Optimization of Dynamic School Bus Routing Problem by Using Metaheuristic and Clustering Methods

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1 Introduction and Problem Description

Vehicle routing problems (VRP) are complicated problems, which can be encountered in a variety of different fields and are not possible to solve using conventional methods. Thanks to the technological advancements in areas such as the global positioning system (GPS), geographical information systems (GIS), mobile communication networks, and traffic sensors, it is now possible to solve the vehicle routing problems in a dynamic and real-time manner [3]. There are many metaheuristic methods developed for the solution of the problem; and it was observed that metaheuristic methods prove to produce more successful results compared to common heuristic methods. In their study conducted to implement Genetic Algorithm(GA) to solve School Bus Routing Problem (SBRP), Sghaier, Guedria, and Mraihi concluded that they can reduce the total distance to cover from 162.410 km to 154.880 km, resulting in a total cost saving equal to 17.87% [1].

Today, school bus transportation is widely preferred by parents due to reasons such as lower schooling age, increase in the distance between the school and home, and safe and fast transportation compared to other means of transport especially in greater cities with high density of traffic. SBRP, which is a subgroup of VRP, is defined also as a kind of travelling salesman problem. The SBRP includes determining the shortest route for a school bus to pick up all the students from the pre-determined stops and to take them to school, and to pick the students up from school and leave them at the pre-determined stops.

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Although a number of studies focusing on SBRP can be found in the related literature with a variety of purposes, the following issues appear as the most frequent goals:

– To minimize costs associated with transportation
– To minimize time spent on transportation [2]
– To minimize the total number of vehicles used for transportation

This problem consists of a number of sub-problems. The problem is solved in five steps [4].

– Data preparation
– Selection of stops (assigning students to stops)
– Route development
– Scheduling school bell
– Route planning

In this study, visual software in which Ant Colony Optimization and GA metaheuristics and K-means clustering method were applied was developed by using C#.NET language for the optimization of a dynamic school bus routing problem. According to vehicle capacities and the distance matrix between the student stops and the school, clustering method is used to assign student stops to school buses and this helps to determine the optimized routes by using the metaheuristics. The present study aims to improve currently available routes, and to update these routes online using the instantaneous GPS locations of the students, tracked down by means of mobile software support. The goal is to avoid the current time, cost, and work-load losses and to reduce air pollution and traffic density by improving the routes. Comparisons of the performances of ACO and GA metaheuristics used on the school bus route optimization were carried out in terms of time, number of trials, and route distances, and the obtained experimental were presented.

2 Study method and developed software

For this study, the school bus routes within the Sincan district in the capital city of Ankara were used as case studies. The school bus routes were recorded by using the Android application and instantaneous GPS monitoring method. The home address of each student was taken as a stopping point. At the end of each route, the distances between the beginning and end points were recorded. After transferring the obtained route data into the system database, the optimized routes are determined by using the clustering techniques and metaheuristic methods. Figure 1 shows the study method as described above.

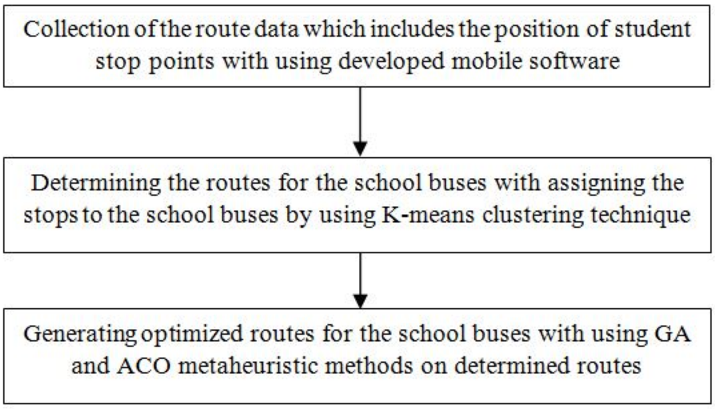

Fig. 1 Study method

The application was developed for both mobile and desktop. GPS locations of student stops and the school bus were transferred to a server in real time through the Android-based mobile software and with the desktop software that operated ACO and GA. The most suitable routes were formed by the locations of these coordinates on Google Maps and then communicated to the school bus over the server. With this method, factors such as a change in the starting location of the school bus, some of the students being absent for that certain day, and changes in the current roads due to various reasons were possible to dynamically reflect on the generation of route. Figure 2 shows the block diagram of developed application as described above.

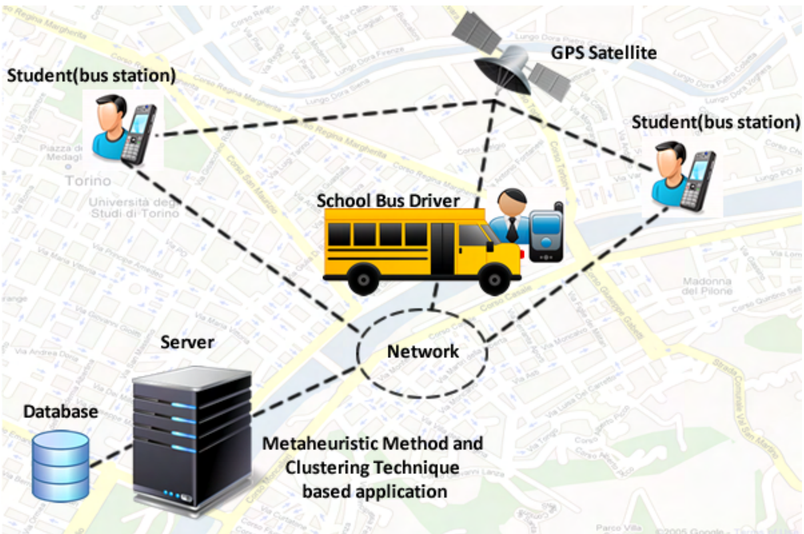

Fig. 2 Block diagram of developed application

Table 1 Obtained experimental results.

Details of the collected routes				Results of algorithms							
No	Bus Stop Count	Time (min)	Distance (km)	Iteration Count		Best Route Time (min)		Best Distance (km)		Optimization Rate (%)	
				ACO	GA	ACO	GA	ACO	GA	ACO	GA
1	11	15	4.23	5395	1389	14	13	4.21	3.79	0.47	10.40
2	17	38	17	183	606	37	34	17.08	14.72	-0.47	13.41
3	18	45	19.9	70	71	44	40	19.78	16.31	0.60	18.04
4	5	22	12	8	1	19	19	8.86	8.86	26.17	26.17
5	6	21	9.84	7	1	20	20	9.38	9.38	4.67	4.67
6	13	32	15	3473	167	31	28	12.63	11.69	15.80	22.07
7	7	13	4.1	87	1	12	12	3.47	3.47	15.37	15.37
8	6	18	6.8	41	1	16	16	5.98	5.98	12.06	12.06

The desktop software through which the optimization was applied was developed using C#.NET language. In order to store the planned route and points at the route, on the other hand, a SQLite database was used. GMap.NET add-on was utilized to visualize stop information on the routes on Google Maps. Coordinates of stops on the route were recorded with their latitude and longitude values. The mobile software was developed for school bus drivers and students using Java programming language on Android mobile operating system. The mobile software was used also during the data collection process.

3 Experimental Results

The application through which the experimental results were obtained for the optimization of current routes was operated on a computer with 64 bit Windows 7 operation system and with 4 GB of RAM and an INTEL i5-2410 M processor. Experimental results that were obtained by applying ACO and GA are shown in Table 1.

As the number of stops increase, it was concluded that distances were possible to optimize at a higher rate. It was observed that in routes in which the school is set as start/finish, the best solution is reached more quickly. In line with the obtained results, the conclusions mentioned below were reached by comparing the methods:

– Generally, GA produces more successful results compared to ACO
– ACO provides the results faster compared to GA in terms of the total operation time. However, GA produces the results at a lower number of iterations. The advantages of pheromone use in ACO, and cross-breeding and mutation processes taking time in GA have an effect on ACO operating faster compared to GA
– An attempt is made to improve the routes based on the density of pheromone amounts obtained through random routes produced by ACO in the beginning. Here the success of initially produced routes determines the success

of the routes significantly, and not so many major changes occur in routes throughout the operation of the algorithm. GA operates in a more flexible way compared to ACO. Many faulty routes have been generated throughout the operation of the algorithm, however, well application of mutation and cross-breeding techniques, the ability to make changes on routes without depending on any factors (amount of pheromones), the exclusion of bad routes from the population, and the inclusion of good routes to the population as a result of cross-breeding and mutation are the major reasons for the results to be more successful

4 Conclusions

Today, transportation and distribution systems have quite a common use in all fields of life thanks to the advancements in technology, as well. Due to the problems that resulted from the use and the structure of these systems that increasingly become more complex, such as the cost of the labor force, environmental pollution, and traffic, their professional management has become unavoidable. Thanks to the current technological opportunities, routing studies can be carried out more dynamically and as such, more productive results can be produced.

The developed application was tested on existing school bus routes in the Sincan District of Ankara Province. It was clearly seen that the application helped achieve successful results in the optimization of school bus routes. Based on the results obtained for the sample routes, it was concluded that the total distance to cover can be improved by 16.51%. Thanks to the mobile-support feature of the application, real-time solutions can be obtained.

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