Route Schedule Optimization Method of Unmanned Aerial Vehicle Implementation for Maritime Surveillance in Monitoring Trawler Activities in Kuala Kedah, Malaysia

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***Abstract*— Unmanned aerial vehicle (UAV) or drone has been used worldwide nowadays and operate beyond our expectations. The potential of drone usefulness not only in the film industry or simply a leisure activity, search and rescue but also encompass various aspects of human life. Trawler activities in Malaysia are one of the problems that need to be worried. These activities harm and disrupt income of the small angler by entering the specific zone for the fishery activities. UAVs play an important role as a most effective way for maritime surveillance. The purpose of this research is to create the route optimization method of unmanned air vehicle implementation for maritime surveillance in monitoring trawler activities in Kuala Kedah. The objectives are (1) to identify the main factors that interfere with flying drone and (2) to identify the best route for routine monitoring schedule system for maritime surveillance in Kuala Kedah. The route planning of UAVs is the most critical and challenging problem of operation process conducted. An innovative maritime surveillance operation in which a boat concept collaborates with a drone monitoring of making a new variant of the traveling salesman problem (TSP) that we call the TSP with drones (TSP-D). In addition, this research applies the heuristic method to several artificial instances with different characteristics and sizes. Our numerical analysis shows that substantial savings are possible with this concept in comparison to boat-only delivery.**

***Keywords*—** *unmanned aerial vehicle, traveling salesman problem with drone, optimization and heuristic method*

1. Introduction

Trawl making fisheries resources in Malaysia over-exploited over the past few decades. Fishing zoning system is a system that is well known throughout the country in order to limit fishing by anglers. In 1983, fishing licenses have been introduced to control the issues. In Malaysia, an area is her reported arrest of fisheries resources are in the seacoast, 12 nautical miles from shore. To address encroachment by anglers continues, the government has made the concept of marine protected areas (MPA) for restricting trawling fishing activities in areas that are not supposed to [1].

2. Fishing Zoning Systems

In 1981, fishing zoning systems under New Licensing Policy has been introduced which consists of 4 fractions zones: namely, Zone A (0-5 nautical miles), Zone B (5-12 nautical miles), Zone C (12-30 nautical miles) and Zone D (30 nautical miles and above). A zone of 0-5 nautical miles of the area is devoted to marine life and forbidden to trawlers to operate in the area [2]. The aim of the zone is to protect the shoreline habitat and biodiversity from being destroyed by trawlers and further avoid the conflict among the traditional anglers and trawlers [3].

However, the authorities have tightened the area for fishing trawlers to enact a zoning system in 2014. The trawlers of less than 40 Gross Register Tonnage (GRT), should not be operating 3 nautical miles further away than before, up to 1-8 nautical miles under suspension of enforcement circulars in June 2014. But the area that is subject to legislated state on the West Coast of Peninsular Malaysia, namely Selangor, Perak, Penang and Kedah. While 0-1 nautical miles are, the areas provided for the purpose of conservation of marine animals and no fishing activity for all parties. Nevertheless, all aquaculture activities such as fish farming in cages are allowed under the provisions of the community-based fisheries management (CBFM). Figure 1 below shows the new mapping structure of the fishing zoning system in Malaysia.

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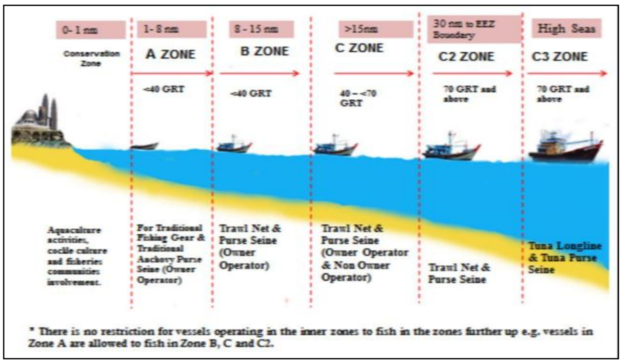


Sources: Department of Fisheries

Figure 1. The new mapping structure of the fishing zoning system in Malaysia (Selangor, Perak, Penang and Kedah)

3. Definitions of Unmanned Air Vehicle

The term of drone widely used by the public, it refers to a sailing on the aerial with powerful sound without the unmanned vehicle. However, the aviation professionals and the government regulator do not adopt these terms. Drone means an unmanned aircraft controlled remotely and it should come in various sizes and shapes. Drones have been used in various applications in public or military defense [4].

The drone is intended as a system with the ability to fly a plane with a semi or fully supervised autonomous control of the on-board computer and sensors. Agility and quality image of their abilities make them useful as a mapping tool for monitoring of environmental, but there are still having some challenges and concerns must be addressed [5]. Currently, the drones are no human pilot and have the ability to an ever expanding rapidly and cost of manufacture or production on the market is decreasing [6].

4. Traveling Salesman Problem

The Traveling Salesman Problem (TSP) has seen applications in the areas of logistics, genetics, manufacturing, telecommunications, and neuroscience. Sir William Rowan Hamilton first described the TSP in the 1800s as the problem of the "Hamiltonian Circuit". The problem was whether a directed graph has a circuit which passes exactly once through every node. This question starts with a basic model of the Minimum Traveling Salesman Problem (MTSP). The simplicity of the TSP, coupled with its apparent intractability, makes it an ideal platform for developing ideas and techniques to attack computational problems in general. Along the way we cover the interplay of applied mathematics and increasingly more powerful computing platforms, using the solution of the TSP as a general model in computational science [7].

Fundamentally, the basic TSP-D is thus given a number of spot points of contact at the sea and the costs of traveling from any point to any other point, what is the least-costly round-trip route that visits each point exactly once and then returns to the starting point or depot. The target with the UAV or the drone scenario of this research is not necessarily finding the shortest path or effective way, but to find the maximizing the bones collected from each of the destination points, since not every point can be visited due to some constraints [8].

The primary contribution of this research is to introduce or bring out a new variant of the traditional traveling salesman problem (TSP) that addresses the challenge of determining an optimal monitoring route for a UAV or drone monitoring with an authority's boat. The TSP-D can be considered to fall in the class of vehicle or authority boat routing problems that require synchronization between vehicles [9]. There it describes a variant of the classical TSP-D where the drone is firstly launched or set up from the authorities boat, proceeds to make live visual monitoring to the monitor and finally joins back the authorities boat in a third location. This research, there are types of nodes:

- Truck node: Visited by the boat separated from the drone
- Drone node: Visited by the drone separated from the boat
- Combined node: Visited by both boat and also drone

5. Mathematical Problem

The aim of the TSP-D is to find the shortest tour, in terms of time, to cover all locations at the sea by either the boat or the drone. In practice, not all locations may be suitable for drone application. Throughout our analysis, we arrive at the following four fundamental assumptions with respect to the drone.

i. The drone has limited battery capacity and must be returned to the boat for recharging the battery.
ii. The drone should be landing and depart from the boat while the boat are moving.
iii. The drone can not operate in bad weather.
iv. The drone can not operate in restricted areas.

TSP can be formulated as an integer linear program. Mark the spot points with the numbers 1,…,n and define:

$$x_{ij} = \begin{cases} 1 & \text{The path goes from point } i \text{ to point } j \\ 0 & \text{Other wise} \end{cases} \qquad (1)$$

For i = 1,…,n, let Ui be a dummy variable, and finally take Cij to be the distance from the point i to point j. Then TSP can be written as the following integer linear programming problem:

$$\min \sum_{i=1}^{n} \sum_{j \neq i, j=1}^{n} c_{ij} x_{ij} \qquad (2)$$

where

$$0 \le x_{ij} \le 1 \qquad i,j = 1,\ldots,n \qquad (3)$$

$$u_i \in Z \qquad i = 1,\ldots,n \qquad (4)$$

$$\sum_{i=1, i \neq j}^{n} x_{ij} = 1 \qquad j = 1,\ldots,n \qquad (5)$$

$$\sum_{j=1, j \neq i}^{n} x_{ij} = 1 \qquad i = 1,\ldots,n \qquad (6)$$

$$u_i - u_j + n x_{ij} \le n - 1 \qquad 1 \ge i \neq j < 1 \qquad (7)$$

The first set of equalities needs each point will be calculated starting from the exactly of the other point, and the second set of equalities needs of each point there are departures to exactly one other point. Last constraints enforce that there is only a single tour covering all the points, and not two or more regular visits only collectively cover all points. Figure 2a below show the information for each symbol for illustration in this research.

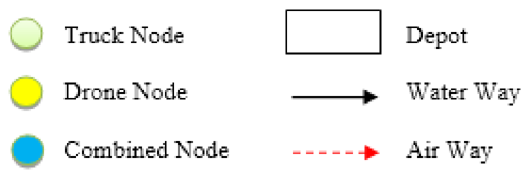


Figure 2a. Information for each symbol used

Based on Figure 2b, there are 8 nodes including depot that need boat to pass through during patrolling the sea. Figure 2c is a complete turnaround made by researchers at random to determine the distance to a boat to complete a round. The total distance a trip by a randomly drawn by researchers is 35.99 km.

The question here is whether these are the shortest way to the boat to patrol the sea. Therefore, researchers have made calculations using TSP for a short trip to the boat. Based on the ability of drones in the present, for example, brand DJI Phantom 4, maximum speed is 72km/h. Battery capabilities should also be taken into consideration by researchers and maximum flight time for this model is 28 minutes. Therefore, drone should be flight not more than 33km per flight. Thus, drone will be recharged on the boat to make the drone to be flown back. Researchers expect the drone capabilities in the future is that it will increase. Therefore, the distance would be able to fly drones at all will be more distant.

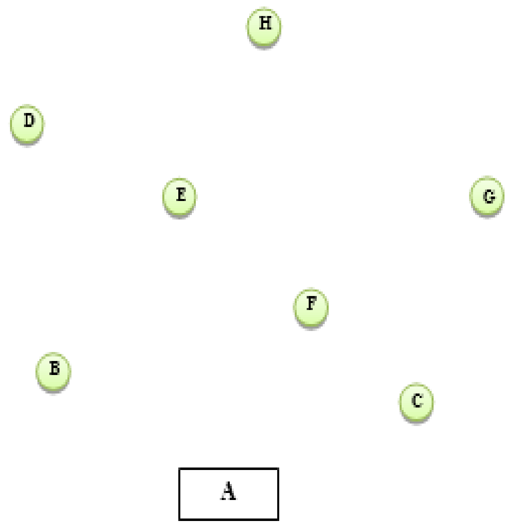


Figure 2b. The nodes that boat to cover at the sea.

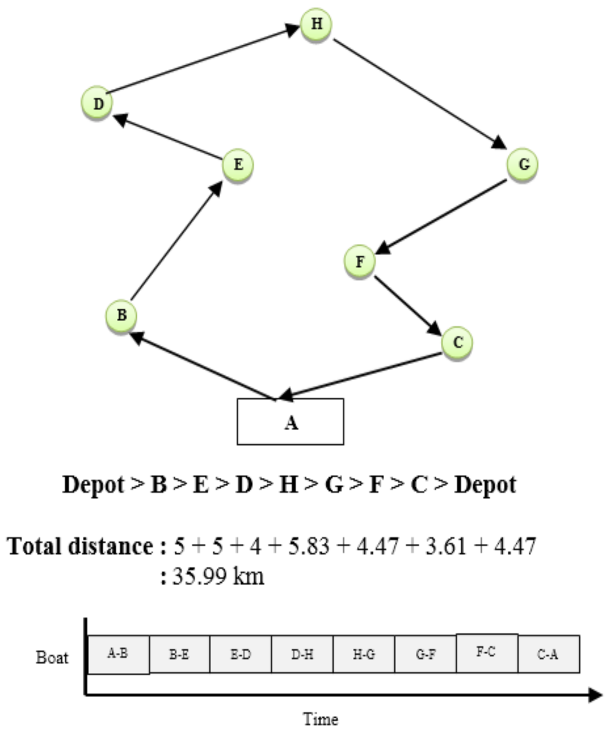
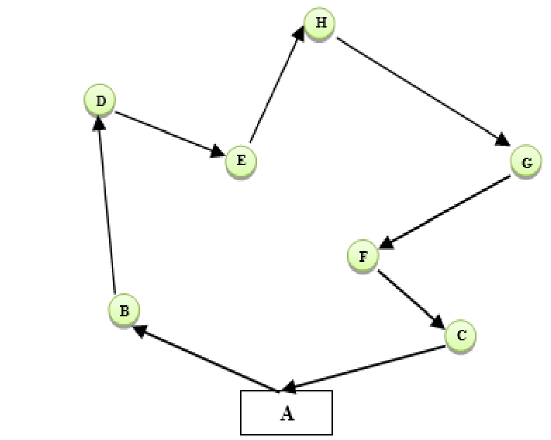


Figure 2c. The random route for boat cover at the sea without TSP calculation method.



Depot > B > D > E > H > G > F > C > Depot

Total distance : 5 + 4.12 + 4 + 3.16 + 4.47 + 3.61 + 3.61 + 4.47
: 32.44 km

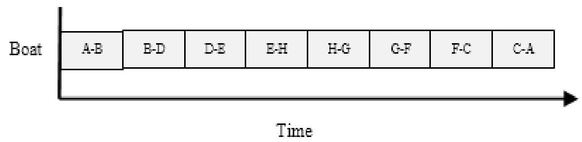
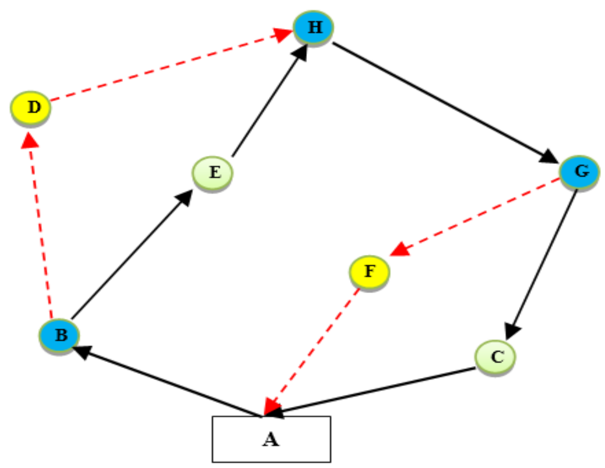


Figure 2d. The route based on TSP calculation method.

TSP calculation method can outrun a shorter trip of 32.44 km. So with this, there is a reduction not only can shorten the travel distance, but it saves time and fuel costs. Thus, researchers have been chosen at random two nodes that need drones to pass through. Figure 3 below shows a boat a trip with the help of drones.



Route for boat:

Depot > B > E > H > G > C > Depot

Route for boat:

B > D > H & G > F > A

Total distance for boat
: 5 + 5 + 3.16 + 4.47 + 6 + 4.47
: 28.1 km

Total distance for drone
: 4.12 + 5.83 + 3.61 + 5.39
: 18.95 km

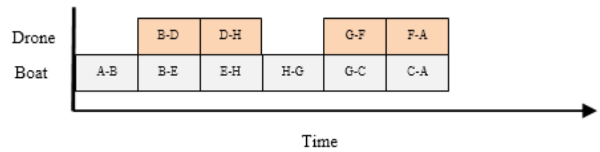


Figure 3. The route for boat and drones.

Using TSP calculation method, researchers can determine the shortest distance that can be travelled by boat while patrolling at sea. After that, the researchers set up several nodes to be used for the flights of the drones with regard to existing assumptions. According to figure 5, seen the short traveling by boat only 28.1 km away and another nodes monitored by drones.

6. CONCLUSION AND RECOMMENDATION

In this research, we study the combination of a boat and a drone in the distance of the traveling at sea. The purpose of TSP-D is to find a short tour, in terms of time, to cover all locations at sea either by boat or boat and a drone. As this is one of the first paper to address the collaboration use of a boat and a drone, we see many potential areas for future research, especially in areas with high trawling problems.

In conclusion, the use of drones in monitoring by boat for enforcement is very helpful at all. It can save time and reduce fuel consumption. Not only that, this drone is able to record all the observations made in the sea and it is valid for the perpetrators of trawlers in court. Researchers expect the drone capabilities in the future is that it will increase. Therefore, the distance would be able to fly drones at all will be more distant.

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