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UAVs path planning architecture for effective medical emergency response in future networks

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ABSTRACT

With the advancements of the Unmanned Aerial Vehicles (UAV) technology for use in different environments, it can be easily substituted for traditional transportation in event of emergencies. In the medical domain, UAV can play a vital role in the fast and efficient delivery of first aid and medical supplies. In the current study, safe and smooth UAV navigation from the initial position to the medical emergency location was achieved with optimal path planning through a proposed algorithm. On the notification of patient about his health condition using GSM band, doctor drone was sent from the nearest hospital facility. To avoid traffic congestion the doctor drone provides medical assistance with minimum computational time and transportation cost. The vehicle routing was carried out through proposed algorithms i.e., capacitated Vehicle Routing Problem (CVRP), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and Genetic Algorithm (GA). The comparison between the algorithms was carried out at different vehicle capacities and numbers. The CVRP was found to outperform other algorithms with a runtime of 0.06 sec and cost of 419 at vehicle capacity 10, which is 50% less having the same number of the vehicles but increasing the capacities to 20. The results indicate that the effective path planning method could be applied to provide medical aid in real-time with efficacy.

1. Introduction

During natural calamity or medical emergencies, severe casualties occur and it is essential to reach the victims in time to safe their life [1], The first aid and medicines need to be delivered to the victim onsite instead of bringing them to the hospital due to inaccessibility and the health condition of the person. Instead of using the traditional mode of transportation such as vehicles and helicopters, UAV can be used instead for the fast and efficient delivery of medical aid [2]. Over the decade, the UAV technology has advanced and shortest path to the target location can be located with efficient path planning models and algorithms [3]. However, in a real-time application, the situation is more complex to solve than the traditional route planning problem which will involve routing, scheduling, delivery of medical at a different location and provide feedback to the hospital facility about the condition of the victim.

Major drone applications in the medical environment include disaster assessment, delivering medicines, blood, aid packages, first aid and medical supplies in remote and inaccessible locations [4,5]. Delivering test kits and transporting disease samples in highly infected regions, and rapid access to defibrillators for cardiac patients. For instance, in Papua New Guinea, dummy tuberculosis samples were transported using drones from rural to the urban city. The country having large TB burden can use this technology effectively for diagnostics [6]. Similarly, in Malawi, Africa having the highest incidence of HIV infections, drones were used by the United Nations Children Funds (UNICEF) for delivering HIV testing kits [7]. This significantly reduced the testing time for people living in remote areas. Furthermore, there is an early potential of using a robot-like technology for mobility assistance in aged people. In future drones may be used for telemedicine having diagnostic imaging potential and advice could be sought

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from health specialist from distance [8,9]. Despite the advancement of drone application in different fields, the progression in medical applications of drone technology has been slower. Due consideration must be given to the critical and urgent nature of the medical scenarios that limit control over the time and emergency location. Enhance research efforts are needed concerning response time, the safety of the patient and best practices [10]. Thus, the delivery of medical supplies, diagnostics and rapid access to treatment can be revolutionized in the health sector with the application of drone technology.

The traditional vehicle routing problem has been studied in different fields and focuses on the delivery of goods/services from the depot to assigned customers. The main goal of VRP is to enable a vehicle to visit all the nodes in a network while minimizing the costs [11,12]. The nodes represent the affected locations/medical emergency which are to be visited by the rescue team. Practically it may not be possible to visit all these nodes due to limited resources. In such a case the goal is to visit the nodes with the highest priorities. Some routing problems aim towards maximizing the profits earned by visiting each node in the network in the least possible costs. Such studies are referred to as "routing problems with profits" [13], depending on the methods followed to perform maximization of the profits and the minimization of costs to reach the nodes. Both the goals of cost minimization and profit maximization are combined particularly in the Selective or Profitable Tour Problem in the objective function. The orienteering problem (OP) uses an objective function to maximize profits from the nodes in the network and defines new constraints to minimize the costs. According to Allahviranloo [14] prioritization of important nodes is crucial in the conditions where demand surpasses the total supply in the disaster recovery operations. To support the distribution of aid among victims in such circumstances, they proposed a selective routing problem in which the profit achieved from visiting a node in the network is unknown [14].

With different conditions, new constraints are added to the NP-hard combinative optimization problem and have been extended with time. It has extended with time constraints (time-dependent VRP-TDVRP), limiting carrying capacity (Capacitated VRP-CVRP), routing problem with multiple depots (multi-depot VRP) or involving routing based on periodic timing (Periodic VRP-PVRP) [15–18]. Besides economic cost other factors such as time, area coverage, vehicle emissions, land ratio are also considered. The mathematical models for CVRP have continuously been extended by various researchers. The Periodic Capacitated Vehicle Routing Problem (PCVRP) was presented as an integer linear programming formulation solved by an exact branch-and-cut algorithm [19]. A two-phase heuristic approach has been used as an optimal solution for CVRP, however, longer execution time and lack of precision is major limitations [20]. Recently meta-heuristic approaches have been popular among researchers for providing an optimal solution with limited information and computational capacity. On small scale, the VRP optimization problem can be resolved using algorithms such as dynamic programming or integer linear programming. While the main motivation to use these meta-heuristic algorithm to solve the VRP such as ant colony optimization, genetic algorithm, PSO and CVRP is that they can find, generate and select the path providing sufficiently best solution without sufficient information.

The main contribution of this paper are as follows;

- UAV navigation from the initial point to the medical emergency location was achieved with optimal path planning algorithm.
- To avoid traffic congestion the doctor drone provides medical assistance with minimum computational time and transportation cost.
- The CVRP was found to outperform other algorithms providing 50% less computational time having the same number of the vehicles.
- Drone uses GSM technology, equipped with life-saving supplies and provides non-technical life-saving techniques as first aid.

The rest of the paper is organized as follows. Section 2 defines the related literature kind review. Section 3 defines notations used in the paper, introduces the problem, and proposes an optimization method based on linear integers. Section 4 represent the simulation results. Section 5 discusses the findings of the paper and Section 6 draws the conclusion and further work.

2. Literature review

Thedrone technology was first used in the early 1900s for various military operations. They are built in various sizes, shapes, weight, and capacity. They can be as small as insect-sized devices and large drones capable of carrying high loads at higher altitudes. The drone technology has expanded and has been used in different fields including medical and public health. Various studies have investigated the application of drone technology in the medical emergencies and provision of medical supplies in remote or high infection areas (Table 1).

The drones can be used within the hospital facility to transport medicines and blood samples from one unit to another during an event of a pandemic or medical centres undergoing renovations [30]. The expensive pneumatic transport systems can be replaced by drones which can deliver specimens and medications from one department to another at a lower cost. The challenges for the intrahospital drone are related to the radiofrequency or GPS communication interference which may hinder its application. There is a need to enhance navigation program for assisting the drone by keeping cost constraints and equipment size in due considerations. There is a potential for enhancing patient care in hospitals using drone technology.

The drone technology is also being investigated for providing relief to an aged population who have limited movement. A robot like drones can be used for performing simple household chores, giving medication, food and water [30]. These drones can be part of patient daily life by understanding patient needs and psychology. However, the safety and security of the patient can be compromised in an environment where drones are flying. Any incident can lead to injury or fatal accident. Advance research is being carried out to develop drones that can sense people motion, reaction, heartbeat, and head tilt. Thus, a human drone and environment friendly can be an important breakthrough in the care of elderly people and their wellbeing. With further advancement in technology, it is hypothesized that drone can be developed with diagnostic capabilities in the field of digital imaging. This can prove to be helpful in remote areas for diagnostic purpose and through imaging detail about patient's disease condition can be sent to a specialist in the city. The medical centre in rural areas can take advice from a medical specialist in cities through a telecommunication system. The drone can play a part in improving the field of telemedicine. Such as long-distance consultations can be facilitated, the remote-controlled examination of patients, cardiac ultrasound or ultrasound of other organs can be carried out in remote locations [31].

A medical supply delivery was carried out by National Aeronautics and Space Administrations (NASA) tested to a medical clinic in a rural area in Virginia to carry out first government-approved drone delivery in the US [32]. The supply to the remote clinic included mediations for high blood pressure, diabetes and asthma. The feasibility testing was carried out successfully as it was safe, efficient, reduced cost and minimize the delivery

Table 1
Summary of related articles.

References	Emergency scenario	Methods/Algorithm used
[21]	Multi-objective algorithm for blood supply via unmanned aerial vehicles to the wounded in an emergency	CVRP
[13]	A two-phase heuristic algorithm for the problem of scheduling and vehicle routing for delivery of medication to patients	PVRP
[22]	Use of UAV for medical product transport	UAV
[23]	Locating AED enabled medical drones to enhance cardiac arrest response times	AED enabled medical drones
[24]	Biological sample transportation	UAV technology
[25]	UNICEF test first drone for infant HIV diagnosis	UAV technology
[26]	UK-funded drone deliveries aim to save mothers, babies in Tanzania.	UAV technology
[27]	Development of e-Juba, preliminary proof of concept UAV (Unmanned Aerial Vehicle) designed to facilitate the transportation of microbiological test samples from remote rural clinics to NHLS laboratories	UAV technology
[28]	Deployment of smartphone-enabled nucleic acid-based diagnostics for mobile health care, 3D printed snap-on attachments	Drone-based bioanalysis
[29]	Drone delivers medicine to rural Virginia clinic	

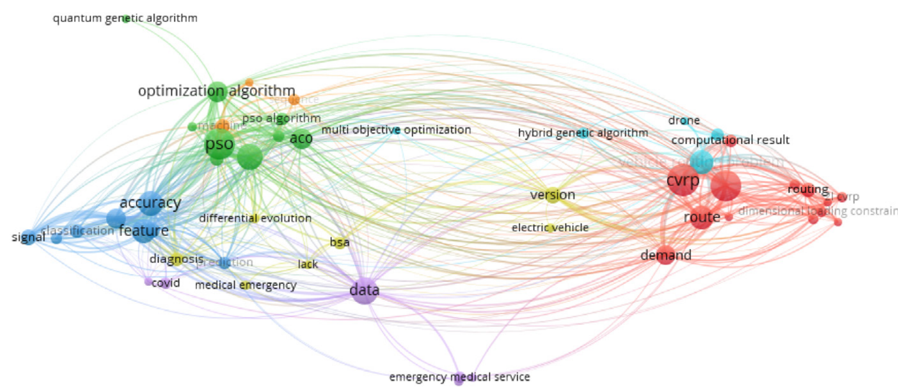

Fig. 1. Most repetitive Keywords in the research articles related to PSO, CVRP, and ACO.

time. In Rwanda, Africa Global Positioning System and the cellular network was used to deliver medicines and blood supplies to a remote region and inaccessible hospitals [6]. The demand for the medical supplies was sent by the hospital through text messages and the delivery was carried out within half an hour. The blood supply is important for small hospitals that are dealing with patients who are dealing with massive blood loss and the medium-sized hospitals run out of blood supplies and blood types quickly. Drones can facilitate in the fast delivery of the blood samples [33]. Different studies have shown that blood products, vaccines and microbial samples can be safely transported by the drone [34,35].

3. Methodology

A list of keywords was generated and depending on the most researched keywords used by research community was considered in this current research study. The keywords used for this research include, UAV, CVRP, Path Planning, Medical Emergency, Medical Environment First Aid, PSO, ACO and Genetic Algorithm [36,37]. Popular and widely used search engines were opted to retrieve research articles for the current study. Scopus, Google Scholar, Science Direct, Elsevier, Springer, ACM and MDPI were the chosen search engines [38,39]. A set of queries were formulated to be used in each search engine for article retrieval to exhaust the search engines for a maximum number of papers matching with an area of interest. After the keywords research, the most repetitive keywords found in the articles included CVRP, optimization algorithm, Medical Emergency, PSO Algorithm, ACO optimization etc., as shown in Fig. 1. This also showed the data collected for this research revolved around the PSO and CVRP

3.1. Review stage

Fig. 2 depicts that Doctor Drone which contains all the necessary medical toolkit that can automatically fly to a targeted location using GSM technology and provides non-technical life-saving procedures. During a medical emergency, a response time is a critical issue which can make the difference between life and death. On average, ambulances get struck as per traffic congestion and arrives almost 10 min late. Contrary to that, doctor drone can in time provides the necessary oxygen supply or medicines to save a life of serious patient.

Using the GSM band, the patient notifies the nearby hospital regarding his health. The hospital sends the doctor drone with first aid kit and ambulance to reach to the patient. As per the traffic congestion, we introduced doctor drone to provide the first aid it with minimal transportation cost and minimal computation time. While, in case of heart attack or coronavirus, first aid is important to save the patient by supplying oxygen or basic medicine. However, for a proper treatment ambulance will reach the patient to provide extensive care and medication. Thus, the cameras and sensors attached to the doctor drone can provide fast and reliable information to the nearby hospital, diagnosing the disease and providing precautionary measure to save a life. The drone technology can be correlated with UAV path planning to find the path efficiently and within a confined time frame in order to provide first aid to patient.

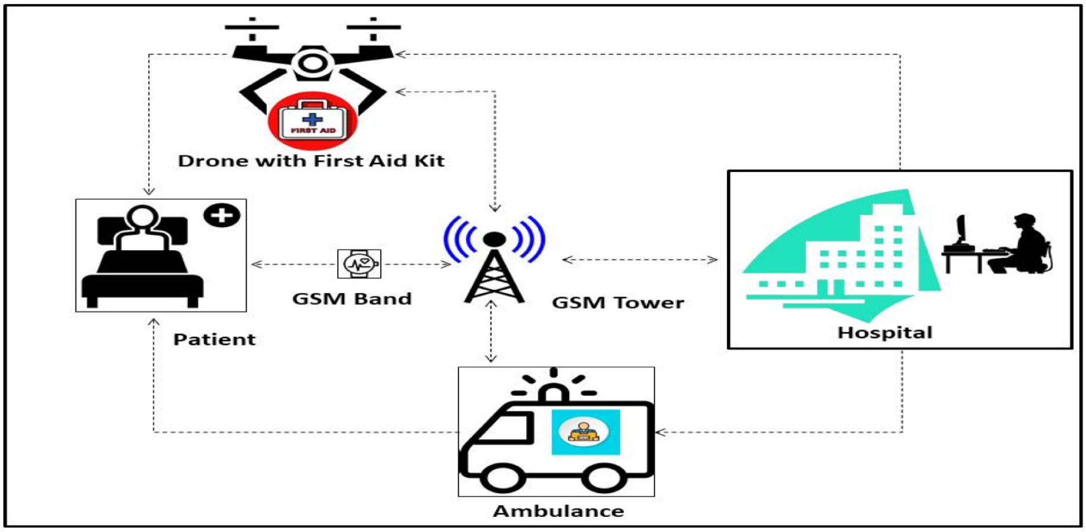

Fig. 2. Schematic illustration of Medical Aid.

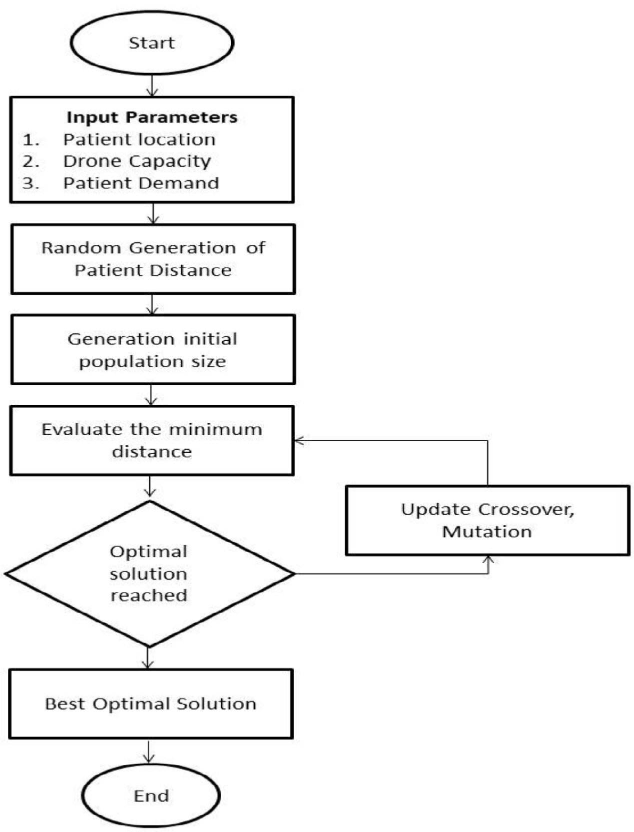

Fig. 3. Methodology flow chart for Doctor Drone path planning.

3.2. Path planning stage

Fig. 3 provides the flowchart of Doctor Drone path planning. The input parameters are initially initialized with patient location, drone capacity and patient demand. Then the best particle position and its velocity are initialized by setting it to zero. The fitness of the particles is calculated for random generation of patient distance and a minimum distance between the initial and target points are analysed. The optimal solution is calculated and if reached, the loop will exit otherwise continue to loop again till the optimal solution comes out. The values of the best and global particle are calculated till the termination criteria is met. If the criteria are not met, the position of particles and its velocity is again updated and is again processed. Establishing a UAV path planning method is important for finding an optimal path between source and target to reduce the time, which is an important factor when dealing with emergencies. In this study, four different algorithms, i.e., CVRP algorithm, PSO algorithm, algorithm, ACO, and GA, are used to find the optimal route. Based on the obtained results algorithm providing the shortest and safest route to the location is selected.

4. Problem formulation and proposed solution

The VRP model is composed of a set of drones that are to be used to carry medical aid supplies and tool kit to the patients in remote locations or disaster-struck region. Each drone has a certain capacity, which represents the amount of medical aid equipment it can carry. The emergency locations that are to be visited by these drones are called nodes, while the edges represent the paths followed to reach these nodes, connecting two nodes. A directed graph is composed of the set of these nodes and edges.

4.1. VRP network

Fig. 4 depicts a network composed of different nodes, each node indicating the emergency location to be visited by the medical team for providing first aid to the person who is in critical health. The medical aid relief items are dispatched from the single depot via drones. Each drone has a specific capacity to carry the medical aid to be delivered to the patient who is located at the specified nodes in the network. In the directed graph these nodes are termed as the vertex. The patients to be visited will be represented by $1, 2, 3, \ldots, n$ which belongs to set of patients as C. As the route for the drone will start and end on the same depot, the sum of vertices in the directed graph will be $|C| + 2$, where the depot is depicted by the nodes 0 and $n + 1$, while the vertices are given as $0, 1, 2, 3, \ldots, n + 1$. The patients are connected to the depot and each other with the edges in the graph. Edge originating from the depot node 0 and terminating at the depot node $n + 1$. Each edge connecting two patient's p and m is associated with a cost value. Each drone has a constrained capacity, and the need of each patient is different regarding the medical assistance. Table 2 defines the notations and terminologies used in the problem formulation and solution.

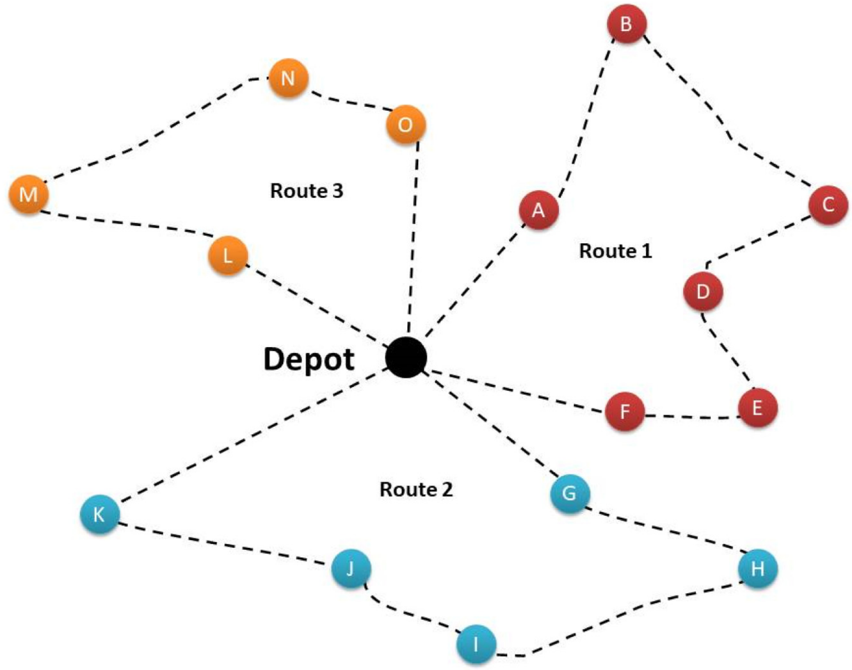

Fig. 4. VRP network with an edge connecting the depot with the patients.

Table 2
Definitions of mathematical notations.

Notation	Definition
V	Set of homogeneous drones
C	Set of patients to be visited
G	Directed Graph
P_{pm}	Cost (distance) required to move from patient p to patient m
n	Total number of patients to be visited
$n+1$	Depot node where each route terminates
q	Capacity of a drone
d_p	Demand of the patient p
N	Set of vertices 0, 1, 2, 3. . ., $n+1$
D	Depot
$start_D^v$	departure time of vehicle $v \in V$ at depot
end_D^v	return time of vehicle $v \in V$ at depot
$open_D$	opening time of depot
$close_D$	closing time of depot

4.2. VRP model

The following variables are used to model the VRP model:

$$x_{pm}^{t} \begin{cases} 1 & \textit{if vehicle t visits a patient p after patient m} \\ 0 & \textit{otherwise} \end{cases}$$

The major goals of the VRP model are outlined below:

1. Formulate a set of routes with minimum costs.
2. Each drone will have one route assigned to it.
3. Each patient will be visited once only.
4. Each route starts at node 0 and terminates at node $n+1$.

Based on these goals, the objective function for the system is defined as:

$$min \sum_{t\in V} \sum_{p\in N} \sum_{m\in N} P_{pm} x_{pmt} \quad (1)$$

This objective function subject to the following constraints:

$$\sum_{t\in V} \sum_{p\in N} x_{pmt} = 1 \quad \forall r \in C \quad (2)$$

$$\sum_{p\in C} d_p \sum_{m\in N} x_{pmt} \leq q \quad \forall t \in V \quad (3)$$

$$\sum_{m\in N} x_{0mt} = 1 \quad \forall t \in V(4) \quad (4)$$

$$\sum_{p\in N} x_{pit} - \sum_{m\in N} x_{imt} = 0 \quad \forall i \in C, \forall t \in V \quad (5)$$

$$\sum_{r\in N} x_{rm+1t} = 1 \quad \forall t \in V \quad (6)$$

$$x_{pmt} \in \{0, 1\}, \quad \forall p, m \in N, \forall t \in V(7) \quad (7)$$

$$start_D^v \geq open_D \quad \forall v \in V \quad (8)$$

$$end_D^v \leq close_D \quad \forall v \in V \quad (9)$$

The objective function (1) ensures that the costs associated with the total distance are minimized. The constraint (2) ensures that each patient is visited only once. According to the constraint (3), the load carried by each drone should not exceed its capacity. The constraints (4), (5) and (6) make sure that each drone starts the journey by leaving the depot node 0. On reaching a patient's location the drone leaves the patient again. Finally, the drone arrives at the depot node $n+1$. Constraint (7) is the integrality constraint which models the discrete nature of the decision. Constraint (8) ensures that the starting time of the drone is greater than the opening time of the depot. Constraint (9) ensures that the drone completes its mission within the closing time of the depot.

4.3. Routing mechanism

Fig. 5 explains the pseudocode illustrates the routing mechanism for doctor drone to efficiently deliver the first aid kit to the patient utilizing minimal transportation cost and computational time. In Step 1, the parameters vehicle capacity (q) and several vehicles (n) are initialized for the proposed model. Depot is set which is the starting and endpoint for the drone. Possible routing mechanism is applied to cater the drone displacement to reach to the patient in time, Step 2. Step 3 compares the four algorithms

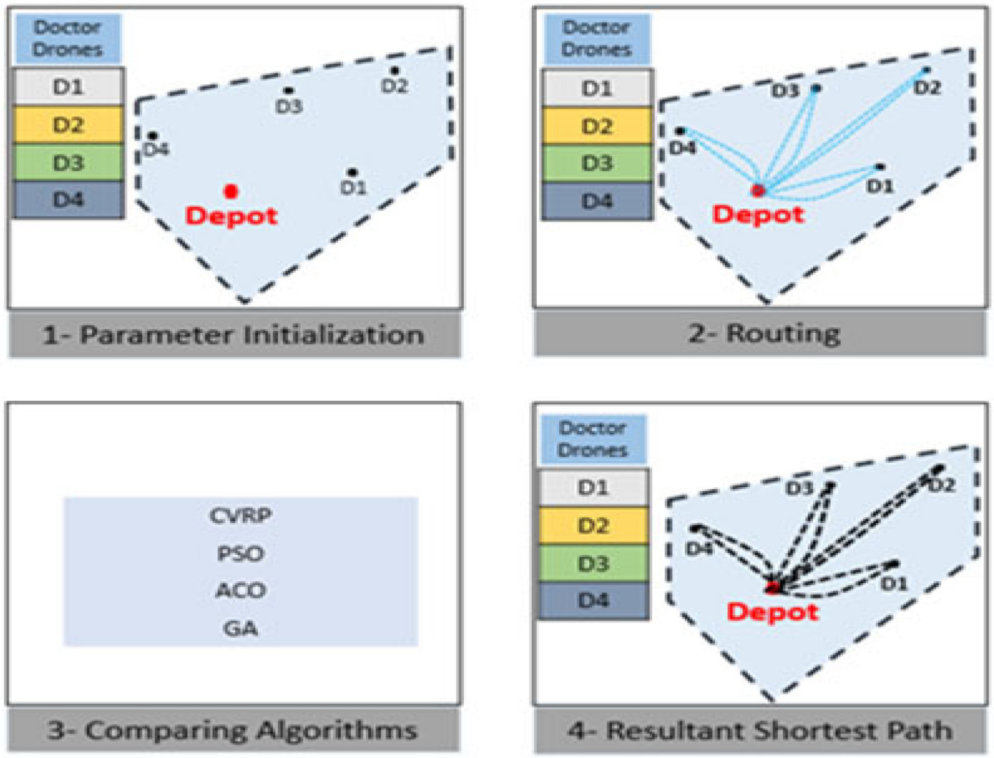

Fig. 5. Routing mechanism to calculate the best transportation cost.

CVRP, PSO, ACO and GA. CVRP outperforms the other algorithms in terms of computational time and cost which is employed in Step 4 showing the resultant shortest path.

5. Simulation results

To assess the performance of the VRP models proposed in the current research extensive experimentation was carried out. The main objective was the implementation of the well-established optimization problem for assisting the medical emergency, by providing the first aid tool kit and medical supplies to the patients who are in critical condition and has limited time. There is a limited number of drones and several medical emergency locations that must be visited. The aim was to estimate the optimal route for the swarm of drones that begin their journey from the depot for delivering medical supplies to all the identified patients. Heuristic approaches were used to determine an approximation of the optimal solution. It was crucial to compare the proposed CVRP method with other optimization approaches. The experiment analysis was carried out by coding in python. The framework used is IntelliJ. The hardware specifications include an HP Envy laptop having Intel Core i7 @ 1.30 GHz processor, a memory of 16 GB, 1500 MHz DDR3 and a Windows 10 operating system. The test performed were classified into four main categories as below:

Category 1: Firstly, the results were generated for the CVRP based solution proposed in this paper. The objective function of the CVRP algorithm involves solving for the number of drones, cost incurred, minimize distance, environmental cost, increase profit and other factors. The CVRP model was used to solve the problem for the medical emergency by selecting the best solution until the optimal is reached.

Category 2: Secondly, a PSO based solution for the problem scenario was explored. It is one of the most used swarm intelligence algorithms used for object tracking. PSO tracks the local mode of the similarity measure for accurately finding the local minima and global minima. The algorithm provides optimal trajectory to discover target locations in the network. It has graphic processing unit framework resulting in minimizing the computational time.

Category 3: Third, an ACO algorithm is applied which is an iterative process for solving trajectory analysis in UAV path planning. This method finds an optimal path and with adapting to modifications. It is applied for travel plans for salesmen for finding the shortest possible route and provides multiple solutions for issues about trajectory planning. It has better performance than GA and Bayesian optimization methods.

Category 4: Fourth, a GA method is applied which is an evolutionary algorithm. It facilitates finding the optimal path for drones in a 3D environment. Each generation is better than the earlier generation and has been improving over time. This algorithm was used to solve the UAV path planning for Doctor Drone to deliver the medical supplies in the least cost and time.

Table 3 depicts the generated results after running the four algorithms to solve the VRP model. UAV path planning opted for medical first-aid delivery perspective in case of severe emergency. Four of the most popular algorithms CVRP, PSO, ACO, and GA were compared based on the computational time and cost. The parameters used in the algorithms for the optimal path planning are vehicle capacity, number of vehicles, iteration, inertial weight, damping ratio, personal and global learning coefficient to calculate the best transportation cost and computational time. A homogeneous fleet of UAVs has been considered for vehicle

Table 3
Comparison between algorithms for UAV path planning.

Vehicle capacity (q)	No. of vehicles (n)	CVRP		PSO	ACO	GA			
		Runtime(s)	cost	Runtime(s)	cost	Runtime(s)	cost	Runtime(s)	Cost
10	5	**0.06**	418.965	0.08	418.965	0.08	418.965	0.07	418.965
	10	**0.17**	722.639	0.19	722.639	0.18	722.639	0.19	722.639
	15	**2.43**	844.938	2.47	844.938	2.44	844.938	2.47	844.938
	20	**3.37**	1522.7	3.41	1522.7	3.42	1522.7	3.38	1522.7
20	5	**0.11**	316.38	0.12	316.38	0.12	316.38	0.11	316.38
	10	**0.70**	483.934	0.71	483.934	0.71	483.934	0.71	483.934
	15	**100.01**	479.046	100.01	479.046	100.01	479.046	100.01	479.046
	20	**100.01**	865.979	100.01	865.979	100.01	865.979	100.01	865.979

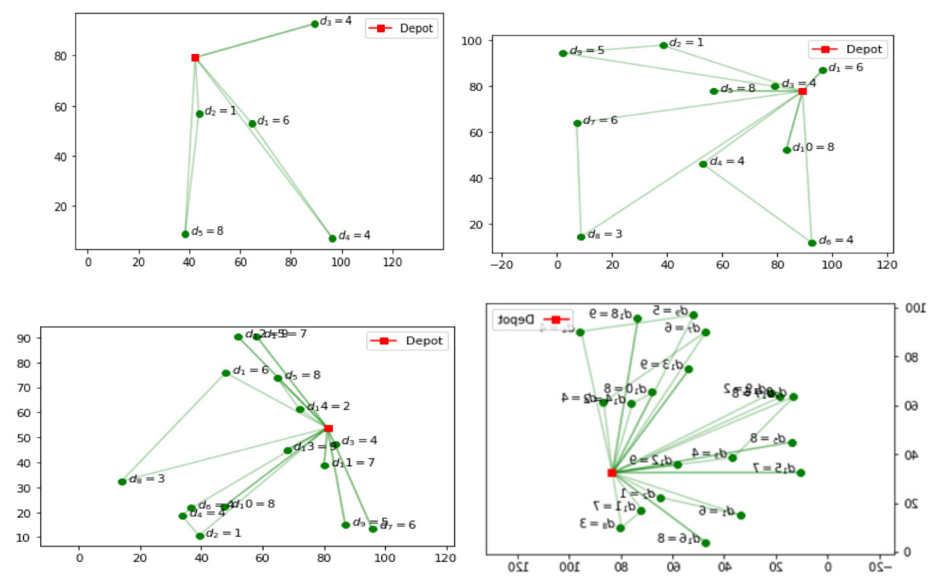

Fig. 6. 2D scenario of UAV path planning using CVRP/ PSO/ ACO/ GA algorithm $q = 10, n = 5,\ 10,\ 15$ and 20.

capacities 10 and 20 for carrying out the medical aid operations. The number of vehicles utilized has been gradually increased considering the increased number of patients needing first aid. The number of vehicles was gradually increased from 5 to 20 and the runtime and cost were compared along with different algorithms i.e., CVRP, PSO, ACO and GA. The patients are randomly located on the map with each node having one victim. Vehicle capacity and the number of vehicles is usually predetermined for carrying out any relief mission or medical emergency and are increased depending on the requirement. The number of drones which will be visiting the patients were incremented gradually to determine the change in the output parameters under varying conditions. With the increase in the number of patients who were in urgent need of first aid, drones were increased and resulted in a higher cost. As shown in Table 3 as the number of drones were increased the computational time was changed and a linear relationship was found between the two parameters. When the number of vehicles is 5 having a capacity of 10, CVRP utilizes a computational time of 0.06 s for path routing, which is 50% less having the same number of the vehicles but increasing the capacity to 20. When the number of vehicles is increased to 10 and 20 at vehicle capacity 10, the minimum computational time of 0.18 and 3.38 was observed for ACO and GA, respectively. Fig. 6 illustrates a 2D scenario of path planning, where the drones fly from the depot (which is a platform where drones stay) and come back again to the depot after providing the first aid to the patient. In this scenario, we took five of the targeted locations where drones d1…d5 fly to the location where the patient needs first aid and come back to the initial position (depot). The best transportation cost and computational time are calculated based on the drone delivering the first-aid kit and returning to the initial point. Fig. 6 shows the results for the algorithms where vehicle capacity ($q = 10$) and several vehicles ($n = 5, 10, 15, 20$). While Fig. 6a shows the best transportation cost when vehicle capacity ($q = 20$) and several vehicles ($n = 5, 10, 15, 20$).

However, on increasing the vehicle capacity to 20 and the number of vehicles to 15 and above, similar runtime and cost was observed for all algorithms. Thus, the algorithm failed to solve VRP as the number of vehicles was increased above 20 at 20 vehicle capacity. The results achieved using the four algorithms applied to the problem scenario indicated that the least computational time is attained using the capacitated vehicle routing algorithm, while maximum computational time was observed for GA. Other approaches like PSO and ACO delivered better results than GA, however, the performance of CVRP was found to be better than the rest of the algorithms. Demonstrating the efficient performance of this vehicle routing algorithm over standardized optimization methods like PSO, ACO and GA. Hence, CVRP outperforms the other three algorithms in terms of runtime while the cost remains the same at most of the instances.

6. Discussion

In this study, a different heuristic algorithm was used for UAV path planning and route optimization. On comparison of four different algorithms, CVRP achieved the least computational time

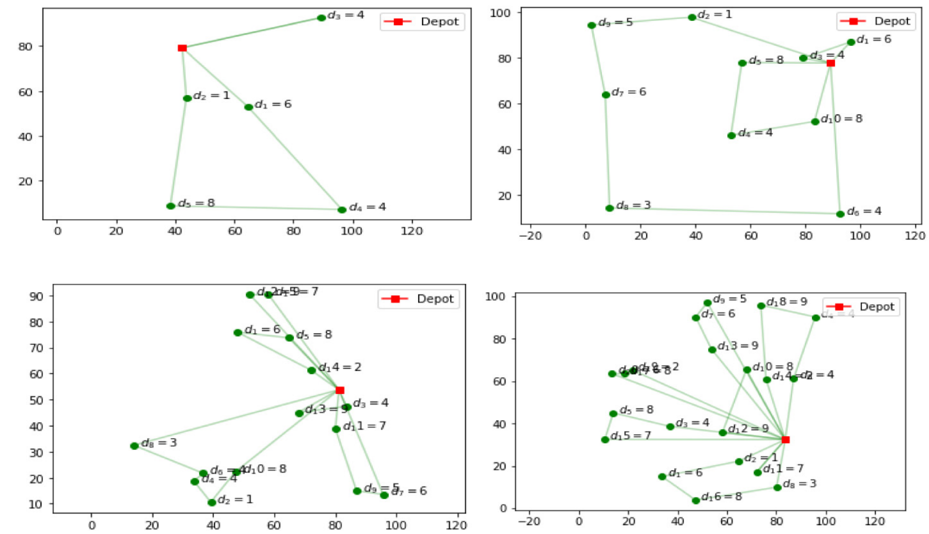

Fig. 6a. The 2D scenario of UAV path planning using CVRP/ PSO/ ACO/ GA algorithm $q = 20, n = 5$, 10, 15 and 20.

among the rest. In the medical field, drones can play an important role in the efficient and speedy delivery of medical tool kits and supply of medicines. The complexity of the problem increases with medical emergencies as the life of the person is at stake with time constraints. The medical supplies like blood samples and testing kits need to be maintained at specific temperatures during transportation. The drones scheduling and routing planning at multiple sites with a limited carrying capacity of medical supplies can be an arduous task to solve. Wen, et al. [21], introduced the transportation appendage into the traditional capacitated vehicle routing problem (CVRP) taking into the factors of distance and weight. A series of experiments were performed based on the VRP public datasets using a combination of decomposition-based multi-objective evolutionary algorithm and local search method. The blood temperature changes in comparison to the external environment were studied. The proposed method achieved better optimization results and time performance as compare to the traditional CVRP. The algorithms CVRP, PSO, ACO and GA uses in this research have been analysed and compared as follow; *(1) CVRP* algorithm involves solving for the number of drones, cost incurred, minimize distance, environmental cost, increase profit and other factors. The model was used to solve the problem for the medical emergency by selecting the best solution until the optimal is reached. *(2) PSO* based solution for the problem scenario was explored. It is one of the most used swarm intelligence algorithms used for object tracking. PSO tracks the local mode of the similarity measure for accurately finding the local minima and global minima. The algorithm provides optimal trajectory to discover target locations in the network. It has graphic processing unit framework resulting in minimizing the computational time. *(3) ACO* algorithm is applied which an iterative process for solving trajectory analysis in UAV path is planning. It is applied for travel plans for salesmen for finding the shortest possible route and provides multiple solutions for issues about trajectory planning. It has better performance than GA and Bayesian optimization methods. *(4) GA* algorithm is applied which is an evolutionary algorithm. It facilitates finding the optimal path for drones in a 3D environment. Each generation is better than the earlier generation and has been improving over time. This algorithm was used to solve the UAV path planning for Doctor Drone to deliver the medical supplies in the least cost and time.

The drone technology has been used for the inspection of disaster areas for tracking disease spread, biological or chemical hazards that limits human access. With the help of a drone, information and data can be collected for the patients that need care in high-risk areas. In the Philippines during Typhoon Haiyan in 2013, initial relief efforts were facilitated through the aerial surveillance with the help of drones [40,41]. Similarly, in southern Spain, the spatial distribution of tuberculosis in large mammals was tracked using drones [33]. Contagious viruses like Ebola and *Staphylococcus aureus* has been detected by the researchers using nucleic acid analysis modules [42]. The emerging field of telemedicine can make use of a drone to remotely diagnose the patient with the help of telecommunication technology [43]. The key importance lies in the telecommunication systems. There is a need for developing instant telecommunication infrastructure supporting drone technology which could facilitate in communication pre and postoperative examination of the patients. This will help the remote patient to get advice from a specialist which is otherwise difficult to access. The remote guidance by experienced surgeon or specialist with emerging tools and technologies of telecommunication comes under Tele monitoring [10,44]. According to Gupta, et al. [45], drone demonstrated the establishment of a wireless communication network between the surgeon and robot for performing tele surgery. The surgeon operated remotely with the help of a robot on site. All the surgical manoeuvres were performed by the robotic arm successfully. Furthermore, a telemedicine drone was used to deliver the medical supplies and packages for a medical scenario for providing care to the patient by the physicians [46,47].

7. Conclusion

The research study was focused on meeting patient demand in a medical clinical scenario. The UAV path planning problem was investigated in deciding for attaining optimal solutions for the medical relief team. A sample network was proposed with patients randomly located on the map that required specific care. Response time is a critical issue that can make a huge difference in saving the life of the person in critical condition. Due to traffic congestions, the ambulance reaching the emergency location 10 to 15 min late can be lethal to the patient. In such cases, Doctor Drone can provide medical supplies or defibrillator for the person who is having a cardiac arrest and other serious daises. In the current study, safe and smooth UAV navigation from the initial position to the medical emergency location was achieved with optimal path planning through a proposed algorithm. On the notification of patient about his health condition using GSM band, doctor drone was sent from the nearest hospital facility. The vehicle routing was carried out through proposed algorithms i.e., capacitated vehicle routing problem (CVRP), particle swarm optimization (PSO), ant colony optimization (ACO) and genetic algorithm (GA). The comparison between the algorithms was carried out at different vehicle capacities and numbers. The main concluding points are highlighted as follows:

- A mathematical model was developed to address the problem keeping all the attributes and constraints in consideration.
- The selected properties were maximized to reach the target destination within the time constraint.
- The proposed Doctor Drone was equipped with life-saving supplies and provides non-technical life-saving techniques.
- It travels the distance to the emergency location using GSM technology.
- To avoid traffic congestion the doctor drone provides medical assistance with minimum computational time and transportation cost.
- The CVRP was found to outperform other algorithms with a runtime of 0.06 s and cost of 419 at vehicle capacity 10, which is 50% less having the same number of the vehicles but increasing the capacities to 20.

The results indicate that the effective path planning method could be applied to provide medical aid in real-time with efficacy. Thus, with the advancements of the unmanned aerial vehicles (UAV) technology for use in different environments, it can be easily substituted for traditional transportation in event of emergencies. In the medical field, UAV can play a vital role in the fast and efficient delivery of first aid and medical supplies.

Future research can be carried out towards defining the CVRP algorithms without using the computational resources that limit the advance routines in the field. It is important to achieve optimal benchmark solution for evaluating the performance of the real-time heuristics. Subsequently, it is really interesting to analyse the outcome of algorithm when the number of patients increases rapidly. There is a need to focus on the critical and urgent nature of the medical scenarios that limit control over the time and emergency location. Enhance research efforts are needed about response time, the safety of the patient and best practices. Many unpredictable scenarios may occur during emergency relief operation, it is important to keep that factor in consideration while developing algorithms. The proposed model forms the baseline for future work in the usage of drone technology for medicine and public health. Moreover, in the future works we will be considering the real time scenarios where the weight and distance travel by the drone for travelling to the destination is of paramount importance. The decision-making procedures, the complexity of the medical scenario and most importantly devising the solution which is focused on the best care and wellbeing of the patient is essential.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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