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/작품 최종보고서

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제목 : Factors guaranteeing QoS in shared bus scheduling

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1. Abstract

A shared bus can serve groups of passengers from different pick-up locations to drop-off locations. Previous research papers tried to provide algorithms for the most efficient and fastest path from the perspective of public transportation with minimum travel time, travel distance and energy cost. Greedy algorithm is one of the known algorithms to solve the Traveling Salesman Problem (TSP) in polynomial time. Meanwhile, the COVID-19 pandemic has changed the travel behavior, for instance, avoiding crowded buses at peak hours. This project will experiment three Quality of Service (QoS) factors that can affect the travelling time of passengers, particularly the number of buses running, the number of passengers taking the bus at once and the number of waiting passengers in bus stops. In this project, the Simulation of Urban Mobility (SUMO) program is used to test the relationship between each QoS factor and the average travelling time of passengers taking buses based on the greedy algorithm.

2. Introduction

The COVID-19 pandemic has changed the travel behavior of people all around the world. Taking public transportation, including buses, carried the risk of transmitting the virus from passengers to passengers. 53% of survey respondents from [1] agreed that the knowledge of COVID-19 severity affected their decision on riding buses. Furthermore, low ridership and government restrictions led to a reduce in buses running and an increase in bus fares.

As of today, we are living in the post-pendemic world, however, the passenger perception of COVID-19 risk and other viruses still exist. It is natural that the perception affects the ridership of passengers in shared buses. Additionally, if a bus is arriving at a bus stop and it is too crowded that there's no available seat left, then it is safer for passengers to wait for the next bus. Existing navigation apps in Korea, such as Kakaomap, provide number of available seats only for express buses. So, most passengers have to wait and see if the expecting bus has available seats or not.

Shared bus scheduling problem is an evolutionary TSP that solves the most efficient path that serves many passengers from different origins to different destinations. Shared buses are different from existing ride-sharing systems. Notably, shared buses have a centralized system, while exisitng ride-sharing systems like Uber have a distributed system.

Travel time, travel distance and energy cost are main factors in measuring the performance of any proposed scheduling algorithms. Previous research papers have been scaled too much into computational efficiency in perspective of vehicles and possibly ruled out QoS in perspective of the passengers. For example, the QoS factors can include the number of buses running per route, the number of passengers taking the bus at once and the number of waiting passengers in bus stops. Shared bus scheduling is currently an open field. Therefore, it is meaningful to find a relationship between the passenger QoS factors and the passenger travelling time.

In this project, the performance of passenger QoS factors will be tested based on the greedy algorithm and a simulation program is used to check and record the performance. The Simulation of Urban Mobility program, also known as SUMO, is a program that allows implementation of pedestrian, vehicle and other public transportation activities and experiments via simulations. In this project's simulation, a vehicle is defined as a bus, stopping at different bus stops on a predefined and created bus route. The bus drives on the road network that consists of a

1-lane road in a 9x9 grid. Buses start from the same bus stop (source) and visit bus stops according to the bus route. Passengers are added at source bus stop, wait or ride buses and arrive at their destinated bus stops.

3. Related work

In such mobility-on-demand field, solving the shared bus scheduling problem is challenging because it is a NP-hard problem. Existing strategies usually follow pruning and selecting scheme. For instance, like *Figure 1*, road network space is divided into cells. Buses can be located at any cells and their locations are dynamically recorded. If there is a request for a pick-up, buses nearby cells of source location will be first ones to be examined. In the pruning stage, buses that cannot satisfy the constraints of requests will be filtered out. Then most ideal buses are selected, and requests are added to their path. Xu et al. [5] propose more advanced algorithm GeoPrune that specifically focuses on "finding vehicles that satisfy the service constraints of trip requests rather than any particular optimization goal."

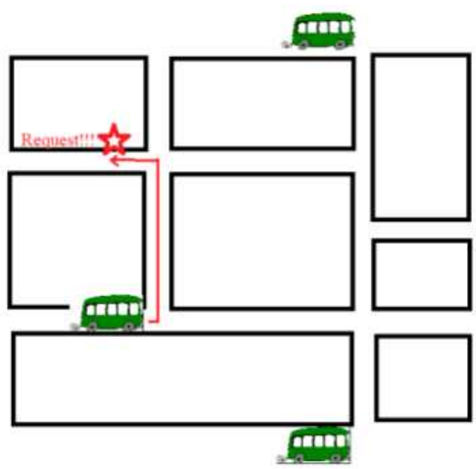

Figure 1. Self-drawn simple illustration showing shared buses driving in a road network space and nearest bus to the request source location being assigned.

Some papers are restricted to high-capacity ride sharing on large road networks. Zuo et al. [7] propose a “clustering-based multi-request matching and route planning algorithm Roo” without computing distances between nodes in advance. In particular, Mahin and Hashem [4] propose an Activity-aware Ridesharing Group Trip Planning (ARGTP) query on large road networks, but multiple point-of-interests (POIs) are pre-defined and used. However, all the above strategies cannot be applied in the real-world scenario where distances and points can be changed in any given time, for instance, due to road repairing.

Less research works focus on QoS. To reduce the total cost, Liu et al. propose Cooperative Intelligent Transport Systems (C-ITS) to minimize the total cost of Public Vehicle (PV) utilization on long distances [3]. C-ITS consists of path generation methods using simple near optimal method and reset near optimal method. C-ITS also involves greedy based path scheduling method. On the other hand, Zhu et al. [6] suggest short waiting time and less detour can be factors that provide high passenger QoS. Additionally, few PVs in a network can save travel distance at traffic peak time, but that means more passengers have to share PVs in limited space. Therefore, the number of PVs in the network can affect the level of passenger QoS.

In summary, majority of heuristic solutions for shared bus scheduling problem are related to greedy algorithm. And they are scaled to reduce the computational complexity and the total cost of bus utilization rather than enhancing passenger QoS. In this project, it is meaningful to investigate the relationship between the passenger QoS factors and their average travelling time, so passengers can make better choice in transportation in post-pandemic era.

4. Project architecture

The simulation in this project manages people that waits for bus at a same bus stop, takes bus and arrive at randomly assigned destinations in single ride. The only behavior is riding bus. Each person's total travelling time is recorded by adding waiting duration, boarding duration, and riding duration to the destinated bus stop. Then, the average travelling time will be calculated.

The simulation runs on SUMO which allows to work on the road network involving passengers who can walk and take a ride on public transport. TraCI, short for Traffic Control Interface, is a python library that allows users to define, retrieve values of objects, like passengers and buses, control their behavior dynamically and record the generated logs.

In the simulation, the road network is made of edges, nodes, lanes and bus stops. Each edge is formed by lanes. Edges are connected by nodes. Like *Figure 2* and *Figure 3*, the network is a 9x9 grid shape and each edge is composed of a lane. Edges with bus stops have sidewalks. The bus can halt, go straight, turn left and turn right. All bus routes starts from a source bus stop on the bottom left corner, named S2. The bus routes are not round-trips, which means they start at the source bus stop and vanishes at the last bus stop without returning to source bus stop.

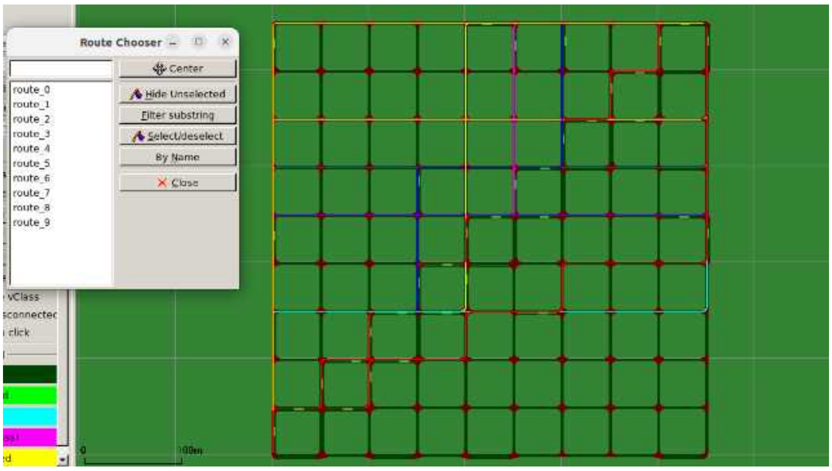

Figure 2. Simulation road network in 9x9 grid shape. 10 bus routes and bus stops are defined.

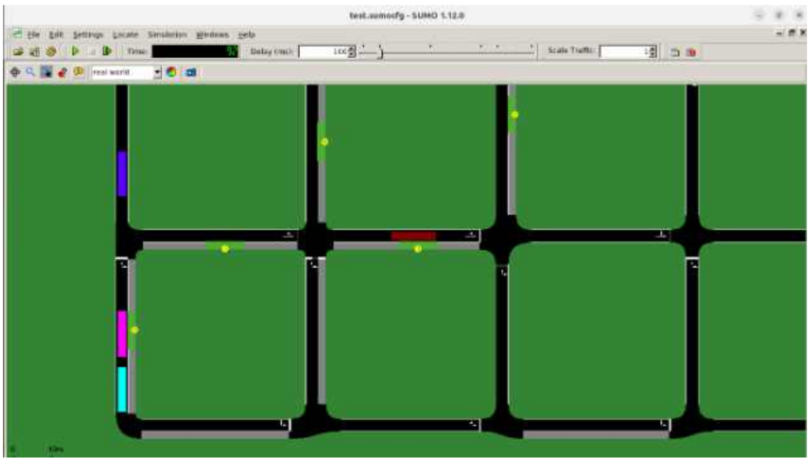

Figure 3. Buses halts at a source bus stop, named S2, on bottom left grid, for 20 simulation time, and then moves along the predefined routes and halts at the next bus stops.

5. Experiment hypothesis

Firstly, if more buses are running on the same route at a time, the passenger's average travelling time will decrease because the passengers will ride on the bus after short waiting time. Thus, it supports the increase in passenger's QoS level. Secondly, if maximum passenger capacity in each bus increases, then more passengers will get to ride the bus at once with lesser waiting time at the bus stops. Therefore, it supports the increase in passenger's QoS level, too. Last but not least, if more and more passengers arrive at the bus stop and wait for the bus, then both waiting time and average travelling time will eventually increase because of limited passenger capacity allowed to take the bus. For this reason, passenger's QoS level will decrease.

6. Comment and Future Work

The TraCI python programming is quite challenging, especially starting from assigning destination bus stops to each person. SUMO TraCI programming in Python required many references and tutorials including SUMO Pydocs documentation. Although this project failed to achieve the goal of moving passengers and calculating the average travelling time in TraCI code, it was very meaningful to study and apply the knowledge of simulation step by step. Thanks to a master degree student, Kwon Jun Hee, in IoT lab, weekly appointments were helpful sessions to understand NETEDIT, SUMO and TraCI. Personally, this project was very meaningful because one always returned, tried to understand the programming and put more effort in the project over a few semesters. Future research can be focused on achieving the goal mentioned earlier and also giving recommendation on faster travelling bus route for passengers who are dealing with similar routes that contain the destination bus stop. It can also be a possible factor affecting the QoS of passengers.

7. References

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