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H-PSO Routing Optimization Model for Zoomlion Ghana Limited

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JK, EA and FBKT designed the study, performed the statistical analysis and wrote the protocol and the first draft of the manuscript. Author LB managed the analysis and proof read the manuscript. All authors read and approved the final manuscript.

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Review Article

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Abstract

This research combines Particle Swarm Optimization (PSO) with Crossover and Mutation Operators of Genetic Algorithm (GA) to produce a hybrid optimization algorithm to solve a routing problem identified at Zoomlion Ghana Limited, Sekondi Takoradi branch. PSO is known to converge prematurely and can be trapped into a local minimum especially with complex problems. On the other hand, GA is a robust and works well with discrete and continuous problems. The Crossover and Mutation operations of GA makes the iterations converges faster and are reliable. The hybrid algorithm therefore merges these operators into PSO to produce a more reliable optimal solution. The hybrid algorithm was then used to solve the routing problem identified at Zoomlion Ghana Limited, Sekondi Takoradi branch. A total of 160 public waste bin centers scattered in the metropolis and the distance between them were considered. The main aim was to determine the best combination of the set of routes connecting all the bin centers in

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the municipality that will produce the shortest optimal route for the study. MATLAB simulation was run of the list of distances to determine the optimal route. After 10,000 iterations, PSO produced an optimal result of 81.6 km, GA produced an optimal result of 88.9 km and the proposed hybrid model produced an optimal result of 79.9 km

Keywords: PSO; GA; H-PSO; optimization; hybridization; Zoomlion Ghana Limited; crossover; mutation; vehicle routing problem.

1 Introduction

Waste management is one of the pertinent global problems fighting for a bigger slot in the national budget of many countries. Ghana is not an exception. In Ghana, like many other African countries, the government, as part of his keep Ghana clean agenda, is spending huge sums of money every year to manage waste and maintain sanitation [1]. In Africa, urbanization is the root cause of the increase in waste production in urban areas than in rural because many people are traveling to these urban areas for greener pastures and the higher the population in a particular area, the greater the volume of waste they produce [2]. Urbanization is expected to continue to increase in the near future [3].

In Ghana, the rate at which waste is generated in the urban areas is very alarming. Though government is trying his best to curb this sanitation problem by supporting the services of waste management companies like Zoomlion Ghana Limited, FG Plastic Recycling Ghana Limited, TrashSmart, etc. but the situation still remains a leading challenge to the countries' sanitation problem due to some pertinent problems faced by these companies [4]. The proportion of populations living in urban areas in Africa is expected to increase from 40% in 2010 to about 57% in 2050 which definitely implies that the generation of waste will continue to increase in these areas [5]. In respect to that, there is the need for proper waste management plan for urban areas in order to curb the situation.

Even though technology has changed how business are run these days, certain components the business today has not been replaced by any technology yet and that is routing [3]. There are different companies that depends on routing for their daily services like mail delivery services, laundry service companies, travelling salesmen problems (TSP), etc. [6]. These companies need to have a daily route plan with multiple stops to ad in the daily operations. Unfortunately, many of them don't realize how important route optimization can increase their operational efficiency and gains [7].

Route optimization is the process of determining the most cost-efficient set of routes [8]. It's not only about finding the shortest path between two points, but it's rarely that simple: You must account for all relevant factors involved such as the number and location of all stops on the route, arrival/departure time gap, effective loading, etc. [9,10]. Route optimization is the means for finding a solution to vehicle routing problems (VRPs) in companies that depends greatly on routing to provide services to clients [11]. On the other hand, Vehicle Routing Problem (VRP) is the challenge of designing an optimal routes plan that connects all routes linking the depot to a set of destinations each with business-specific constraints, such as vehicle limitations, cost controls, time windows, resource limitations concerning the loading process at the depot, etc. [12]. The idea is to serve customers along a specifically defined route map making sure each customer or service point is visited once [13]. The first classic VRP is known as the traveling salesman problem (TSP), which originated in the early 1800s and became widespread in the days when door-to-door salesmen peddled vacuum cleaners and encyclopedias [14].

Ghana has most of its waste production in the urban areas than the rural areas. In the urban areas, a variety of these wastes are produced, ranging from solid waste, chemical waste, liquid waste, construction waste, industrial waste etc [3]. The predominant wastes being domestic solid waste, industrial waste and construction waste. These wastes are sent to a few dumpsites, but majority end up in drains, streams and open places [15]. Most of these wastes are disposed of by open dumping, open burning, uncontrolled burning and tipping at dumpsites. This has created a pressing sanitation problem as many towns and cities are overwhelmed with management of municipal solid and liquid wastes [13]. Some part of the urban areas smells very badly due to poor management of these wastes. The current state of waste management leaves much to be desired. Less than 40% of urban residents are served with solid waste collection services and less than 30% by an acceptable household toilet facility [16]. The traditionally applied methods of dealing with wastes have been unsuccessful, and the resulting contamination of water and land has led to growing concern over the absence of an integrated approach to waste management in the country [14].

Waste recycling has become a viable economic option in the country despite the considerable cost of collection [17]. Some industries are using waste recycling technologies to circumvent the need for treatment and the discharge and disposal of large volumes of waste and to reduce demand for raw materials, energy and water [17]. Some of these industries have found waste recycling as effective ways of improving the economic competition of their products. For example, Guinness (Ghana) Limited, Kumasi, derives part of its revenue from the sale of yeast and spent grain used as animal feed [18]. Generally, scavenging has often been considered a hindrance to municipal waste disposal operations, however they play a vital role in the waste recycling process [19]. Ways of officially incorporating scavengers into municipal waste operations should be seriously considered. For example, they can be designated as official used-materials merchants and given training and status upgrading [20].

One of the problems waste management companies are facing is the need for an optimal routing plan for the garbage trucks can visit the waste bin centers within the shortest possible distance [21]. This will help the companies to increase productivity, serve a large number of customers within a short time and also serve customers on time [22]. The problem this study seeks to solve is to use MATLAB simulations on PSO and GA to find the shortest possible set of routes connecting all the waste bin centers so that the trucks wouldn't have to visit any bin center more than once during service. The focus will be on the shortest set of routes connecting all bin centers and the hybrid HPSO will be employed for the analysis [18].

1.1 Related research work

Many works have been done on vehicle routing using many optimization algorithms such as Particle Swarm Optimization, Genetic Algorithm, Simulated Annealing, etc. According to [23], PSO has been used on many optimization problems and the result proved better in many situations and also, GA with its operators: crossover and mutation, has always provided a faster simulated process. Comparing of the performance of PSO with GA showed that, GA run faster as compared to PSO. PSO on the other hand is easy to implement and produces much better result than GA.

1.2 Contribution to knowledge

There are many VRP solved with different optimization algorithms. Many of these problems apply these algorithms separately and arrives at a result based on their stopping criteria. In this paper, a new hybrid optimization algorithm is introduced and add to knowledge a faster, dependable and more reliable optimization algorithm that combines crossover and mutation with particle swarm optimization to solve routing problem.

2 Methodology

2.1 Source of data

The data was obtained from Zoomlion Ghana Limited, Sekondi Takoradi Branch. The data was generated on January 30, 2021. It specifies the number of waste bins placed at various vantage points within the metropolis and the distance between the waste bin locations. MATLAB was used in the analysis. Fig. 1 shows the map of Sekondi Takoradi. The metropolis covers a land area of $219km^2$ with Sekondi as the administrative headquarters. It is located on the west coast with the trans West African highway passing through. The Metropolis is located on the south-western of Ghana, about 242km west of Accra, the capital city. It is also approximately 280 kilometres from the La Cote d'voire border in the west. [24]. A total of 160 public waste bins located at different towns in the Sekondi Takoradi metropolis are considered.

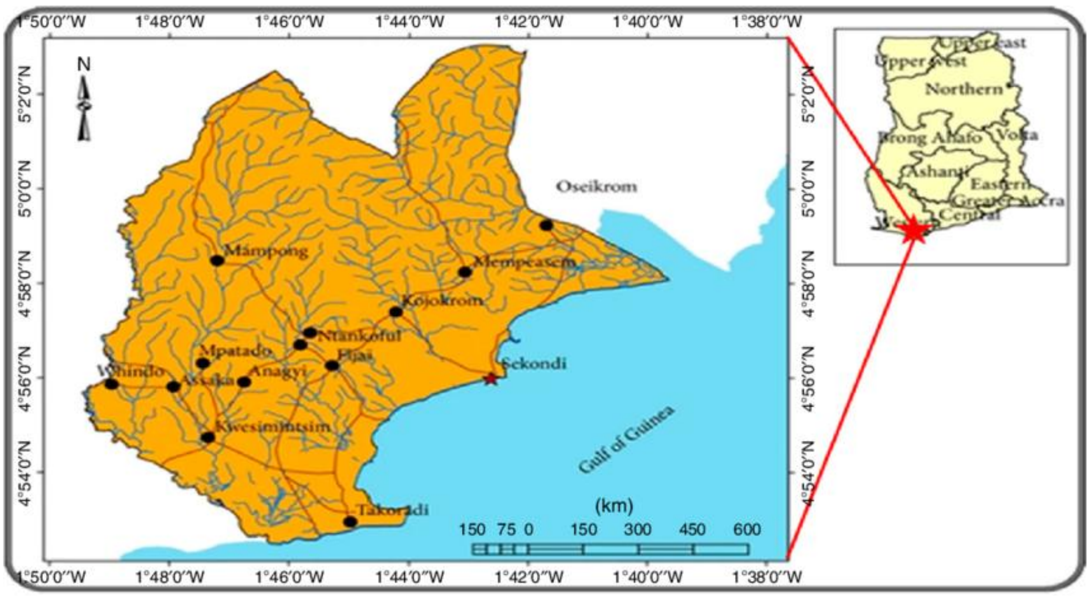

Fig. 1. The Map of Sekondi Takoradi Metropolis

2.2 Particle Swarm Optimization (PSO)

Particle Swarm Optimization forms part of the hybrid algorithm used in this paper. This algorithm aims at narrowing down the search space into an optimal search space. The algorithms follow the following framework: Initialization, fitness value calculation, update of the particle's velocity and position. At the initialization stage, the routes are encoded into arrays taking into consideration the position, velocity and particle best positions of each particle [7]:

$$x_i = (x_{i1}, x_{i2}, x_{i3}, \dots, x_{in}) \tag{1}$$

$$v_i = (v_{i1}, v_{i2}, v_{i3}, \dots, v_{in}) \tag{2}$$

$$P_i = (P_{i1}, P_{i2}, P_{i3}, \dots, P_{in}) \tag{3}$$

The fitness value of each particle determines the strength of each particle in the search space. During each iteration, the velocity of each particle v_{it} moves the particle x_{it} towards a new velocity $v_{i(t+1)}$ based on the previous velocity value $v_{i(t-1)}$. The objective function for the fitness value is defined as $\sum_{i,j\in N}^{n} x_{ij}$ where n is the number of bin centers [17].

After the fitness value the velocity and position of each particle was updated using the following equations:

$$v_{it} = v_{i(t-1)} + c_1 \times r_1 \times \left(pbest - x_{i(t-1)}\right) + c_2 \times r_2 \times (gbest - x_{i(t-1)}) \tag{4}$$

And the equation for updating the position of each particle is

$$x_{i(t+1)} = x_{it} + v_{i(t+1)}) \quad (5)$$

The PSO model algorithms is stated below:

Decision variables:

$$x = \{x_1, x_2, x_3, \dots, x_n\}$$

Objective:

$$minimize \sum_{i,j \in N}^{n} x_{ij}$$

i.e., the distances between the waste bin centers,

Subject to: equations (4) and (5) above

Fig. 2 presents the order of the implementation of particle swarm optimization algorithm. The number of iterations depends on the stopping criteria by the researcher. The iteration repeats after the update of the position and velocity of the particle.

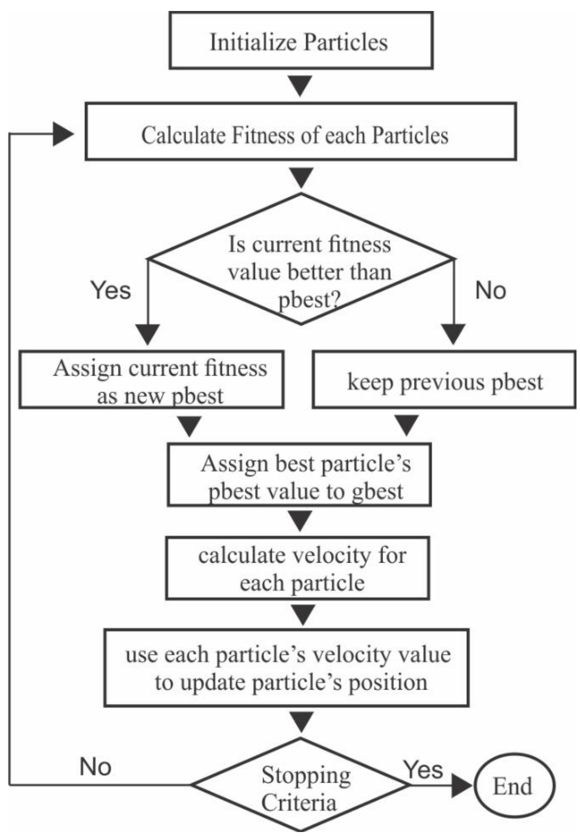

Fig. 2. The framework of particle swarm optimization

2.3 Genetic algorithms

Genetic algorithm is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation [5].

The process of natural selection starts with the selection of fittest individuals from a population. They produce offspring which inherit the characteristics of the parents and will be added to the next generation. If parents have better fitness, their offspring will be better than parents and have a better chance at surviving [11].

GA goes through five phases: Initialization, Fitness evaluation, Selection, Crossover and Mutation Fig. 3 presents the order of implementation. The routes are encoded into population, chromosomes, genes, alleles before selection, crossover and mutation operators are applied.

The Model for GA is defined below:

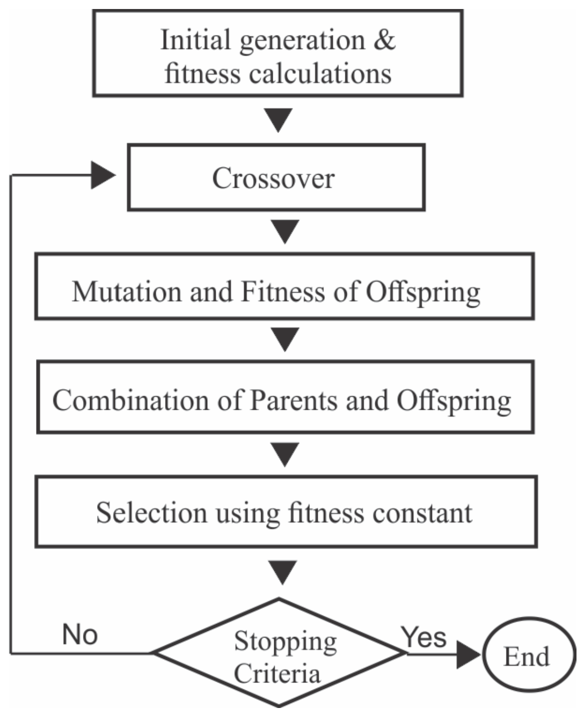

Fig. 3. The framework of genetic algorithm

2.4 Hybrid algorithms

The hybrid algorithms combine Crossover and Mutation operators of GA with PSO. This was the algorithm used in this paper. The routes were converted into arrays and simulation was run with MATLAB. The hybrid algorithms follow the following steps: Initialization, Fitness calculation, Update of a particle's velocity and position, Crossover and Mutation [8].

The hybrid algorithms eliminate Particle Swarm Optimization's drawback of premature convergence. It also eliminates the fast rate of information flow between particles which usually results in the creation of similar particles that increases the probability of being trapped in local optima. HPSO also ensures that the problem dependency associated with the stochastic approach of PSO is eliminated [14].

2.5 Parameter used

A total of 200 population size (waste bin centers) were used. A maximum iteration of 10,000 was used with crossover percentage of 0.8%, mutation percentage of 0.3%. the mutation rate is 0.02. two different selection approaches were used: Roulette wheel and tournament selections.

3 Results and Discussion

MATLAB simulation was performed on the data collected from Zoomlion Ghana Limited, Sekondi Takoradi branch and the result are presented below. The distances between the waste bin centers were run separately in MATLAB using Particle Swarm Optimization algorithm, Genetic Algorithm and hybrid algorithms. A stopping criterion of 10,000 iterations was set for all algorithms. The results are presented below.

3.1 Result of particle swarm optimization

Fig. 4 present the result of the PSO after the distances between 160 waste bin centers were run in MATLAB. The total iteration that produced this result was 10,000. The duration for this simulation was 2432.594 seconds. At the end of the iterations, the optimal route distance was 81.6 km. the stopping criteria set here was a maximum of 10,000 iterations.

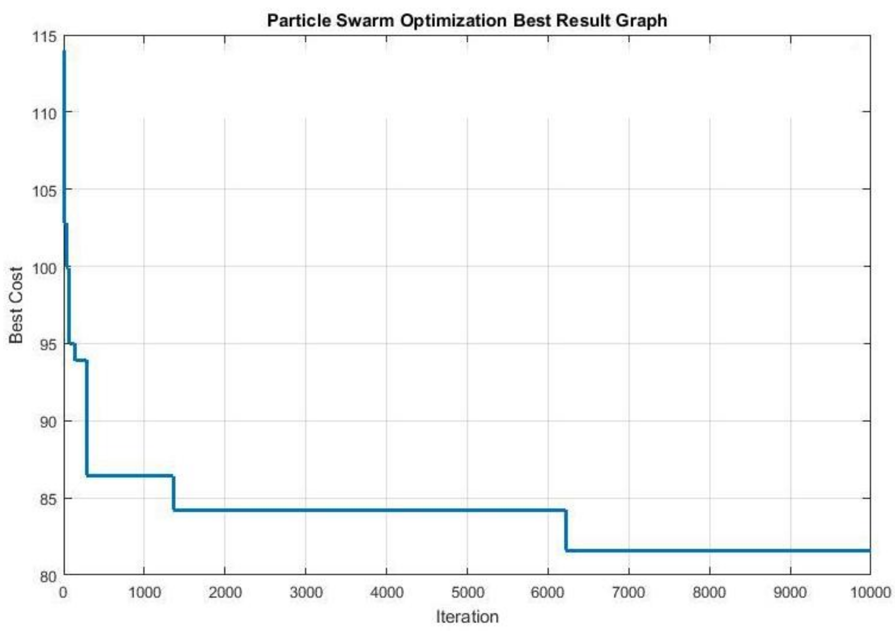

Fig. 4. PSO results after 10,000 iterations

3.2 Result of genetic algorithm

Fig. 5 present the result of the GA after the distances between 160 waste bin centers were run in MATLAB. The total iteration that produced this result was 10,000. The duration for this simulation was 259.4684 seconds. At the end of the iterations, the optimal route distance was 88.9 km. the stopping criteria set here was a maximum of 10,000 iterations.

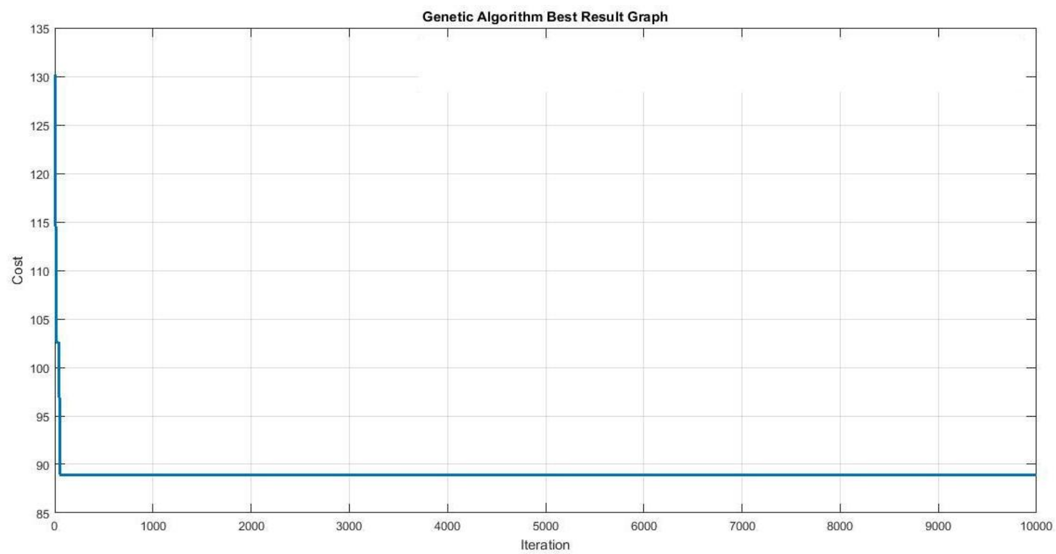

Fig. 5. GA results after 10,000 iterations

3.3 Result of hybrid algorithm

Fig. 6 present the result of the Hybrid algorithm after the distances between 160 waste bin centers were run in MATLAB. The total iteration that produced this result was 10,000. The duration for this simulation was 2855.1353 seconds. At the end of the iterations, the optimal route distance was 79.7 km. the stopping criteria set here was a maximum of 10,000 iterations.

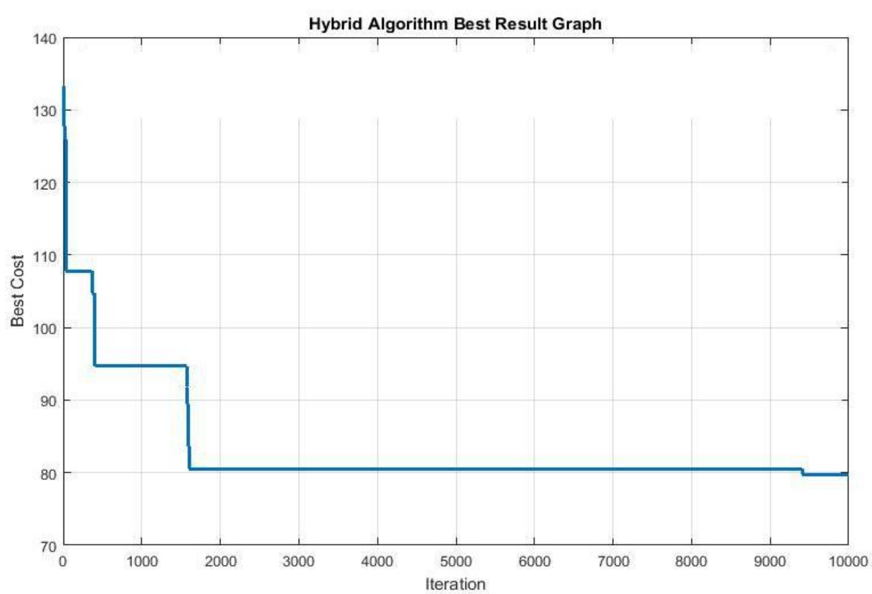

Fig. 6. GA results after 10,000 iterations

3.4 Discussion

Table 1 presents the summary of the algorithms, iterations, durations and optimal route results of the simulation. Even though PSO is easy to implement as compared with GA, it is known to converge prematurely to local optimal. After 10,000 iterations, an optimal distance of 81.6 km was achieved in 2432.594 seconds. In the same number of iterations, GA produced 88.7 km in 259.4684 seconds. This confirms that the crossover and mutation operators in GA makes the algorithm run faster as compared to PSO but PSO is much optimal in result than GA. The hybrid algorithm which combines crossover and mutation with PSO produced a minimal optimal result of 79.7 km after 10,000 iterations in 2855.1353 seconds. It is evident that, merging the two operators increases that duration of iterations but it produced the best result as compared to PSO and GA separately.

Table 1. Summary of algorithms, iterations, durations and optimal result

Algorithm	Iterations	Duration	Optimal distance
PSO	10,000	2432.594 secs	81.6 km
GA	10,000	259.4684 secs	88.9 km
Hybrid	10,000	2855.1353 secs	79.7 km

4 Matlab Code Structure

The code used in running the hybrid algorithm combines the code for Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). The hybrid code begins by initializing random data from the sample data. It then calculates the fitness value of each particle and select the particles with minimal values. It continuous to update the position of the particles and recalculate the fitness values. At this point, another selection of particles is made then the second part of the code involving GA begins. At this point, crossover and mutation code begins and the final optimal solution is arrived based on the programmed stopping criteria

5 Conclusion

In this work, a hybrid algorithm where crossover and mutation parameters of GA was merged with PSO was implemented. After running 10,000 iterations with the distances between 160 waste bin centers of Zoomlion Ghana Limited, Sekondi Takoradi branch, an optimal route of 79.7 km long was achieved. This shows that a better result has been achieved by the hybrid algorithm than with the separate PSO and GA algorithms. This paper adds to knowledge, a faster and more reliable optimization algorithm for solving route optimization problems.

Competing Interests

Authors have declared that no competing interests exist.

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