The Smart Medicine Delivery Using UAV for Elderly Center

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Summary
Medication safety and medicine delivery challenge the well-being of the elderly and the management of the elderly center. With the outbreak of COVID-19, the elderly in the care center were challenged by the inconvenience of the medication restocking. The purpose of this paper accentuates the importance of the design and development of an UAV-based Smart Medicine Case (UAV-SMC) to improve the performance of medication management and medicine delivery in the elderly center. The researchers came up with the design of UAV-SMC in the light of the UAV and IoT technology to improve the performance of both Medication Practice Management (MPM) and Low Inventory Detection and Delivery (LIDD). Based on the result, with UAV-SMC, the performance of both MPM and LIDD was significantly improved. The UAV-SMC improves the efficacy of medication management in the elderly center by 26.97 to 149.83 seconds for each medication practice and 9.03 mins for each time of medicine delivery in Subang Jaya Malaysia. This paper only investigates the adoption of UAV-SMC in the content of elderly center rather than other industries. The authors consider integrating the UAV-SMC with the e-pharmacy system in the future. In conclusion, the UAV-SMC has significantly improved the medication management and guard the safety of elderly and caretaker in the elderly in the post-pandemic times.
Keywords:
Drone, Medicine Box, Elderly, Telemedicine, UAV, Low Inventory Detection

1. Introduction

The elderly has comparatively more apparent challenges of living than young people in the activities of daily living (ADLs). For this reason, a certain number of elderly tend to stay at the elderly center rather than being unattended and unsupported at home. Medication safety of the elderly is an essential matter to ensure their quality of living and their well-being. In the elderly center, due to geriatric problems, routine medication plays an important role in the ADLs of many elderly [1, 2]. On the other hand, as shown in the Figure 1, centers are still equipped with manually performed medicine closets, which creates hidden dangers of medicine retardation, mismatch or overdose by careless caretakers [3]. Many previous designs of medicine boxes [4] focus on the single user in a hospital or independent living context rather than being specific to the elderly with caretakers. In this case, many designs of the medicine box and related kinds have been adopted in different application scenarios (e.g., independent living and hospital) in the support of medication management.

Fig. 1. The closet for medicine management in an elderly center.

On the other hand, the medicine delivery to the elderly center has critically challenged their management, especially during COVID-19. According to Li, et al. [5, 6], the application of drones can reduce delivery time as well as manpower error, and the risk of infection from the outside to the elderly center. The abovementioned advantages imply the application of UAV in medicine delivery has the potential and significance on behalf of sustainable elderly center management. The purpose of this paper accentuates the importance of the design and development of a UAV-based Smart Medicine Case (UAV-SMC) in the context of an elderly center. Therefore, this paper aims to present how the UAV-SMC can be used to improve the performance of medication management and medicine delivery in the elderly center.

This research contributes to the technology application in the elderly daily living context to enhance the quality of independent living of the elderly in the care center. Specifically, the IoT-based medication management system improves the accuracy and efficacy of medication practiced by caretakers. Moreover, the automation of the medicine delivery practically used a drone as the means to improve

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medicine delivery from pharmacies to elderly center. Lastly, the use of drones in medicine delivery process can reduce the likelihood of infection during the pandemic.

In this paper, the authors reviewed past literature on the use of the IoT-Based Medicine Box and Unmanned Aerial Vehicle in section 2. In section 3, the authors proposed the design and development of UAV-SMC and explained how the functions work to the medication management and medicine delivery in the elderly center. In section 4, the authors analyzed data and measured the performance of UAV-SMC and discussed the results in section 5.

2. Literature Review

The authors reviewed related works from the past literature in the topics of IoT-based medicine box design and development as well as the scientific and practical applications of UAVs in different industries. To end-users, IoT is considered the most satisfying networking paradigm for connecting their living in digit [2]. Hence, the user-centric principle [1] has been widely accepted by system developers in their framework design, and it also helps to construct functionality of a system [5, 6]. In any case of elder-centered system design and development

2.1 IoT-Based Medicine Boxes

The smart medicine box has been invented for years, and it contributes to the automation of everyday medication practice for individual patients but not in multi-user environment. In the past few years, the design of smart medicine boxes and other Internet of Things (IoT) based similar kinds focused on applications (e.g., reminders and dispensers, etc.) in the hospital, disabled [7], and independent living context [8].

In Figure 2, Carlos [9] improves the previous designs with multiple user interactions in the power of the cloud and local central computing. Kumar, Goh, and Balakrishnan [10] proposed their design of a smart medicine reminder for the independent elderly including the modules of medicine information collection, real-time clock, user interface, pillbox detection and interaction.

Many medicine boxes are designed in the architecture of a hybrid web-based program interacting with the mobile application on the user's side and the hardware programs in the smart devices [10, 11]. Other reminders adopted sound [12] and LED/LCD signals [13] as indicator of the medication. Specifically, a similar system by AL-Shammary et al. [14] responded to the problem of miss-dose and overdose with multiple cells to categorize the different types of medicine.

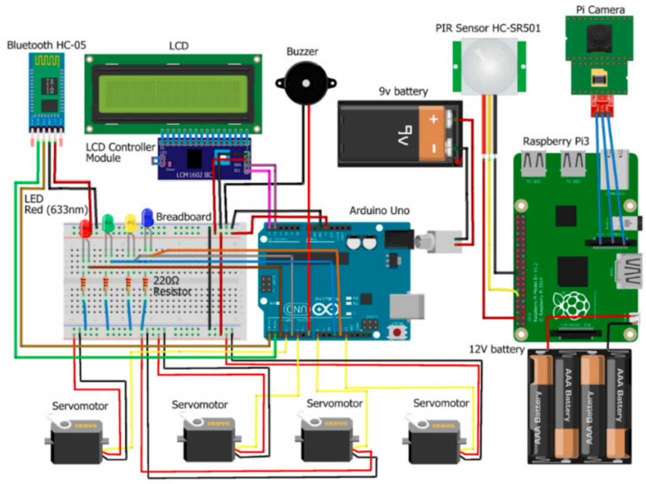

Fig. 2. The design of the smart medicine dispenser [9]

2.2 Unmanned Aerial Vehicle Application

In UAV-SMC, the drone can be homed with a fulfilled container with default GPS location. With the drone homing algorithm planned, the travel distance per task will be decreased so that its service coverage can also be increased in the same payload and battery capacity. The UAV-SMC also involves the quadcopter to perform the medicine delivery to fetch medicine from a target pharmacy. There is no doubt that drone can significantly diminish the cost of delivery in terms of energy consumption and clean energy usage [5]. With the years of development, UAVs has become a reliable monitoring solution (e.g., filming, surveillance, etc.) and load-carrying purposes [5]. Specifically speaking in load-carrying, the capability of load-carrying varies from quadcopter to hex-copter in different industries, including agriculture [15], medicine [16], and law enforcement [17]. UAVs has been used as emergency medical ambulance for outdoor medical response [16], [18], [19] such as in sports event [4]. For medical purposes, drones have been widely used in organ and first-aid kit delivery, which are recognized as the inspiration for medicine restocking in UAV-SMC. AFAS [16] delivers the first-aid kit via GPS navigation but once the kit package reaches the location in one way. In recent years, the studies on UAVs focus on the adoption of neural networks [20] and machine learning algorithms [21]. [22], [23] for the improvement of flying performance and decision-making mechanisms in various application scenarios e.g., visual signal analysis, drone homing, and automatic flying system [24].

UAV can cut down on expenses and save time during service delivery and tracking [20], [25]. When it comes to drone deliveries, a mathematically based computer technique (e.g., Dijkstra's) that supports a viable routing plan can greatly strengthen the app's logic and speed [25]. By considering the output of delivery efficiency, Alsamhi et al. [25] provide a thorough routing algorithm in the input variables (such as total cost, time cost, object weight, energy cost, initializing time, routing timing vector, etc.). To return a drone to its starting point quickly and easily, the concept of "drone homing" was developed. The visual measurement strategy based on an actual camera will lend a hand in calculating the estimated altitude. The problem of position estimate in the context of a shortened route planning procedure can be addressed with the help of a map of the surrounding area and some factors about the current location thanks to the simultaneous localization and mapping approach (SLAM) [28].

There is no such thing as a guaranteed foolproof fix for any given problem. In another study of vehicle-assisted multi-drone parcel delivery to multiple customers in different locations, Peng et al. [29] devised a novel algorithm involving pipelines of tournament selection algorithm of frequent-use node, local search algorithm, and anchor node-based child-route education to minimize the cost of vehicle-drone delivery and increase service reach in this challenging scenario [30], [31].

2.3 Research Gap

There is no such thing as a guaranteed foolproof fix for any given problem. In another study of vehicle-assisted multi-drone parcel delivery to multiple customers in different locations, Peng et al. [29] devised a novel algorithm involving pipelines of tournament selection algorithm of frequent-use node, local search algorithm, and anchor node-based child-route education to minimize the cost of vehicle-drone delivery and increase service reach in this challenging scenario.

Rochon & Schmader [23] indicate the average medication practice for the elderly center (per 10 pax) is 14 times a day. Medication practice is important for elderly center management and the administrator should avoid the malpractice of medication in the elderly center [3, 26]. From the literature review, it is noticed that the IoT-based medicine box designs have advantages to regulate the medication practice of patients in the elderly center. The UAV application is widely used for short-distance (within 3-5 km) outdoor delivery, which can be potentially used in our case to reduce the time and energy input for medicine delivery. Based on the previous medicine box designs, the researchers came up with a solution to effective medication management in the context of multiple elderly to support the medication service in the elderly centers. Also, the researcher extends the UAV application into the use of medicine delivery from the pharmacy according to the prescription information stored in the central database, to the elderly centers when any medicine runs out of stock.

Table 1: Summary of Literature

Author/Year	***Research Gap***	***Remark***
Kumar & Jeeva [4] Kumar et al. [10] Ranjana & Alexander [27] Zeidan, et al. [12] Carlos [9]	Not providing the delivery function in smart medicine box design	Medicine delivery is critical to the elderly in care center especially during pandemic times
Kumar & Jeeva [4] Carlos [9] Davis [17] Fakhruddin, et al. [16]	The previous usage of UAV mainly focuses on the load carrying and monitoring in the filming, law enforcement, medical, and agriculture industries	The UAV in the elderly center for medicine delivery is applicable in the usage scenario of elderly center medication management.

In this research, the research team collaborated with scholars from social science disciplines to investigate the challenges faced by the older people in Malaysia. From the literature review, we found out the IoT based medicine box has its advantages to regulate the medication practice to the patients. The UAV application is widely used for short-distance (within 3-5 km) outdoor delivery, which can be potentially used in our case to reduce the time and energy input for medicine delivery. Based on the previous medicine box designs, the researcher came up with solution to the effective medication management in the contest of multiple elderly to support the medication service in care centers. Also, the researcher extends the UAV application into the use of medicine delivery from the pharmacy according to the prescription information stored in the central database, to the elderly centers when any medicine runs out of its content.

Based on the literature review, the current design and development of the medicine box did not involve the medicine delivery feature in their design and development. The use of UAV can be considered since it has widely applied in the usage scenario in different industries. However, the medicine delivery is critical in the context of elderly center especially in the pandemic and post pandemic times.

3. System Design and Development

The purpose of the study is to improve the medication management & medicine delivery in the context of the elderly center. The algorithm for both Medication Practice Management (MPM) and Low Inventory Detection and

Delivery (LIDD) are determined to realize the proposed functions of UAV-SMC.

3.1 Medication Practice Management

$$|T| = \frac{T\text{practice time} - T\text{defined time}}{3600} \qquad (1)$$

To identify whether the medication practice is conducted according to the defined medication practice time within an hour (3600 seconds), Equation (1) for time calculation is used to determine whether the time interval is valid for the regulated meditation practice time. If |T| is less than 1 meaning that the medication practice time is considered successful; If the |T| equals 0 means the practice time doesn't exist so the medication practice is considered failed; if the |T| is greater than 1 which means the medication practice has not been conducted within an hour. Therefore, Equation 1 is adopted in Algorithm 1 below:

Algorithm 1 Medication Management

Input: i UserID, j ContainerID, t medicationTime, t2 Accurate Medication Time

Output: s Medication Status

```
function MedicationRecording (i,j,t, t2)
s = 1;
    while (i && j ) do
        for each j in i do
            if (!t) do
                s = 0;
            else if (t2 - t < 3600) do
                s = 2;
            end if
        end for
    end while
    return s;
end Function
```

In the above algorithm, i represents the elderly user and j indicates the medicine in different containers. The t is the medication time for medicine intake and t2 is the actual time of the medicine intake marked by a caretaker. When the medication time arrives for the elderly, the caretaker will support the elderly and mark down the medication practice time. Whenever the medication practice is completed, the record status is marked as successful (s=1). However, if the medication time is not recorded properly, the medication practice is considered as failed (s= 0); if the medication time is recorded but is later than an hour, the medication practice is considered delayed (s = 2).

3.2 Low Inventory Detection and Delivery

To identify whether the inventory of a particular medicine is sufficient for the next day's medication practice, we come up with Equation 2 to determine whether the medicine inventory is enough for the next day's consumption. Y represents the inventory status; Q indicates the inventory quantity that remains in stock; P is the pills per intake, and N is the number of intakes per day.

Algorithm 2 Low Inventory Detection

Input: i UserID，j ContainerID, q Quantity in stock, p Pills per Intake, t Intake Times per Day, s Status

Output: s Low Inventory Status

```
function LowInventory (i,j,q,p,t)
s = 0;
    while (i && j) do
        for each j do
            if (q <= p * t) do
                s = 1;
            end if
        end for
    end while
    return s;
end Function
```

If the value of Y inventory is greater than 1, we can consider that the inventory is still sufficient for the next day's practices. However, if the Y is less than 1, the inventory is insufficient for the next day's medication practices.

In the meantime, Algorithm 2 checks the quantity left of each medicine contained if it still has enough stock for another one-day intake. Otherwise, this algorithm marks the status as 1 (low-inventory indicator) in the database and all the low inventory items (s = 1) can be listed with the GPS coordinate of the pharmacy proceeding to medicine restocking using UAV.

3.3 System Design

First and foremost, the primary user of UAV-SMC is the caretakers who need to fulfil their duty to operate both medication and medicine delivery functions in the system. From the past studies, we have found literature background to continue our study on the IoT and UAV solutions to correspondingly achieve the functions of MPM and LIDD.

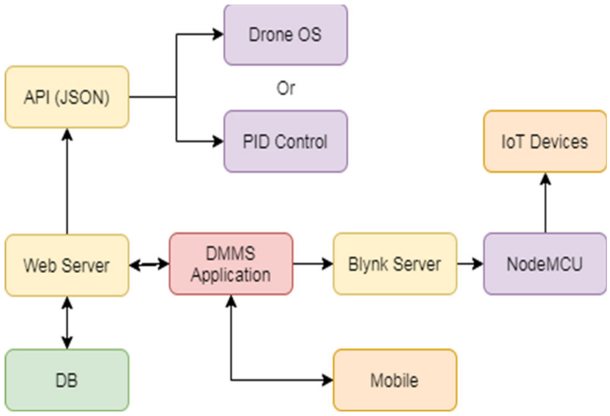

Fig. 3. The underlying data communication framework of the UAV-SMC

Figure 3 above has demonstrated the underlying data communication framework of the UAV-SMC using Blynk and Web server in a WIFI environment. The advantages of using Blynk are its implementation minimizes memory and bandwidth usage and more efficient information distribution with high scalability of the integrated system. The UAV-SMC uses a mini-processor (i.e., NodeMCU), which integrates memory and CPU on a single piece of the circuit board. The UAV-SMC realizes the LIDD function using a web server which provides API service to facilitate the drone operation.

3.4 API Development and Integration

```
protected function myerror($message_Long, $message_Lati, $name)
{
    $this->logerror($message_Long, $message_Lati);
    $return = array(
        'status' => 0,
        'name' => $name,
        'GPS_Long' => $message_Long,
        'GPS_Lati' => $message_Lati,
    );
    echo json_encode($return);
    die;
}
```

Fig. 4. Json query of low inventory medicine with the GPS information

Correspondingly, for both Medication Practice Management (MPM) and Low Inventory Detection and Delivery (LIDD) functions, the code is programmed in PHP script placed in a web server Algorithm 2 is realized using PHP script to realize the refill detection in UAV-SMC. The particular container is indicated once the medication practice starts, and the program retrieves related inventory information inside of the database. The program compares to determine the availability of the medicine for the next round of medication practice. If the inventory quantity can afford the quantity of the next day's medication practice, the availability status remains 1; otherwise, the status will be updated to 0 to indicate the unavailability of the inventory of the particular medicine. Figure 4 above demonstrates how the API can be created using PHP under ThinkPHP 5.0 framework in the web server and deserialized using a C# program, which can be adopted in any drone operating system. The program uses the get method to receive the API string and initially validates its content. Then the program can break down the JSON file based on the proposed GPSModel and the Variable exarate is the result of the GPS data.

3.5 System Development

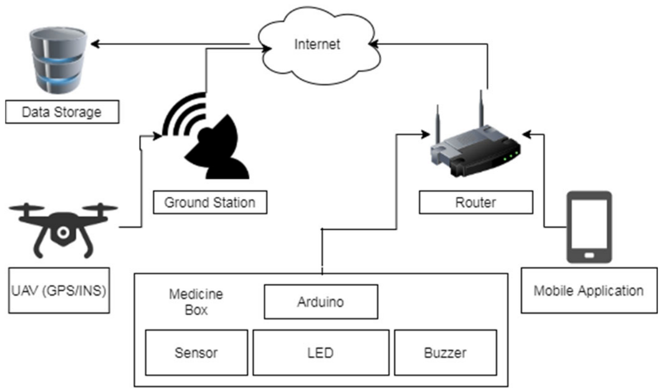

Fig. 5. The system architecture of the UAV-SMC

Figure 5 presents the devices used in the UAV-SMC system. The automation of medicine cases relies on Arduino, which processes embedded algorithms to regulate the daily medication practices of the elderly and transmit the output data to the NodeMCU so that the users can interact with the automated device on the user-friendly interface (See Figure 6) on the mobile end and finally, the data will be stored as in the structured inside of the database on cloud.

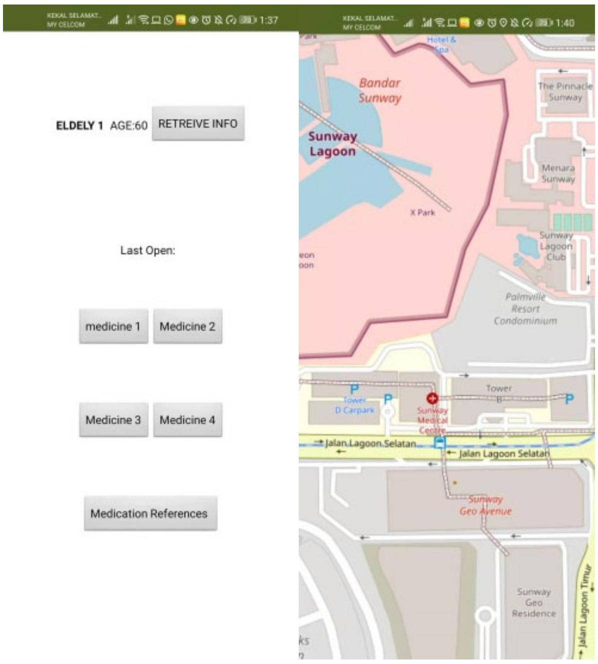

Fig. 6. The user interface of UAV-SMC

Fig. 7. The prototype of the proposed system

On another side, the status of the drone is updated within the system once any medicine is indicated in empty inventory. Finally, the prototype was developed as shown in Figure 7 above.

4. Testing and Results

Table 2: Result Summary of the Performance Test

System Reliability	**Average System Response Time**	1.95s
	Mobile Starting Time	0.461s
	High input Latency	3%
	CPU Consumption	<27.035%
	Highest Memory Usage	123152b
	Highest Network Usage	Received: 2,833,943b
		Sent: 87,872b
	Blynk Server Response Time	0.02s

As shown in Table 2 above, the average system response time cost 1.95 seconds to load the system on the smartphone end, which requests less than 27.035% of CPU consumption. When the GPS service started, the system invested its highest memory usage 123152 bytes and network usage (2833843 bytes in receiving and 87872 b in sending requests). Lastly, the Blynk Server response time cost 0.02s to send the instruction message to the NodeMCU controller.

4.1 MPM Test Result

As shown in Figure 8, the reliability test was conducted and there were 31 rows inserted, which represents 31 times medication practices happened in 2 days test process.

□□□□ dmms, □: medication_record, □□□ □□□□

record_ID	time	status	user_ID	medicine_name
1	2021-01-14 15:00:48	1	1001	medicine A
2	2021-01-14 15:01:24	1	1001	medicine C
3	2021-01-14 15:01:52	1	1001	medicine D
4	2021-01-14 15:02:29	1	1002	medicine E
5	2021-01-14 15:03:01	1	1002	medicine F
6	2021-01-14 15:03:20	1	1002	medicine G
7	2021-01-14 15:03:35	1	1002	medicine H
8	2021-01-14 20:00:50	1	1001	medicine B
9	2021-01-14 21:00:23	1	1001	medicine A
10	2021-01-14 21:00:42	1	1001	medicine C
11	2021-01-14 21:01:21	1	1002	medicine E
12	2021-01-14 22:00:15	2	1002	medicine H
13	2021-02-04 09:00:11	1	1001	medicine A
14	2021-02-04 09:00:39	1	1001	medicine C
15	2021-02-04 09:00:58	1	1002	medicine E
16	2021-02-04 09:01:16	1	1002	medicine F
17	2021-02-04 09:01:47	1	1002	medicine H
18	2021-02-04 10:00:17	1	1001	medicine D
19	2021-02-04 10:30:19	1	1001	medicine B
20	2021-02-04 15:00:21	1	1001	medicine A
21	2021-02-04 15:00:59	1	1001	medicine C
22	2021-02-04 15:01:22	1	1001	medicine D
23	2021-02-04 15:01:54	1	1002	medicine E
24	2021-02-04 15:02:24	1	1002	medicine F
25	2021-02-04 15:02:53	1	1002	medicine G
26	2021-02-04 15:03:10	1	1002	medicine H
27	2021-02-04 20:00:29	1	1001	medicine B
28	2021-02-04 21:00:21	1	1001	medicine A
29	2021-02-04 21:01:02	1	1001	medicine C
30	2021-02-04 21:01:44	1	1002	medicine E
31	2021-02-04 21:02:21	1	1002	medicine H

Fig. 8. The user interface of UAV-SMC

As indicated in the figure above, the 31 rows were all successfully inserted based on the medication practice status. Row 12 was recorded as delayed due to more than 1 hour delay for this intake practice. Therefore, it can be recognized that all (p = 100%) the inserted rows are correctly inserted according to the medication practice time set in the medication practice timetable shown above.

Table 3: Descriptive Results

	AVG(T)	Std_Dev (T)	Minimum	Maximum
Medication Practice	88.4000	61.34110	11.0000	215.0000
Estimated Distribution Parameters				
			Time_diff	
Normal Distribution	Location		88.4000	
	Scale		61.34110	
The cases are unweighted.				

The time efficiency indicates the level of timesaving in the automated process of DIoT compared to the conventional approach currently used in elderly centers. To understand the time consumption of the medication practice using UAV-SMC, we conducted the descriptive analysis to find out the average medication practice time using the rest qualified samples (n = 30). In the case of UAV-SMC, the medication management function generated the result regarding the medication record of each practice time in our earlier pilot test. We further process the data from Figure 8. to calculate the average time difference and deviation (regulated time of each medicine in Figure 8 and actual practice time in medication record shown in Figure 8) and medicine delivery time. Row 12 was taken out since it is not successful status.

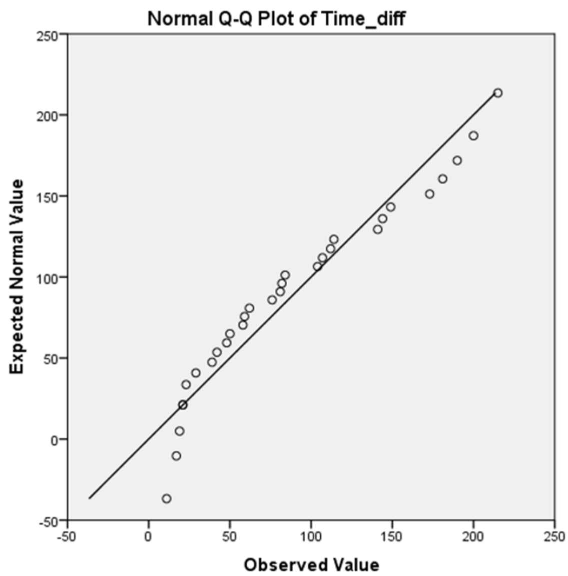

Fig. 9. The user interface of UAV-SMC

In Table 3, for all the 30 samples collected, the Q-Q Plot diagram in Figure 9 above demonstrates the distribution of data where the longest medication practice time was 215 seconds whereas the shortest time was recorded at 11 seconds. The average medication practice time in UAV-SMC is 88.4000 seconds with a standard deviation value of 61.4311 seconds. Therefore, the normal practice time using UAV-SMC is in the range between 26.9689 seconds (88.4000s – 61.4311s) and 149.8311 seconds (88.4000s + 61.4311s). Hence, it can be concluded that one single caretaker can sustain at least 24 (3600/149.8311) to 133 (3600 / 26.9689) medication practices accurately using UAV-SMC within an hour.

4.2 LIDD Test Result

In the test of medicine delivery, the time from preparation until the setup of restocked item was recorded in 9 minutes 45 seconds at 9:00 am; 9 minutes 12 seconds at 12:00 pm and 8 minutes 15 seconds at 16:00 for 2.7 Km direct distance flight from Taylor's Lakeside Campus to a pharmacy in SS15. The average time consumption was calculated at 9.07 minutes.

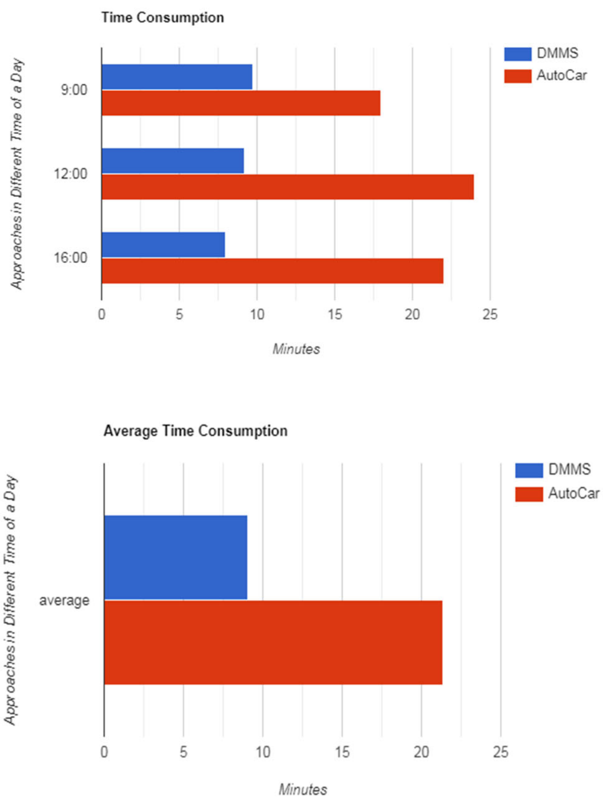

Fig. 10. Time comparison between UAV-SMC and car driving

Furthermore, in the Fig.10 above, the average time consumption was tested using a wheel vehicle for the medicine delivery function using Google Maps time estimation service. The data were adopted from Taylor's University to a pharmacy at SS15 and the estimated time at 9:00 in the morning was recorded as 18 minutes; 12:00 was 24 minutes with medium traffic volume; 16:00 was recorded as 22 minutes with high medium traffic volume for the 6.2 km road distance. Therefore, the average time consumption using car driving was calculated as 21.33 minutes. In conclusion, UAV-SMC improves medicine delivery efficiency by 2.35 times higher than the conventional car driving approach.

5. Discussion and Comparison

In this research, the performance of UAV-SMC was tested using Firebase and Bitcatcha. The overall result of the performance test indicates the UAV-SMC prototype has great reliability to be used. In Table 4, authors compare the key performance indicator to the previous similar designs. the overall test case success rate is 100% which is higher than the figure (97%) of the previous design of the medicine box by Zeidan et al. [12] and the accuracy of the medication record is 100%, which is higher than the 85% of satisfactory record by Zeidan et al. [12]. According to Rochon & Schmader [23], the normal requests of the medication requests in the elderly center for over 10 people is 14 times but our system can practice 24 to 133 times medication in the elderly center. According to Westbrook et al. [26], the average time for the medication practice is recorded as at least 42 seconds but the UAV-SMC can reduce the practice time to 26.97 seconds. The average delivery time using a drone is 9.07 mins with 3.1 mins of preparation which means the 2.7 KM flight took 5.93 mins which is slightly higher than the results from the research by Hii, et al. [22]. Furthermore, the UAV-SMC can afford 53 times of medicine delivery in 8 hours of operation which is slightly higher than the design [24] and can practice 50 to 150 times in a day. Compared with [10], [14], all the medicine box designs have the feature of medication practice alert. However, comparing with other designs of medicine boxes [10], [14], UAV-SMC implements drone as its major components in medicine restocking in which medicine can be fetched back from pharmacy/hospital in the concept of last miles parcel delivery [28] in the average time of 9.07 minutes. One of the weaknesses of SMB, SMRD, and ARMB is lack of application integration. For the multi-users system, the performance test indicated that UAV-SMC can sustain at more 133 times accurate medication practice within an hour for different elderly residents. In UAV-SMC, the mobile application was adopted to support the medication management for clear information delivery to the caregivers. Medicine containers are designed to be demountable for its convenience in drone-based delivery. As a result, comparing with other similar projects, we have made contribution in telemedicine automaticity with Drone-based IoT approach.

Table 4: Test Result Summary

	Testing Content	Result	Comparison
Test Cases	**Test Cases Success Rate**	All Pass	97% (3% Error) [12]
Accuracy	**Medication Record Insert**	All Pass	85% (satisfactory) [12]
Efficiency Improvement on the Process	**Average Time Spending per Medication Practice**	88.4 sec	At least 42 sec [26]
	Normal Medication Practice Time Spending	26.97 to 149.83 seconds	At least 42 sec [26]
	Maximum Capacity per Hour	24 to 133 practices	14 practices [23]
	Drone Flight Time per Delivery	9.07 mins (3.1 mins preparation)	30 mins for a 20 KM distance [22]
	Times of the Medicine Delivery	53 times in 8 hours	50 – 150 times [23]

The UAV-SMC improves the medication management and restocking process in the elderly center management. The system supports the daily medication practices by objectively indicating the accurate medication practice time and status as medication records for medical purposes and hence the medication management efficiency is improved compared to the traditional management approaches used in elderly centers. The UAV-SMC indicates the low inventory item one day ahead if mismedication happens to the elderly patient. With the adoption of the drone delivery approach, it reduces the time (Less than 10 mins within a 3km distance) and electricity energy input during the normal medicine restocking process. During the pandemic time, UAV-SMC can significantly sustain the independence of the elderly center while maintaining the medication safety of the elderly residents.

Table 5: Test Result Summary

Medicine Delivery	UAV-SMC	Conventional Approach
Low inventory detection	Automated	Manual
Medicine Delivery Time	9.07 mins	21.33 mins
Personnel	Drone	Caretaker/Relatives
Distance	Direct	Roadway

Table 5 shown above indicated the advantages use UAV-SMC. Comparing the UAV-SMC with current conventional approaches used in Malaysia elderly centers, UAV-SMC takes part of the duty from the caretaker and improves the efficiency of medication management in the elderly center. First, the UAV-SMC can alert the caretaker when the medication time arrives for any elderly residents to reduce the likelihood of medication delay, forgetting, and mismatch. Also, the UAV-SMC can automatically indicate the low inventory items and update the pharmacy information to the caretaker to execute the medicine delivery task using a drone, which significantly reduces the time and energy input in the conventional medicine restocking process. All the medication record is stored in the database as medical references.

In UAV-SMC, system centralizes information from multi-users at care center to assist medication management by the means of multi-user medicine case for its systemic enhancement on the reliability of medication management in terms of reinforcing medication schedule for center elderly at the same period of medication time. In other word, the medication safety can be guaranteed for the sake of wellbeing of elder residents at institution.

6. Conclusion

The UAV-SMC has demonstrated the strength of Drone and IoT applications in the medication management service provided in the elderly center. This paper contributes to the digital health in the sector of elderly ambient assisted living. With the trend of digital-connected lifestyle, elderly should be included as the beneficiary of the technology improvement in the future.

The limitations of the study call for future study in the area of telemedicine regarding the ADL challenges faced by the elderly in the context of independent living. First, the author aims to exam the usability of user acceptance tests in the context of elderly center during post-pandemic. Beyond the solution of medication practices in the elderly center, the elderly is also facing geriatric issues such as dementia and emotional disabilities. Ways to support the ADL of the elderly has challenge the scholars and engineering practitioners in their disciplined area not only in the elderly center but also in the ambient assisted living environment as well.

In conclusion, UAV-SMC is an evidence of telemedicine adoption in the elderly community. Broadly speaking, the research outcome has contributed to Goals No.3 (Good Health & well-being), No.9 (Industry Innovation & Infrastructure), and No.11 (Sustainable cities & communities) in United Nations Sustainable Development Plan. UAV-SMC can supportively administrate medication management for multiple elder residents at the care center. To be extended from the medicine case design, the UAV-based medicine restocking has effectively lessened the workload of caretaker and time use compared with traditional approaches. However, the system also has its limitations. Primarily, it does not contain a medicine auto-distribution function for elderly patients, which means the caretaker still needs to dispense medicines according to the prescription prompted on a mobile device. Furthermore, UAV-SMC can be only used in WIFI environment indoors. Finally, at the moment, the UAV-SMC is only at the stage of integration test, which requires further user acceptance testing before going further to be implemented in the elderly center. With the consideration of the scalability of the system, prescription synchronization needs to be realized between pharmacist and care center administration to move a single step forward to standardized medication management for elderly center.

Beyond that, both UAV and IoT technologies are still in the early stage to be commercialized in the daily lives of people, especially the elderly due to the perceived usability and ease of use consideration. From the technology angle alone, the improvement of HCI experience is important to the telemedicine system design and development. In this case, the future study should concentrate on the user-friendliness of the system design and development. The UAV-SMC can accurately mark down the medication practice time in our system which is recognized a great potential to have predictive model adoption to determine the wellbeing of elderly resident in the care center such reliable parameter of medication practice time. Therefore, our research will extend the current outcome to the study area of Machine Learning in the future to safeguard the wellbeing of institutional elderly in care center.

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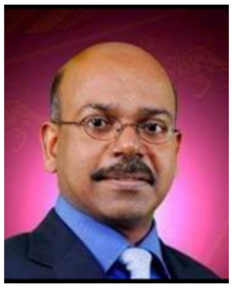

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