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Research Article

Intelligent Surveillance Drone System for Health Care Enhancement in a Smart City

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Abstract. Accelerating medical services to provide appropriate health care within the available time is essential, especially in critical cases. Achieving this goal depends on the response speed of the health care teams in reaching the accident scene and the people who are seeking or needing health care services. Response speed depends entirely on the data provided to these teams by the requesters of these services. This work utilizes drone technologies through a set of developed algorithms to ensure the provision of the required data in the shortest possible time. Drones fly for a specific time to carry out the required tasks over a specified area. The area of interest is divided into a group of zones, and a set of drones is allocated to each zone. The provided algorithms will minimize the maximum completion time required to perform all assigned tasks for all regions. Practical experiments were performed using two classes of 280 different instances to assess the performance of the developed algorithms; different criteria were used to measure the performance of these algorithms. The obtained results showed the ability of the presented algorithms to achieve the assumed goal by reducing the maximum completion time. Results showed that the best algorithm is *MCZ* with a percentage of 100% and a 0.00 average gap.

Keywords. Healthcare, Unmanned aerial devices, Surveillance, Time management, Algorithms, Work schedule tolerance

Mathematics Subject Classification (2020). 68M20

1. Introduction

Accidents are defined as sudden, unintended, not expected, nor foreseen, and not planned events. Occurs unintentionally and usually causes harm, damage, injury, loss, mishap, etc.

(James Jr. [8], Suchman [20], and Al-Masaeid [2]). Accident locations and times were not previously identified, which complicates accessing these locations and limits the available resources. The accident problem becomes even worse and more complex because of some or all of the following: the seriousness and number of injuries are not known, the nearest location of rescue and civil defense teams, the nearest available health care organization that can receive the number of injuries and finally, the fastest and easiest path to reach the accident location. The main problem becomes the volume of the available data and the time it takes to transfer the data to the concerned authorities to provide the rescue teams with the necessary information to reach the accident location as fast as they can. Therefore, the main objective of this study is to employ drone technologies and utilize them to fulfill missing parts in rescue operations and enhance response time. Technology will be used to provide the required data to the control center, which in turn will analyze this data and then provide rescue teams with the necessary information to ensure their arrival at the scene of the accident and to carry out their duty in terms of providing the required health care in the least possible time and effort. The developed algorithms were based on scheduling algorithms presented by Alharbi and Jemmali [1], Fayez *et al*. [7], Jemmali *et al*. [14], Jemmali [9–13], and Melhim [16].

This research will focus on using drones to act as air surveillance that permanently provides the required data to the control centers. Drones are widely used in smart cities to achieve a set of tasks, by flying over various areas within smart cities, which makes drones one of the important sources that directly affect the style of performing a wide range of tasks within smart cities. Time is a critical factor in health care operations. This research will develop a set of algorithms that will help these drones minimize the total time required to carry out all the surveillance tasks within different areas of smart cities and provide near-real-time data that can be used to save lives and enhance the level of provided health care services, especially during accidents, or on occasions when reaching health care seekers requires special support.

Utilizing different technologies to enhance health care, in general, is a common trend that has been adopted by many researchers. For example, the authors in Melo and Araújo [17], Park *et al*. [19], Karajizadeh *et al*. [15], Choi *et al*. [6], Tith *et al*. [24], and Tougui *et al*. [25] discussed the use of different technologies and their effect on health care and how to use those different technologies to boast or enhance the health care process in general. The given results in these studies indicate the extent of the impact that this technology provides in supporting the health sector and raising the level of health care to previously unattained levels.

Using drones to perform different tasks within smart cities was discussed by many researchers. For example, Nayyar *et al*. [18] presented the *Internet of Drone Things* (IoDT), which can be used to enhance the intelligence of drones for various tasks within smart cities. While Sungheetha and Sharma [21] integrate cloud computing, IoT sensors, drones, wireless sensor networks, and image processing technologies to formulate rules that improve fire detection rates in several area types. On the other hand, Barmpounakis and Geroliminis [3] addressed the urban traffic congestion problem by presenting pNEUMA (New Era of Urban Traffic Monitoring with Aerial Footage), which will use drones to build a data set that contains the recording of traffic monitoring in an urban multi-modal congested environment. The developed system provides opportunities for researchers to study traffic congestion problems and enables researchers from different disciplines to use this system to develop and test their models.

The task of search and rescue during disasters was presented by Bourbakis and Ktistakis [5] presented Tzitziki, a system that is designed to extract visual and audio signals of the presence of people under destroyed buildings or inside ground cavities. Smart farming was discussed by Behjati *et al*. [4], where the authors integrated drones, low-power wide-area networks, and IoT technologies to develop an aerial-based system that can monitor farms' water supply, collect data on large-scale farms, and optimize drone flight paths. While Thakur *et al*. [23] presented a comprehensive review of the research that addressed air surveillance by drones in smart cities and explained the employment of deep learning to maximize the benefit of the presence of drones.

Drones encounter many challenges, such as limited power resources that limit their flying time. For all tasks, flying time is the critical factor that determines the success rate of these tasks. This research will discuss the problem of minimizing the required drone flying time, with the objective of minimizing the maximum completion time. This problem was discussed by many researchers in the literature. For example, Wang *et al*. [26] introduced the problem of vehicle routing with drones. A set of vehicles equipped with drones deliver different packages to customers who are not on the direct path of these vehicles, with the objective of reducing the maximum required time to complete all given deliveries by calculating the maximum flight duration (range) of each aircraft and assuming several worst-case scenarios to derive some of the worst results. This solution will connect the path of the drones with the path of the used vehicles. Also, it assumes that all delivery missions fall within the actual range of the drones and requires the provision of a special vehicle type that fits with the used drones, in addition to providing appropriate training for the people involved in the delivery process. All of these assumptions will add additional costs and increase the required time to carry out the required tasks.

Tamayo *et al*. [22] presented the problem of agricultural surveillance using one drone with pre-defined paths, in addition to many charging stations that operate on solar energy and are distributed in predetermined locations, within irregular terrain that allows a limited number of locations for the installation of charging stations, to provide the drones with the required energy to carry out surveillance missions in large areas. The main goal of the agricultural surveillance process is to increase crop production by detecting early cultivation problems and taking the required proactive measures. The researchers believe that the solution to this problem lies in the application of the algorithms that were formulated as integer linear programs to reduce the total time required to carry out all monitoring tasks. The presented solution is believed to be a good one, but there should be an option to increase the number of used drones and the number of charging stations.

The rest of this paper is organized as follows: Section 2 provides the problem description, and Section 3 presents the proposed algorithms. Section 4 discusses the experimental results. Finally, Section 5 presents the conclusions.

2. Problem Description

The studied problem is described as follows. A set of drones concentrated to drone station denoted by DS. Each drone is denoted by Dn_i $\forall$ $i = \{1,\cdots,n_D\}$ with n_D is the total number of drones. The smart city is divided into a set of zones as shown in Figure 1. Each zone is denoted by Z_j $\forall$ $j = \{1,\ldots,n_Z\}$ with n_Z is the total number of zones. The distance between drones is supposed to be negligible (= 0). The time to fly from any point in the drone station to any zone Z_j is denoted by tz_j. The time from each zone to any point in the drone station, is supposed to be identical as the going time. The necessary time for surveillance of a zone Z_j is denoted by ts_j.

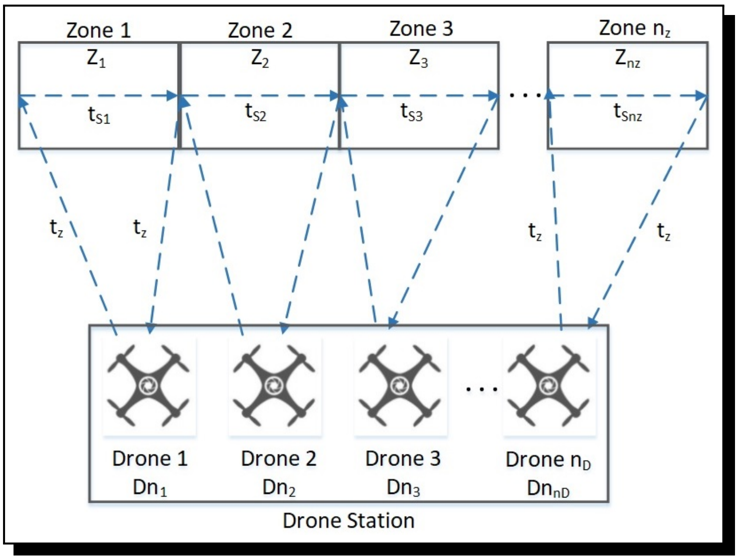

Figure 1. Shows an example of drone station and zones overview

Proposition 2.1. *The necessary time to go from any point of the drone station and make surveillance and return is* $t_j = 2 \times tz_j + ts_j$.

Proof. The time to reach any zone is tz_j. So, the needed time to go and return without surveillance time requires $2 \times tz_j$ time. Adding the surveillance time ts_j, the total spent time by the drone is $t_j = 2 \times tz_j + ts_j$.

The cumulative time after visiting zone j is denoted by Ct_j. The finishing surveillance time by all drones t_f is calculated as follows $t_f = \max_{j=\{1,\ldots,n_Z\}} (Ct_j)$. The objective is reassign the given tasks to minimize the finishing time t_f. □

Example 2.1. Suppose a smart city area consisted of six zones to be visited by two drones. Table 1 shows the total time needed for each zone. Figure 2 shows the zone assigned to each drone and the zone related time as given in Table 1. If the system applies Algorithm 1, $t_f = 110$. However, when Algorithm 2 is applied, $t_f = 95$.

Table 1. The total time needed for each zone as explained in Example 2.1

j	1	2	3	4	5	6
t_j	50	20	10	30	35	40

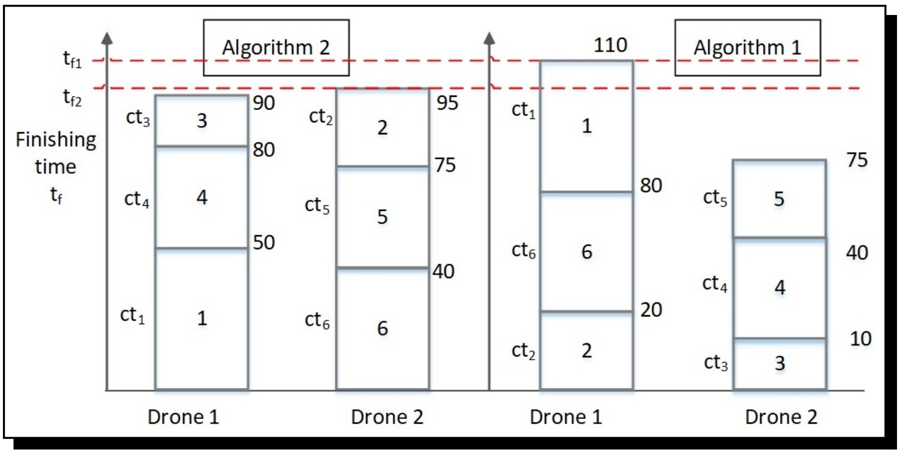

Figure 2. Assignment of drones and zones related to Example 2.1

3. Proposed Algorithms

To reach the required objective of this research, three algorithms will be proposed.

3.1 Zone Biggest Surveillance Time Algorithm (*ZBS*)

First, sort all zones according to the non-increasing order of their t_j. Then start the surveillance with the first zone in the sorting order list, one by one. The selected zone will be visited by the most available drone.

3.2 Zone Smallest Surveillance Time Algorithm (*ZSS*)

First, sort all zones according to the non-decreasing order of their t_j. Then start the surveillance with the first zone in the sorting order list, one by one. The selected zone will be visited by the most available drone.

3.3 Multi-Start Chosen Zone Algorithm (*MCZ*)

First, choose the zone that has the biggest t_j. Then, for all remaining zones, the surveillance will be based on the smallest t_j by the most available drone. The t_f value is calculated and denoted by t_f^1. This is the first iteration of the algorithm. In the second iteration, instead of choosing one zone in the beginning, choose two zones that have the biggest t_j to be surveyed by drones. For the remaining zones, continue by choosing the smallest first. The t_f value is calculated and denoted by t_f^2. After that continue by choosing $3,4,\dots$ and so on until reaching $n_Z - 1$ iterations. The best solution will be picked. The instructions for MCZ is given in Algorithm 1.

4. Results and Discussion

In this paper, all proposed algorithms were coded in a C++ environment. The used personal computer is a Core i5 6200U CPU @ 2.30 GHz and 2.40 GHz with 8.00 GB of RAM and Windows 10. Two classes are chosen to be tested in this paper. The difference between classes is the way that t_j is generated. The first class is the uniform distribution $U(10,100)$. The second class is the uniform distribution $U(50,100)$. The choice of n_Z and n_D is given in Table 2.

Algorithm 1. Multi-start chosen zone algorithm (MCZ)

Set $j = n_Z$
For ($a = 1$ to $n_Z - 1$) ($j > n_Z - a$) **do**
  While ($j > n_Z - a$) **do**
    $Sch(j)$
    $j--$;
  EndWhile
  $j = 1$;
  While ($j \leq n_Z - a$) **do**
    $Sch(j)$
    $j++$;
  EndWhile
  Calculate T_f^a $j = n_Z$
  $j = n_Z$
EndFor
  Calculate $T_f = \min_{1 \leq a \leq n_Z - 1} (T_f^a)$
Return T_f

Table 2. Number of zones and drones distribution

n_Z	n_D
5	2,3
10	2,3,4,5
20	2,3,4,5,10
50	2,5,10

For each fixed values of n_Z and n_D, and for each class we generate 10 instances. Table 2 shows the total number of generated instances $(2+4+5+3) \times 10 \times 2 = 280$.

The indicators that will be measured to asses the performance of the proposed algorithms are as follows:

- T^* the best T_f value given after execution of all algorithms.
- T the T_f value returned by the studied heuristic.
- $G_a = \frac{T - T^*}{T^*}$.
- Pe the percentage among all instances that $T = T^*$ is reached.

Table 3 shows an overview of Pe and G_a given by all algorithms. The best algorithm is MCZ which is dominate. The average gap of the best algorithm is zero. However, the average gap of ZBS is equal to 0.004.

Table 3. Overview of Pe and G_a given by all algorithms

	ZBS	ZSS	MCZ
Pe	88.6%	0.0%	100.0%
G_a	0.004	0.093	0.000

5. Conclusion

Time is the most critical and influential factor in the outcome of rescue and health care operations. For the rescue and health care teams, reaching the desired location in the shortest possible time is their challenge. These teams use the provided information to achieve that goal. This information is derived by the control center from the data obtained by different means. In this research, the utilization of drone technologies will be utilized as a source of the required data, which can be obtained through surveillance missions over the various zones in the monitored cities. In this research, the problem of minimizing the total flying time required to carry out all the given tasks by several drones was raised by developing a set of algorithms that will schedule the assigned tasks to reduce the maximum completion time. The experimental results showed the ability of the developed algorithms to achieve the desired goal. The parameters used to measure the performance of the developed algorithms showed that *MCZ* algorithm has reached the required goal in all cases.

Competing Interests

The author declares that he has no competing interests.

Authors' Contributions

The author wrote, read and approved the final manuscript.

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