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Fatimah Ibrahim
Juliana Usman
Mohd Yazed Ahmad
Norhamizan Hamzah *Editors*

4th International Conference for Innovation in Biomedical Engineering and Life Sciences

Proceedings of ICIBEL 2022, December 10–13, 2022, Kuala Lumpur, Malaysia

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Editors
Fatimah Ibrahim
Center for Innovation in Medical Engineering (CIME), Department of Biomedical Engineering, Faculty of Engineering
Universiti Malaya
Kuala Lumpur, Malaysia

Mohd Yazed Ahmad
Center for Innovation in Medical Engineering (CIME), Department of Biomedical Engineering, Faculty of Engineering
Universiti Malaya
Kuala Lumpur, Malaysia

Juliana Usman
Department of Biomedical Engineering
Universiti Malaya
Kuala Lumpur, Malaysia

Norhamizan Hamzah
Department of Rehabilitation Medicine, Faculty of Medicine
Universiti Malaya
Kuala Lumpur, Malaysia

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Preface

The 4th International Conference for Innovation in Biomedical Engineering and Life Sciences (ICIBEL 2022) convened in Kuala Lumpur from December 10 to 13, 2022. The conference served as a dynamic platform for researchers and industry leaders to share cutting-edge breakthroughs, engage in discussions, and exchange perspectives on biomedical engineering and sciences. Under the thematic umbrella of "Fusion of Healthcare & Technology in the New Era," the event featured distinguished keynote and invited speakers specializing in advanced biomedical, green, and medical device technologies. Additionally, ICIBEL 2022 incorporated workshops on current issues, on medical device registration by the government's Medical Device Authority, as well as on commercialization. Within these pages, readers will discover a collection of 25 peer-reviewed papers addressing timely issues in biomechanics, ergonomics, rehabilitation, biosensing, and life sciences. The volume also explores solutions for technology transfer, telemedicine, and point-of-care healthcare. Rigorous evaluation criteria, including relevance to the conference, contribution to academic discourse, appropriateness of research methods, and clarity of presented results, guided the selection process, resulting in an acceptance rate of 85%.

This biannual conference owes its success to the unwavering dedication of numerous contributors, including the conference committee, the Center of Innovation in Medical Engineering (CIME) at Universiti Malaya, the Faculty of Engineering at Universiti Malaya, Malaysia's Society of Medical and Biological Engineering (MSMBE), the International Federation for Medical and Biological Engineering (IFMBE), sponsors, reviewers, speakers, presenters, and delegates. Special acknowledgment goes to Dr. Noraisyah Mohamed Shah for her invaluable assistance in the editing process. Without the tireless efforts and support of these individuals and organizations, ICIBEL 2022 would not have been possible. We extend our heartfelt gratitude to each of them, and we trust that this volume will stand as a faithful record of the diverse topics discussed at the event while serving as a source of inspiration for new ideas and collaborations.

Fatimah Ibrahim
Juliana Usman
Mohd Yazed Ahmad
Norhamizan Hamzah

Conference Details

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4th International Conference for Innovation in Biomedical Engineering and Life Sciences

Short Name

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Venue

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Healthcare Delivery in the Era of IR4.0: The Rise of the Drone

Zaleha Abdullah Mahdy[1(✉)], Rahana Abd Rahman[1],
Mohamad Afiq Hidayat Zailani[2], Raja Zahratul Azma Raja Sabudin[2], Aniza Ismail[3],
Shamsuriani Md Jamal[4], and Ismail Mohd Saiboon[4]

[1] Department of Obstetrics and Gynaecology, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Jalan Yaacob Latif, 56000 Cheras, Kuala Lumpur, Malaysia
zaleha@ppukm.ukm.edu.my
[2] Department of Pathology, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Jalan Yaacob Latif, 56000 Cheras, Kuala Lumpur, Malaysia
[3] Department of Community Health, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Jalan Yaacob Latif, 56000 Cheras, Kuala Lumpur, Malaysia
[4] Department of Emergency Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia Medical Centre, Jalan Yaacob Latif, 56000 Cheras, Kuala Lumpur, Malaysia

Abstract. The advent of the drones began with unmanned balloons in the eighteenth century, but the uptake into healthcare delivery was as recent as 2014. A systematic review in 2020 produced only three publications involving drones in blood samples delivery. Since then, there has been an exponential increase in research and publications on the medical drone, particularly for healthcare service delivery. Two economic analyses comparing medical drone transportation to motorcycles and to ambulances respectively, revealed rather contrasting outcomes. Local legislation varies among countries, posing a formidable obstacle to conducting on site research into drone flights for healthcare delivery. Differences in climate and topography make it impossible to extrapolate the drone's capability from one geographical location to another, hence the importance of local experience and studies. From the technical point of view, several outstanding issues need to be solved before the drone can take to the skies much more effectively in its role in healthcare service delivery. Topping the list are the cost of drone acquisition, the capacity to monitor autonomous drone flights beyond visual line of sight versus the local network coverage, the drone's power source versus its capacity to fly long distances, its navigation accuracy, and climate challenges.

Keywords: healthcare delivery · drone · review

1 Introduction

The autonomous aerial vehicle (UAV) or drone as it is better known, has made its debut in the crude form of a balloon about two centuries ago, but its potential in medical transportation was only realized recently. Its transport potential in healthcare delivery was demonstrated for the first time in 2014 by Médecins Sans Frontières, by sending

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sputum samples for a diagnosis of tuberculosis in Papua New Guinea using a drone [1]. Despite its significant potential, uptake has been slow, compared to its exploitation for military functions, or even ordinary goods delivery. Reports of drone transfer of clinical items have largely been anecdotal, with the only large-scale usage being Zipline activities in Rwanda, where the focus has been in the field of obstetrics [2, 3].

This mini review shall focus on the controversies surrounding usage of the drone as a mode of medical transportation in the era of the fourth industrial revolution (IR4.0), its benefits, obstacles, and future potential.

2 Benefits

In a systematic review of publications until July 2019, there were only three publications on the use of drones for transportation of blood samples or product [4]. A PubMed search today using the key words "drone", "healthcare" and "transport" retrieved 44 publications (https://pubmed.ncbi.nlm.nih.gov/?term=drone+healthcare+transport), whereas narrowing it down to blood transport retrieved 32 publications (https://pubmed.ncbi.nlm.nih.gov/?term=drone+healthcare+blood+transport), out of which 12 were original articles. Obviously there has been increased interest in the subject, accompanied by much research and reports, implying rising confidence in the feasibility of the system.

Outstanding among the benefits of managing blood transportation using drones is the timeliness of delivery and drastic reduction in wastage of blood products [2]. The time saved was almost two thirds on average, with a range of 3 to 211 min depending on the actual distance from the location of need to the source of blood products. Concurrently, drone transportation of blood products resulted in a reduction of 7.1 units of blood products wastage per month, which translated into two thirds reduction in blood products wastage over 12 months. Without the use of drones, peripheral blood bank units have to be set up in order to beat the delay in transportation when blood products are urgently needed. Because such peripheral units serve smaller populations and the demand for blood products is unpredictable, some of the blood packs may not be used up on time, resulting in expiry of these packs [2]. The savings in terms of time and blood supply with the use of the drones are indeed significant achievements in terms of savings of invaluable resources that are potentially lifesaving.

There are three fundamental arms of medical drone function for healthcare application: search and rescue, medical care, and transport or delivery systems [5]. Search and rescue is most useful in disaster management. Medical care involves combination with remote telemedicine, and transport or delivery systems such as the delivery of blood products, vaccines, medicines, anti-venom, laboratory samples, organs for transplant, and the Automated External Defibrillator (AED) device.

3 Obstacles

3.1 Cost of Drones

Economic evaluations of drone usage in this regard have not been uniformly impressive. Ochieng et al. in 2020 [6] reported the cost per sample of a routine non-emergency transportation as USD0.65 by motorcycle, compared to USD0.82 by drone. In an emergency, the cost was USD24.06 for motorcycles, USD27.42 by drone for an unadjusted model without adequate geographical coverage, and USD34.09 for an adjusted drone model with complementary motorcycles. Motorcycles were more cost-effective compared to short-range drones, but increasing the range and operational lifespans of the drone made it more cost-effective. However, the study did not discuss the human risks of motorcycle transport, such as the possibility of loss of life and limb due to road traffic accidents, which may be significantly common in certain countries.

When compared to transport by ambulance, which is the norm in some parts of the world, the drone costs less due to the shorter travel time, despite a higher cost per minute [7]. The shortening of the journey by almost half resulted in an Incremental Cost Effectiveness Ratio (ICER) of –RM2.95, i.e., a cost saving of RM2.95 per minute using the drone rather than the ambulance. The detailed calculation can be found in the article by Zailani et al., which was published in 2021 [7].

Cost may also be influenced by locality – urban versus rural – as time savings differ between the two settings [8]. The drone may save delivery time by about 20–30% in urban areas, whereas in rural areas the time savings may rise up to 65–74%.

The main component that contributes to the high cost of drones is the acquisition cost [7]. It is possible that, as with many other technological innovations, the drone may become more affordable as time passes and its manufacture becomes more widespread. Manufacturer competition may lead to this.

3.2 Legislation and Societal Acceptance

The law pertaining to drones vary from one locality to another, even between one township and another, depending on the local authority regulations. The lag time between innovation and legislation may hamper integration of useful innovation to benefit society, and this is certainly true to some extent in the case of the drone [9].

Societal acceptance may play a significant role in influencing the legislative climate. Recent surveys in Malaysia and abroad have shown good acceptance of unmanned aerial vehicles for usage in healthcare [10], especially for the purpose of rescue and research [11].

3.3 Technological Limitations

Currently, several technological issues limit the progress of the drone. In the background, the wireless mobile network system that is available in the locality is important [9]. Without a good system in place, it is impossible to deploy the drone and pilot it remotely, especially beyond visual line of sight (BVLOS). The capability to operate the drone BVLOS is essential for its function as an effective vehicle for healthcare delivery.

The flight capacity of the drone in terms of power to cover long distances and carry a reasonable payload is vital for its delivery efficiency. Our study limited the payload to 2.5kg [7], but significant progress has been made in this field, with payloads up to 16kg reported recently [12]. In this regard, agricultural drones have progressed to usage of hybrid engines that are more powerful in terms of both payload and flight distance [13]. Whether this can be adopted by the medical drone remains to be seen.

Aerial navigation and geofencing is another aspect of the drone that requires much research at present, to improve its competence in healthcare delivery. The accuracy of drone landing is important to ensure correct delivery of medical items.

Geographical terrain and climate challenges may be issues in tropical countries, with jungle-clad hills and mountains, and strong winds, heavy rains and thunderstorm to surmount. Whether the drone can eventually be flown amidst these harsh conditions, or its function has to be limited to flights within favorable weather conditions only, remains to be seen.

Specifically, for blood transportation by drone, temperature maintenance matters, in order to retain the quality of the blood samples or blood products. In this regard, the material and design of the drone carriage play a significant role [14]. The required temperature and its maintenance need to be investigated for delivery of other healthcare-related materials such as vaccines, medicines, and organs for transplantation.

4 The Future

The role of the drone in healthcare transportation is still in its infancy and has a long way to go before becoming fully developed as an effective means of transportation. Much research is warranted not only pertaining to the technological aspect but also the social, safety and legislative aspects of drone usage. Impact studies looking at effect of drones on clinical outcomes is an important perspective to explore. Also useful will be innovations to create drones that are more resilient in harsh weather such as tropical thunderstorms. Empowering drones to travel further with larger payloads will widen its potential and improve the feasibility of drone usage. Unmanned Transport Management (UTM) is a whole new area to look into. Nonetheless, once fully functional, the medical drone is an invaluable asset in delivering healthcare services to otherwise inaccessible or poorly accessible locations.

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Path Optimization Algorithms for Unmanned Aerial Vehicles (UAVS) Collision Avoidance

Muhammad Isyraf Ismail[1], Anees Ul Husnain[1], Norrima Mokhtar[1,2(✉)], and Noraisyah Mohamed Shah[1,2]

[1] Department of Electrical Engineering, Faculty of Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
noraisyah@um.edu.my

[2] Malaysia Japan Research Institute, Universiti Malaya, 50603 Kuala Lumpur, Malaysia

Abstract. Unmanned aerial vehicles (UAVs) are frequently being applied at numerous applications and implementations in a tricky task. UAVs cannot operate effectively without path planning. Path planning is a key component of the overall performance of automation systems, particularly when it comes to industrial robots or drones. The mobility of an industrial drone is predetermined by a variety of algorithms that make up the industrial drone path planning system. The purpose of route planning algorithms is to identify safer, more efficient, collision-free, and least-cost travel paths for mobile robots and unmanned aerial vehicles. The path planning for Unmanned Aerial Vehicles (UAVs) can be categorized which is Conventional, Intelligent and Fusion algorithms. In this work, three algorithms were chosen which are A*, Hybrid A* and Dynamic Window Approach (DWA). All the algorithms were being tested in the multiple obstacle setup that had been created. Different obstacle setup was created to portray different complexity of the real situation in software simulation. All the data results for each algorithm were recorded and compared with each other. Based on the simulation generated, all path planning algorithms show the ability to reach the targeted point and avoid the obstacle in all maps created with different time computational and smoothness of the path. The results in terms of computational time and performance based on different complexity of the environment have shown a great potential for automatic UAVs path planning with collision avoidance in a known environment.

Keywords: Unmanned aerial vehicles · path search algorithm · collision avoidance

1 Introduction

Path planning is a computer issue that involves determining the sequence of viable configurations that will transport an item from the node source to the targeted destination [1]. It is also known as motion planning in a field such as robotics, computational geometry, computer animation and computer games.

The objective of the path planning algorithm is to generate a computation of continuous path that connects a start configuration point and a goal/targeted configuration

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point, while avoiding the collision with known obstacles [2]. The obstacle geometry and the robot are described in 2D or 3D environments workspace while the motion is represented as a path in configuration space [3].

According to [2], algorithms for UAV route planning study have been offered by a variety of academics, and they may be loosely split into three categories: conventional algorithms, intelligent algorithms, and hybrid or fusion algorithms, which mix traditional algorithms with intelligent algorithms. The conventional path planning method (CPPM) is the classic approach utilized by researchers for mobile robot route planning throughout the years. Intelligent approaches are methods and tactics that have anything to do with the mimicking of natural events. [4]. The Dijkstra and A-Star (A*) algorithms are well-known examples of traditional route planning methods [5]. Other classic route planning approaches based on division maps, such as the Rapidly exploring random tree (RRT) algorithm and artificial potential field algorithms, are available. Intelligent algorithms, such the Particle Swarm Optimization Algorithm (PSO), the Ant Colony Algorithm (ACA), and the Genetic Algorithm (GA), among others, combine environmental element knowledge with their own position to design real-time pathways. Each algorithm has their own advantages and disadvantages that differ from other algorithms. To achieve a superior route planning fusion algorithm, the benefits of several methods are combined in a third category called fusion algorithm.

Table 1. Comparison of path planning for UAV collision avoidance

Path planning Algorithm	Principle	Advantage	Disadvantage
Dijkstra Algorithm [6]	State space search	Strong searchability	Low computational efficiency
A* Algorithm [7]	Heuristic function Introduce cost function	Simple, easy to implement and fast calculation algorithm	Inefficient when dealing with multi-target points and 3D path planning
RRT Algorithm [8]	Stochastic tree expansion	Strong searchability	The randomness of the algorithm leads to only probabilistic completeness
Dynamic Window Approach (DWA) algorithm [9]	Local path planning algorithm	Good obstacle avoidance	Only detect when the obstacle is close

Based on the result of the literature review summarized in Table 1, the algorithm identified for this experiment is the A*, Hybrid A* and DWA.

2 Methodology

The methodology in this section describes the five distinct obstacles setup for static environment simulation, and the path optimization algorithm used. Comparative analyses are then conducted from the result obtained using a set of performance metrics. All simulation was conducted in Spyder IDE (Python 3.8). The computer configuration is AMD Ryzen 5 3550H with Radeon Vega Mobile Gfx 2.10 GHz, 12 GB.

2.1 Obstacles Setup for Static Environments

Five distinct environments were selected, each of which featured a unique set of spatial characteristics. An assumption is made that one grid cell distance is equal to 1 m. The grid size for the environment has been set with the grid size of 27×18 grid cell. The initial point was set at coordinate (5,5) and the targeted point at coordinate (23,14). Firstly, the environment was initialized to consist entirely of open ground, creating a road across it is the simplest undertaking possible. This environment is illustrated in Fig. 3(a) where the red mark is the initial point, and the blue mark is the target point. Its total surface area is $27 \times 18 = 486\ \text{m}^2$. The optimum pathways for this environment are straight lines from the start node to the finish node.

The algorithm will be tested by setting a few patterns of obstacles near to the beginning point but far from the target point. The dots in the figures below indicate the obstacles that need to avoid by the drone. Next, the complexity of the obstacle is improved by set a few shapes of obstacle patterns in the grid map.

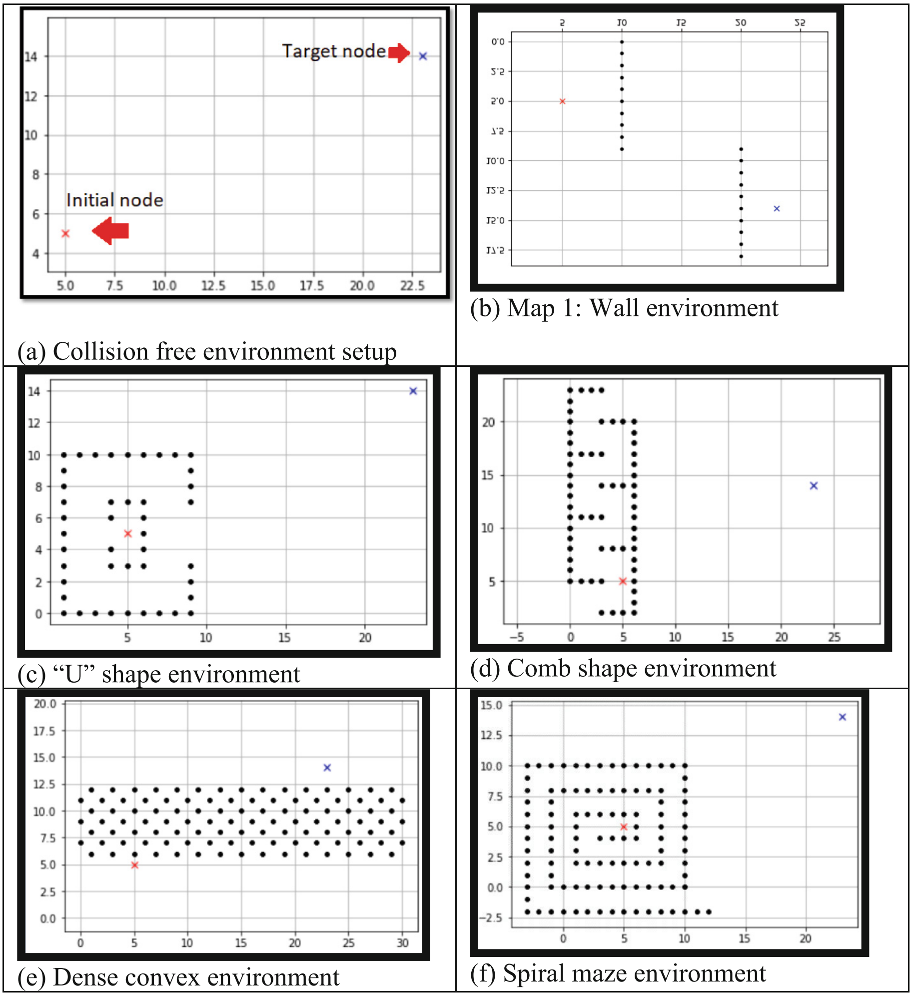
The graphical representation of each map is given in Fig. 1 and their respective description is as follows.

Map 1: Wall Environment. The proposed map was to set a barrier like a wall near the starting point and the end node. The distance between each obstacle is set 1 m apart. The width and the length of the drone are both changed to 1.2 m. This size is to ensure that the drone will not pass through a gap of less than 1 m.

Map 2: "U" Shape Environment. The proposed map is using a combination of "U" shape and a mirror "U". The initial point is set in the center of the small "U" while the goal point is set outside the obstacle at coordinate (23,14). The distance between each obstacle is set 1 m apart. The width and the length of the drone are both changed to 1.2 m. This size is to ensure that the drone will not pass through a gap of less than 1 m.

Map 3: Comb Shape Environment. The initial point is positioned in between the "E" configuration and is identified by a red mark, while a blue mark identifies the destination target. The width and the length of the drone are both changed to 1.2 m. This size is to ensure that the drone will not pass through a gap of less than 1 m.

Map 4: Dense Convex Environment. For Map 4, the obstacles are orderly arranged at a distance of 2 m apart from other obstacles. This is to ensure that the size of the drone is fixed before can pass through it. This convex environment was set up in between the initial point which is above the axis of 5 (is it x-axis?) and the target point below the axis of 14 in the y-axis. The boundary for this map is 27×18. This scenario is identified by growing difficulty as the heavy barriers create tiny routes.



(a) Collision free environment setup

(b) Map 1: Wall environment

(c) "U" shape environment

(d) Comb shape environment

(e) Dense convex environment

(f) Spiral maze environment

Fig. 1. Different obstacle setup for the experiment

Map 5: Spiral Maze Environment. The fifth map is the spiral maze shape with the initial point being set in the center of the spiral. The distance between each obstacle is set 1 m apart. The width and the length of the drone are both changed to 1.2 m. This size is to ensure that the drone will not pass through a gap of less than 1 m. The success is determined when the path generated follows the maze shape to reach the target point that is set outside the spiral maze shape.

2.2 Path Planning Algorithm

From the environment that has been created, the path planning for the algorithm is determined by the red line created in the grid map. The performance of the algorithm is considered a success when the red line can reach the target point and manage to avoid the obstacle that has been set.

A* and Hybrid A* algorithm A* algorithm was proposed as a heuristic algorithm (Weiguang & Xia, 2015), and as a solution to the Dijkstra algorithm's problem of having a large amount of computation and low efficiency. Using a heuristic function, the A* algorithm calculates the ideal route by comparing the value of each generation with the search operation time and distance cost of each path point (Guruji et al., 2016). A* select the path that minimizes the following equation:

$$f(n) = g(n) + h(n) \tag{1}$$

where n is the next node on the path, g(n) represents the cost of the path from the initial node to n, and h(n) is a heuristic function that calculates the cheapest path from n to the target.

Originally, the algorithm computes the cost to all its immediate adjacent nodes, n, and selects the one with the lowest cost. This method is repeated until no new nodes can be selected and all paths have been explored. Then, choose the best path among them. If f(n) represents the total cost, then it may be written as Eq. (1). Figure 2 illustrate the workflow for both A* and the hybrid A*.

Hybrid A* algorithm incorporates the vehicle dynamics, thus the path generated is smoother. Figure 3 shows the comparison of A* algorithm and Hybrid A* where the dot is symbolic of obstacles. As can be seen, the path generated by Hybrid A* is smoother.

Dynamic Window Approach (DWA) Algorithm. Dynamic Window Approach introduced by [10]. Its workflow can be summarized into three steps [11]:

1. Based on how the robot is moving right now, several different paths can be made and simulated. Such paths are ruled out if they lead to obstacles or are too fast for the configuration. This dynamic window shows all possible routes.
2. Cost functions based on the distance between the path and the goal and the direction towards the goal are used to evaluate the paths that are made.
3. Execution of the best course of action, which is the one that costs the least overall. Because of this, the robot moves in this direction.

The DWA was chosen because it was easy to add more cost functions and make it bigger. Any projected trajectories can be tested as hypotheses because they are made in different ways. Because the algorithm already includes the basic ideas of avoiding obstacles and following a path, these things do not need to be considered further.

2.3 Performance Metrics

To evaluate the performance ability of each algorithm, the following parameter were considered.

Number of Steps Count Towards Goal. The distance of the path measured to reach the target point.

$$Number\ of\ steps\ counts = \sum_{i=1}^{Pathsize-1} No\ of\ iteration\ to\ reach\ target\ point \tag{2}$$

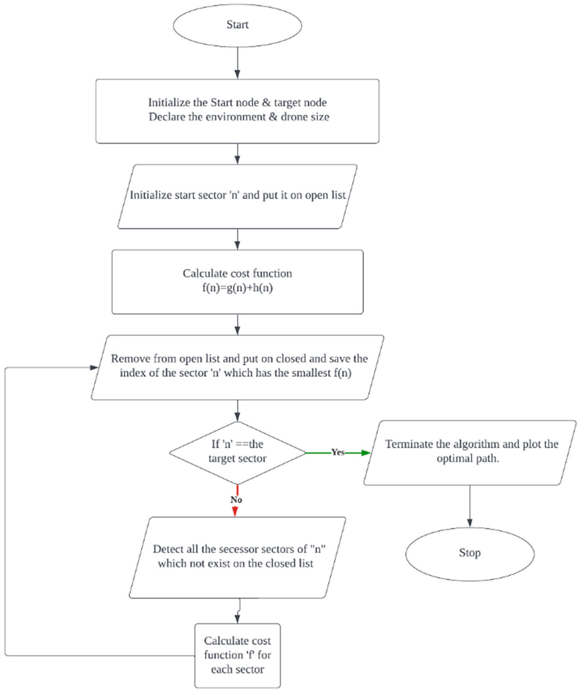


Fig. 2. Flowchart for A* and Hybrid A*

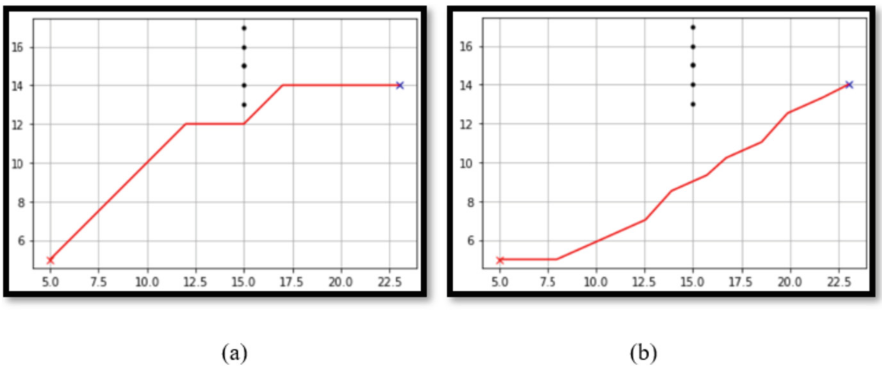


Fig. 3. (a)Path generated by A* (b) Path generated by Hybrid A*. The x and y-axis are coordinates of location

Number of Corners. To calculate the number of corners, the vertices made were counted to calculate the number of corners.

$$Number\ of\ corners = No\ of\ vertices - 1 \tag{3}$$

The ratio of smoothness for the path is determined by calculating using the formula:

$$\boldsymbol{Ratio\ Smoothness} = \frac{\boldsymbol{(number\ of\ corners)}}{\boldsymbol{(path\ length)}} \tag{4}$$

where the path length is the number of steps towards the goal.

Success rate. The success rate of each algorithm in that environment can be calculated as follows:

$$\boldsymbol{Success\ rate} = \frac{\boldsymbol{(number\ of\ successful\ path\ generate)}}{\boldsymbol{(numbers\ of\ successsive\ goals\ the\ algorithm\ must\ produce)}} \boldsymbol{\times 100} \tag{5}$$

3 Result and Discussion

Table 2 below gives a visualization example for the path generated by all algorithms for Map 4 and 5. Map 4 was found to have the shortest execution time for all algorithms, while Map 5 was the longest.

Figure 4 gives the result for all algorithms in terms of time, length and smoothness of path generated towards the goal for all maps. In general, the computational time for A* algorithms is the fastest with an average time taken is 0.2383 s, followed by Hybrid A* with 3.6061 s and DWA with the longest which is 194.7447 s. A* and hybrid A* use global planner for path finding search while DWA uses local planner search. Global planner assumes that a holistic view of the robot's environment is accessible. The advantage of global approaches comes in the fact that a complete trajectory from the beginning point to the target location can be computed offline. While local planner only uses a small fraction of the whole environment model to generate the path. To recalculate the path at a given rate, the map is reduced to the vehicle's surroundings and is updated as the vehicle moves. The entire map cannot be used since the sensors are unable to update the map in all places, and a high number of cells would increase the processing cost.

Map 4 or Dense Convex environment has the fastest computational time in all three graphs that have been compared. This is due to the simplicity of the map itself. The obstacle is set to narrow the path generated to the goal node. However, it does not affect the path generated since the size of the drone is set at 1.2-m width and length which is smaller than the gap between the obstacle that has been set 2 m apart. From all three graphs, the longest computational time taken is map 5 or spiral maze shape environment. Since the size of the drone is 1.2-m × 1.2-m is bigger than the gap between the obstacle, which is set to 1 m, the only option for a path to be generated is to follow the spiral maze shape to reach the goal point.

The next parameter is the number of steps taken to reach the target point, which is given in Fig. 4(b). In general, the lowest number of steps to target represents the optimal path possible. All algorithms have the highest steps in map 5 compared to other maps since they must follow the spiral maze shape to reach the goal. When the number of steps taken towards the goal point increase, the time execution to generate path will become longer.