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OPS Bus Scheduling: A Heuristic Approach to a Three-Tier Multi-Depot Vehicle Routing Problem With Inter-Depot Routes

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Abstract

Omaha Public Schools (OPS) currently uses a Two-Tier Bus Transportation System and is investigating whether switching to a Three-Tier Bus Transportation System would be cost effective by reducing the number of buses and bus drivers OPS uses. This project aims to develop an algorithm that would allow OPS to test whether a Three-Tier system is more cost effective. The "Bus Scheduling Project" is composed of two different software components: a geographical analyzer and a heuristic bus route generator.

Introduction

A shortage of bus drivers has been a significant problem for OPS, so they are interested in investigating whether a Three-Tier Bus Transportation System can reduce the number of buses, and consequently drivers, needed. The goal of the Bus Scheduling Project is simple:

- Determine whether it is feasible for OPS to make the switch from a Two-Tier Bus System to a Three-Tier Bus System with the following conditions:
    - Produced results outperform OPS's Two-Tier implementation by reducing the total bus count.
    - The solution satisfies a list of general transportation constraints – including public school transportation guidelines.
    - Solution is able to be fitted within OPS school start times schedule hierarchy, as shown in *Figure 1*.

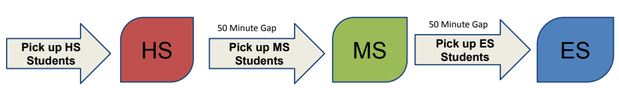

Figure 1: *Depiction of Planned Three-Tier Drop-Off Schedule.*

The Bus Routing Project

GeoGrapher

Using *Bing Maps* API and the graphing database *Neo4J*, the GeoGrapher performs the following actions:

- Finds the latitude and longitude of each address to check if they are real addresses.
- Calculates the distance and duration for a vehicle to drive from one address to another.

Addresses are then stored in Neo4J as nodes as shown in *Figure 2*:

Figure 2: *Graphical representation for how addresses are stored in Neo4J.*

Sweeper and Nearest Neighbor with Penalty

Using data from the GeoGrapher, the Sweeper considers each school's bus stops that are within a circular sector around the school, as shown with the red route in *Figure 3* (Blue routes are generated via Nearest Neighbor with Penalty.) Sectors are made large enough to visit as many bus stops as possible without violating the bus's ***Max Capacity***, OPS's official ***Max Ride Time*** of 75 minutes, and the ***Start Time Gap*** of 50 minutes (shown in *Figure 1*).

Phase One of the Sweeper Algorithm

Phase One focuses on assigning Middle School routes.

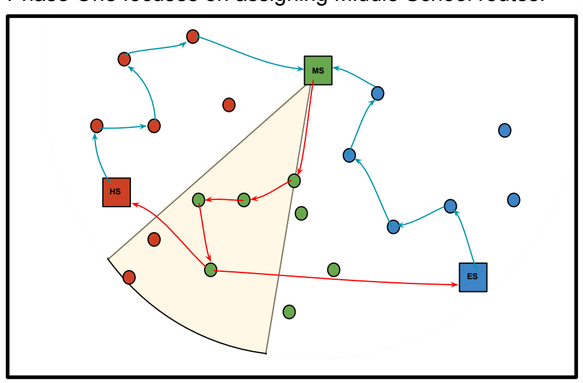

Figure 3: *Depiction of Phase One of the Sweeper algorithm.*

Since there are 50 minutes between school start times, then there is a 100 minute gap between High School and Elementary School start times. Taking advantage of this gap, Phase One creates highly efficient Middle School routes so that Phase Two can focus solely on the remaining High School and Elementary School bus stops.

Phase Two of the Sweeper Algorithm

Similar to Phase One, except that circular sectors are drawn around each High School and Elementary School, and the time constraint is more lenient.

Nearest Neighbor with Penalty (NNP)

The NNP algorithm uses a distance penalty between stops and schools to entice the algorithm to choose bus stops that progress closer to the ending school in a route. An optimization algorithm considers thousands of permutations of each route, and chooses the fastest route. NNP is used in both the Phase One and Two of the Sweeper algorithm.

Results and Future Work

The Bus Scheduling Project is able to produce routes that are both AM and PM feasible, with roughly 20% fewer buses than OPS currently uses. Future development includes:

- Implementing a scheduling model using DOcplex to determine when routes should start in accordance with the school start times hierarchy as shown in *Figure 1.*
- Updating existing coding implementation in the Phase One and Two to improve calculation speed.
- Averaging the duration data obtained from Bing Maps over the course of months in order to determine the expected durations between address (weather delay, construction, traffic delays, etc).
- Modifying the Sweeper Algorithm to allow it to temporarily skip and later revisit bus stops that violate a route's feasibility.

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