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Smart Bus Transportation System for Fast Arrival Time to the Girls Campus at Taif University

Fawaz Assery, Masoud Alajmy, Yasser Albagory
Department of Computer Engineering,
College of Computers and Information Technology,
Taif University, Saudi Arabia.

Abstract

Many universities in Saudi Arabia suffer from the difficulties to offer fast, smart and comfortable transportation systems for their girls students in order facilitate their arrival to the girls campus on time. Therefore, in this paper, an efficient student bus transportation system is proposed based on student feedback and minimum path length calculation. This system optimizes the overall path length and minimizes the delay time where the sequence of picked up students are chosen to minimize the overall path length. Also the student feedback will be an important input to optimize the new path length when the student is absent. The reduced path length and time delay will be reflected on energy and resources conservation as well as reduction in pollution and traffic densities. Simulation results show that to collect and drop 5 students in a medium sized city such as Taif, a saving in the path length of 13 km can be achieved by proper selection of the path. Also if one student is absent, the saving in the path length can be improved to 17.6 km using the proposed student-bus information system.

INTRODUCTION

The bus transportation systems are important in our daily life. Finding the shortest path between two points follow many algorithms and proposed techniques. Passengers should have knowledge of all information provided by the service providers (i.e. buses companies), otherwise the randomness will be the main resource for making decisions such as selecting the right bus or expecting the arrival and departure times. Therefore, some service providers give in advance the information needed by passengers to make better choice. Also, some companies provide a mobile software for bus systems to allow users to find the shortest path to their destinations. Neste Avgang [1] is bus information services which provides the rout information to passengers, and let them select the bus stops he or she want to use most of the time. It is based on mobile web browsers to determine the next departures for a given bus stop. The main limitation of Neste Avange bus system is the disability to use the most important context factors required to determine the updated rout information. TravelMagic [2] is another bus system services which are based on two factors required to be provided manually by a passenger. These parameters are the starting and the destination points. This system identify the expected arrival time to specific destination. The main drawback of this system is the necessity to enter the current location of a passenger manually using Google map, and upload it to the system. Trafikanten [3] is also bus transportation system which uses Android mobile application. It provides passengers the traffic information based on their current locations. The mobile app provides the next departures information. The main drawback of this application is the disability to provide information such as the arrival time and the lake of interaction between bus drivers and passengers. Authors in [4] proposed an application for the transportation system which is based on Global Positioning System (GPS). The system aims to provide some features such as the shortest path from the source to the destination, determine the approximate arrival time for buses and the capacity of selected buses. Authors claim that their proposed mobile app can achieve 98.7% as the satisfaction rate based on their analysis. However, a lake of interaction between bus drivers and the students is main limitation of this application. There is no way to inform a student about a bus which is coming to her area. The proposed system should include interaction methods such as SMS messages. Another issue is that the application should have a smart method to determine the expected arrival time for the bus if it is picking up many students in the rout to a particular student who is waiting. In [5], authors proposed a wireless tracking system for users locations based on GPS. In literature there are many applications for bus systems based on GPS such as the applications which are proposed in [6] and [7]. Versatrans My Stop [8] is a mobile application that provides access to bus information and students ridership data. It is a mobile app that can be used as a tracking system by parents to inform them about the locations of the buses which carry their kids. However, many reviews state that the application has technical problems such as the disability to re-download it from the app store and blank screen is frozen and not functioning very well. Also, some reviews focused on issues such as the arrival time of buses which is not accurate. In addition, capabilities such as SMS messages, GSM and GIS are not supported. Authors in [9] proposed Global Navigation Satellite System (GNSS) for bus system which allows sending SMS messages to passengers to inform them the time required by buses to arrive and the time required to reach to a specific bus stop. It is based on a mobile app which has some functions to reduce the waiting time in a bus stop. But this system suffers from many problems such as the disability to use maps to determine the exact rout for a selected bus. Similar bus transportation system based on the integration between GPS and GSM systems is proposed in [10].

STUDENT-BUS INFORMATION SYSTEM

The problem discussed in this paper goes further than finding the shortest path to the girls campus at Taif university, it also involves the necessity for sharing information and the interacting between passengers and bus drivers. Thus, this paper will develop smart and fast bus transportation system based on some computations related to the shortest path between the students house and the girls campus. We need to redefine the shortest path problem and take extra consideration for available data such as expected time of arrival and available buses. Dijkstra algorithm will be used for this purpose, and it will be tested based on seven locations in Taif city including driver, university campus and five students.

STUDENT FEEDBACK ROUTING TECHNIQUE

In this section, the student picking up path is minimized to reduce the reach time based on the shortest path. First, the matrix of minimum path lengths is built between the student locations. The minimum distances in this matrix are obtained by utilizing the Dijkstra algorithm. Assuming the starting and ending points are always constant which are the driver and university campus. Therefore, the minimum or shortest path for collecting students depends on the starting and sequence of students to be picked up. Other factors such as the traffic information, road maintenance, accidental situations, etc can also affect the sequence of collected student temporarily but are all not taken into consideration in this paper where the main updating information will be the student feedback. Therefore, we first define the minimum distance matrix as follows:

$$L = \begin{pmatrix} l_{0,0} & l_{0,1} & \cdots & l_{0,i} & \cdots & l_{0,N+1} \\ l_{1,0} & l_{1,1} & \cdots & l_{1,i} & \cdots & l_{1,N+1} \\ \vdots & \vdots & & \vdots & & \vdots \\ l_{i,0} & l_{i,1} & \cdots & l_{i,i} & \cdots & l_{i,N+1} \\ \vdots & \vdots & & \vdots & & \vdots \\ l_{N+1,0} & l_{N+1,1} & \cdots & l_{N+1,i} & \cdots & l_{N+1,N+1} \end{pmatrix} \quad (1)$$

Where:

N is the number of students,

$l_{m,n}$ is the distance between the m^{th} and n^{th} points,

$l_{0,i}$ is the distance between the driver home location and i^{th} student location,

$l_{i,N+1}$ is the distance between the university campus and the i^{th} student location,

$l_{i,i}$ is the self-distance of the i^{th} and $i = 0, 1, \ldots, N+1$.

It is clear that the matrix L is a square matrix of the size $(N+2) \times (N+2)$, therefore in the optimization process the optimum path should be found by searching for the shortest path according to the proper starting point after the driver movement from his home location. For each starting point the algorithm will search the shortest student picking up path and the sequence of students, then adding the drivers shortest path for each student and then chose the shortest overall path. Therefore, a submatrix L_{St} which excludes the first row and first column of the matrix L will be the starting optimization search matrix and can be written as:

$$L_{st} = \begin{pmatrix} l_{1,1} & \cdots & l_{1,i} & \cdots & l_{1,N+1} \\ \vdots & & \vdots & & \vdots \\ l_{i,1} & \cdots & l_{i,i} & \cdots & l_{i,N+1} \\ \vdots & & \vdots & & \vdots \\ l_{N+1,1} & \cdots & l_{N+1,i} & \cdots & l_{N+1,N+1} \end{pmatrix} \quad (2)$$

The proposed algorithm can be investigated from the following steps:

1- Build the shortest paths matrix L according to Dijkstra algorithm,
2- Subdivide the matrix L and find the submatrix L_{st},
3- Start with the ith row in L_{st} corresponding to the ith student where i=1, 2, … , N.
4- Find in the i^{th} row, the next collected student j and replace the i^{th} row and i^{th} column with infinity values.
5- At the j^{th} row, repeat (4) till finishing all rows in L_{st} where its elements should be replaced with infinity, or $l_{i,:} = l_{:,i} = \infty$, where : refers to all elements in the row or column.
6- Calculate the path collecting student sequence and its length for each starting student.
7- Add the corresponding shortest path from driver for each collecting path obtained from (6).
8- Choose the shortest path from driver to university campus according to the shortest path in (7).
9- If a student excuses during the predefined period of time, replace his row and column in matrix L and L_{st} with infinity values in order to exclude her from the collecting process, then repeat steps (4) to (8).

CASE STUDIES

Regular Students Pick up and Drop:

The system operation is demonstrated by a case study where it is assumed that the number of collected or picked up students is 5 therefore the minimum distance matrix L has dimensions of 7x7. The student submatrix L_{st} will be 5x5 elements from which the optimum path is deduced by the proposed algorithm.

Assuming that the flow graph shown in Fig. (1) demonstrates the minimum Dijkstra distances from each student to any other point. This graph is the main source to form the minimum distance matrix and subsequent calculations.

$$L = \begin{pmatrix} \infty & 2.3 & 1.3 & 5.1 & 3.3 & 2.4 & 2.8 \\ 2.3 & \infty & 3.6 & 3.1 & 4.1 & 3.2 & 4.8 \\ 1.3 & 3.6 & \infty & 3.9 & 2.0 & 1.1 & 1.5 \\ 5.1 & 3.1 & 3.9 & \infty & 3.7 & 2.8 & 3.4 \\ 3.3 & 4.1 & 2.0 & 3.7 & \infty & 0.9 & 1.4 \\ 2.4 & 3.2 & 1.1 & 2.8 & 0.9 & \infty & 1.6 \\ 2.8 & 4.8 & 1.5 & 3.4 & 1.4 & 1.6 & \infty \end{pmatrix} \quad (3)$$

And the student distance matrix will be:

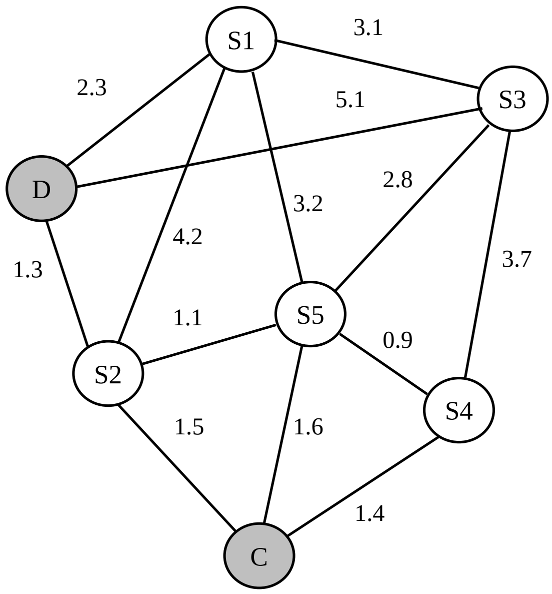

Figure 1: Minimum distance flow graph

$$L_{st} = \begin{pmatrix} \infty & 3.6 & 3.1 & 4.1 & 3.2 & 4.8 \\ 3.6 & \infty & 3.9 & 2.0 & 1.1 & 1.5 \\ 3.1 & 3.9 & \infty & 3.7 & 2.8 & 3.4 \\ 4.1 & 2.0 & 3.7 & \infty & 0.9 & 1.4 \\ 3.2 & 1.1 & 2.8 & 0.9 & \infty & 1.6 \\ 4.8 & 1.5 & 3.4 & 1.4 & 1.6 & \infty \end{pmatrix} \quad (4)$$

On running the algorithm on the matrix L_{st} and adding the minimum driver distance to each path, the resulting paths and its cumulative distances are shown in Table 1. Also the cumulative travelled distance for each path sequence is displayed in Fig.(2) where the first sequence (D-S1-S3-S5-S2-S4-C) has the shortest path among other sequences.

Table 1: Sequence of picked up students at different routes

Starting Point	Next Student and Minimum Link Distance to Previous Point					Ending Point	Total Path Length	Path Time @ 60 km/H
D	**S1**	**S3**	**S5**	**S2**	**S4**	**C**	**12.7 km**	**14.4 min**
	2.3	3.1	2.8	1.1	2	1.4		
	S2	**S5**	**S4**	**S3**	**S1**	**C**	**14.9 km**	**16.6 min**
	1.3	1.1	0.9	3.7	3.1	4.8		
	S3	**S5**	**S4**	**S2**	**S1**	**C**	**19.2 km**	**20.9 min**
	5.1	2.8	0.9	2	3.6	4.8		
	S4	**S5**	**S2**	**S1**	**S3**	**C**	**15.4 km**	**17.1 min**
	3.3	0.9	1.1	3.6	3.1	3.4		
	S5	**S4**	**S2**	**S1**	**S3**	**C**	**15.4 km**	**17.1 min**
	2.4	0.9	2	3.6	3.1	3.4		

Excused or Absent Student Case:

In this case the student matrix will be affected by the temporary absence of one or more students. If a feedback message indicating that i^{th} student is absent, then the corresponding i^{th} row and i^{th} column will be replaced by infinity distance in order to exclude her from picking up and dropping service. For the case study in section xx assume that the second student is absent so the new scheduling of picking up is optimized for another shorter travelling distance. So the new student matrix will be:

$$L_{st} = \begin{pmatrix} \infty & \infty & 3.1 & 4.1 & 3.2 & 4.8 \\ \infty & \infty & \infty & \infty & \infty & \infty \\ 3.1 & \infty & \infty & 3.7 & 2.8 & 3.4 \\ 4.1 & \infty & 3.7 & \infty & 0.9 & 1.4 \\ 3.2 & \infty & 2.8 & 0.9 & \infty & 1.6 \\ 4.8 & \infty & 3.4 & 1.4 & 1.6 & \infty \end{pmatrix} \quad (5)$$

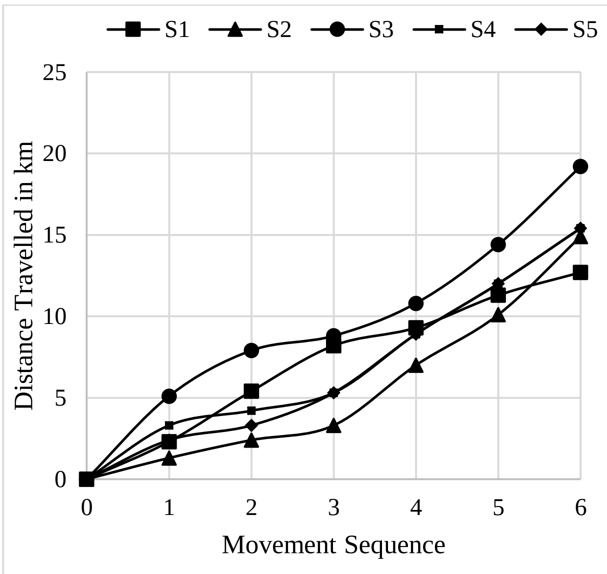

Figure 2: Distance travelled for each minimum path sequence

According to the updated student distance matrix in Eq. (5), the corresponding optimized paths are shown in Table 2 and the cumulative travelled distance is displayed in Fig. (3) where the optimum shortest path will be (D-S1-S3-S5-S4-C) which is shorter than the original path by 2.2 km and leads to a reduction in the travelling time by 2.5 minutes. If the original picking up route is used, the absent student will reduce the path time by only 20 seconds which is the required time for stopping the buss for picking up the student. If more than one student is absent, then the reduction in the path time will be more effective in the two ways.

Table 2: Sequence of picked up students at different routes in case of excused second student.

Starting Point	Next Student and Minimum Link Distance to Previous Point					Ending Point	Total Path Length	Path Time @ 60 km/H
D	**S1**	**S3**	**S5**		**S4**	**C**	**10.5 km**	**11.9 min**
	2.3	3.1	2.8		0.9	1.4		
		S5	**S4**	**S3**	**S1**	**C**	**14.2 km**	**15.6 min**
		2.4	0.9	3.7	3.1	4.8		
	S3	**S5**	**S4**		**S1**	**C**	**17.7 km**	**19.1 min**
	5.1	2.8	0.9		4.1	4.8		
	S4	**S5**		**S3**	**S1**	**C**	**14.9 km**	**16.3 min**
	3.3	0.9		2.8	3.1	4.8		

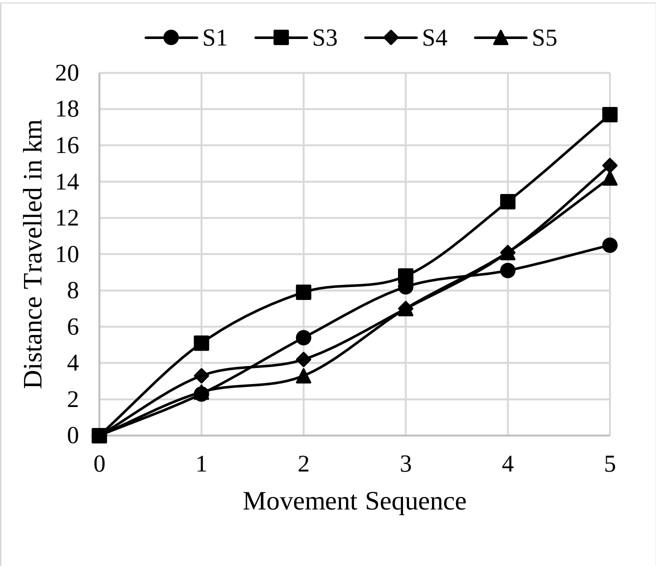

Figure 3: Distance travelled for each minimum path sequence

DISCUSSIONS

Although Dijkstra algorithm provides the shortest path between two points, the overall path that passes through all points is of major importance and should be chosen carefully to minimize the delay between points and overall path delay. As shown from the case study with complete student attendance, the difference between the minimum and maximum path lengths is 6.5 km. This difference is doubled for picking up and dropping so a total of 13 km of driving is wasted per day. The difference in path length can be worse if a student is absent without updating the picking up and dropping paths where the difference between the worst path (19.2 km) and the optimum path in case of absent student (10.5 km) is 8.7 km in one way and 17.6 km in the two ways which represents a huge waste in distance and time delay. The problem exaggerates if two or more students are absent without applying the proposed optimum student path algorithm.

CONCLUSION

In this paper, an efficient student-bus information system is introduced for optimizing the path length and sequence of picked-up and dropped students. The system is based on optimizing the path length and sequence of picking and and dropping of students along with a feedback from excused or absent student. A student distance matrix containing the minimum path lengths to every other point using Dijksta algorithm is built from which the optimum path that collects and drops all students is obtained. For the excused or absent student, the corresponding minimum distances are replaced with infinity and the path is re-optimized to find the shortest path with proper new student sequence. The impact of updating the path for changing student cases is very important on travelled distances and time delays which reduces the consumed energy and amount of pollution.

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