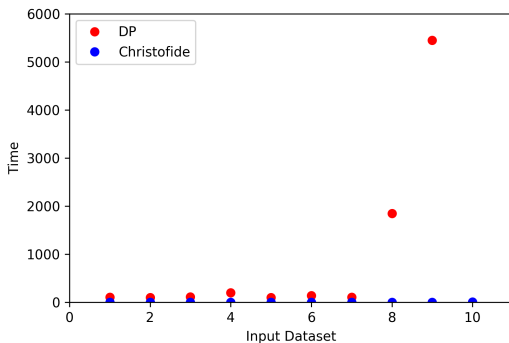


Figure: Comparison based on the execution time in milliseconds.

# Proposal

- ▶ Small cases (20-22 nodes roughly) - DP with bitmasks

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- ▶ Small cases (20-22 nodes roughly) - DP with bitmasks
- ▶ Christofide's heuristic for larger cases

# Future Work

- ▶ Field work like developing maps of garbage bins

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- ▶ More complex cost function

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- ▶ More complex cost function
- ▶ Genetic Algorithm to improve tour



Thank you.