Journal of Engineering Science and Technology
Vol. 16, No. 2 (2021) 1145 - 1166

A DESIGN OF IOT-BASED MEDICINE CASE FOR THE MULTI-USER MEDICATION MANAGEMENT USING DRONE IN ELDERLY CENTRE

JIE LI, WEI W. GOH*, N. Z. JHANJHI

School of Computer Science & Engineering, Taylor's University, Lakeside Campus,
No. 1 Jalan Taylor's, 47500, Subang Jaya, Selangor DE, Malaysia
*Corresponding Author: WeiWei.Goh@taylors.edu.my

Abstract

The elderly community has their particular needs and challenges with different routines. In the care institution, the elderly demand reliable medication services because of geriatric issues. However, the fact is medicine mismanagement potentially troubles them in terms of accidental and overdosed medicine intake. Also, any act of forgetting or delay in medicine delivery by the caregivers or family members would impact the medication safety of the elderly. This paper aims to propose a Medication Management System (MMS) to regulate medication mismanagement and automate medicine restocking processes using the drone. In this case, the researchers proposed a design of medicine case powered by Internet of Things (IoT), which assists multi-user medication at the institutional level. For the medicine restocking purpose, the drone is used as in the pinpoint delivery approach to reload medicine once it runs out of usage from elderly residents. Hence, MMS reinforces medication management and automates the medicine delivery in the elderly centres. Consequently, the proposed system contributes to the adoption of the latest IoT technologies for the elderly community.

Keywords: Care centre, Drone, Elderly, Medicine box, Medication management, Multi-user system.

1. Introduction

The intensification of senior population has been a concern worldwide [1]. Compared to the younger generations, the elderly always experience critical challenges in their activity of daily living (ADL) [2-4]. Rather disconcertingly, most of them are suffering degeneration and geriatric issues, which lead them to be dependent on a long-term medication intake. Consequently, this is causing them to be more vulnerable against potential harms in their living environment [2]. Therefore, many elders prefer to reside in healthcare institutions rather than taking the risk of being less attended to and supported while being at home. However, the absence of standardization management for elderly care institutions in the industry requires some working up. Currently, elderly centres have their particular regulations on administration which not only generates management gaps in operation but also slows down the development pace of the entire industry.

Due to the many issues in geriatric care, routine medication plays an essential role in the ADLs of many elderly. In this case, medicine mismanagement becomes a lethal factor for the elderly in care centres. However, many centres are still equipped with manually performed medicine closets Fig. 1, which post hidden dangers of medicine retardation, mismatch or over dosage perhaps inadvertently or by careless caregivers. Nonetheless, medicine delivery is carried out by caregivers or family members once it runs out of stock, but any act of forgetting or delay on medicine delivery is recognized as unpleasant bordering on to the negligence in centre medicine management.

Fig. 1. Unorganized medicine management in the elderly centre.

Therefore, this research aims to overcome the issues mentioned and improve the reliability of medicine management, which is urgent for the sake of pharmaceutical and medication administration at the care centre level. The objective of the research is to design and develop a Medication Management System (MMS) to regulate medication management and automate medicine delivery using Unmanned Aerial Vehicle (UAV) [5] for the enhancement of system automation and self-sufficiency in the context of the elderly centre. This paper reviews several smart medicine box designs [6-8] based on Internet of Things (IoT) with state-of-art UAV delivery approaches [9, 10] and then proposes MMS as the final research outcome.

In the rest of this paper, Section 2 reviews the existing designs and products of medicine boxes, also the drone delivery approaches. Section 3 presents the design of MMS with the system framework and architecture proposed. Section 4 discusses the significance of MMS and the comparison with other relevant works. Finally, in the last section, the paper concludes its contribution, limitations, and future work recommendations.

2. Literature Review

IoT innovations bring abundant computation and communication into people's lives, which technically support ADL of people in their living environment. With this fact established, the design and development of IoT application become significantly important with regard to higher user acceptance level. For medical and medication purposes, people who inhabited in everyday pattern medication represent a remarkable proportion of the world population. Various relevant designs or products of medicine box in the IoT industry have demonstrated their operability in the digitalization of the medication practice for an individual patient. However, their innovation seldom considers multi-user usage [11], and the automation of medicine restocking approach between the medical authority with the care institution. Thus, UAV is advantageous in last-mile delivery [12], which could possibly be integrated as part of the automatic medication in telemedicine innovation in terms of medicine delivery.

2.1. Technology acceptance

IoT refers to an advanced Information and Communication Technology (ICT) that turns real-world objects into digital form [13-15]. The development of IoT prompted more researches and industry products with the aim to change people's lifestyles. Supported by all-IP based architecture, smart devices with sensors should be able to communicate with each other via exploitation of big data captured and its capabilities of human-computer interaction (HCI) [16]. Consequently, it assists people in their everyday living and working tasks in terms of ambient automation. A remarkable characteristic of ambient automation is its interconnected devices that act in unison [17]. Importantly, IoT should be user-oriented [18]. However, it challenges the development of IoT applications in terms of user resistance and the acceptability of technologies. The IoT-connected world may well be a reality in the future, but concerns over its social impacts [19] simply cannot be ignored.

Many senior people believe their self-efficacy is potentially threatened by new technologies [2]. The Pew Research [20] indicates that the younger generation has overall positive perspectives towards technology adoption than

the elderly. For an IoT application, notwithstanding the remarkable functionalities of ICT, has been demonstrated in its excellence, but the acceptance level is still questionable for many reasons. Generally speaking, user resistance can be studied in technological and intrapersonal aspects. Psychological consideration indicates the dispatching from the real-world of friends and relatives, also the fear of high dependence on technologies are pertinent in user resistance. Moreover, limited educational background and decrease in learning interest caused by ageing [21] significantly impact technology acceptance for elderly users.

Concerns by the end-user over limited accuracy [22] and reliability in the implementation [23] of the IoT cannot be ignored as the usefulness of the technology is of utmost importance during critical situations of the elderly later life. However, with the consideration in the intrusiveness of IoT, research [24] indicates, from the perspective of elder users coupled with their funding approach [24, 25], the affordability [26] of a system is a recurring concern by the end-users. Another research indicates the governmental policies are also acknowledged as an influential factor in creating a favourable atmosphere of new advanced technologies acceptance in the elderly community [27].

The IoT-based systems relentlessly encounter challenges from system interoperability, scalability, usability [28], and data management considerations [29-31]. Almeida et al. [19] explain the data management concerns are from data access, minimization, accountability, and security. Therefore, data management and integration become increasingly significant in the development of IoT applications [31]. In the development case of an e-Health system [32], a cloud-based telemedicine application records and stores large amounts of data in the system, which is recognized to be sensitive and strictly protected by the laws and regulations from any illegal acts of data mining. Scalability is one of the significant challenges in IoT technology development and design, which is strict in protocols communication compared to other computing techniques. Thus, openness of protocol and communication is vital to the system development and innovation with standardized protocols in the future [30].

2.2. Smart medicine box

Nowadays, many people need to take medicine multiple times per day periodically. However, the possibilities of missing medication practice in their ADLs may happen and for this reason, the IoT-driven medicine box (i.e., medicine reminder and pillbox) would be valuable in supporting distracted or negligent medication intake practices [6]. There are various (in Table 1) designs of medicine box [6, 33-36] which have been previously introduced, with the intent to assist in scheduling medication for independent elderly.

Many from the literature emphasized the medicine reminder or box for a single user either at home or at work. Typically, the data from the medicine box need to be organized and processed into the smartphones in the convenience of visual presentation and data manipulation. Such smart medicine devices are Arduino-controlled and has been introduced as a useful AAL solution to regulate medication practice of patients and also for health monitoring [35].

Table 1. The review matrix of smart medicine management approaches.

Direction	Author(s) & Year	Results	Remarks
Medicine Reminder	Kader et al. (2018) [8]	This research developed a smart medicine box to remind the old people or patient in the hospital to take the appropriate dose of medicine in the time suggested by doctor.	The development / implementation of the medicine reminding system in the context of elderly centre is different from home hospital context.
Medicine Reminder	Kumar et al. (2019)[6]	This paper discusses in detail a proposed IoT-Based Smart Medicine Reminder Device that will be designed for the elderly based on the issues faced by the elderly.	As mentioned in the future study, features such as pill weight measuring, wearable device connection can be integrated
Smart Medicine Box	Al-Shammary et al. (2018) [37]	Medication miss-dose and overdose can be a serious problem that occurs to elderly people in their living environment. With the implementation of the system, the user especially elderly patients would be benefited from using such an automated system in their daily medication practices.	The prototype designed is limited by multiple user management. So they should implement a programming algorithm to fulfill the function of managing multiple users.
Smart Medicine Box	Zeidan et al. (2018) [34]	The system can be operated via a smartphone application. And the system can weight each pill	The target audience is child patients and the system error-prone is below 3%
Smart Medicine Box	Ranjana and Alexander (2018) [35]	System functions as medicine reminder in daily medication practices System is a lifesaving design that can also monitor the patient's health like blood pressure and report an emergency.	There are various types of medicine box in the market, and this design is special for reminding elder patients from forgetting and miss/over dose of medicine

Technology is becoming indispensable in human daily activities and it supports the living environment. People with medication intake routines represent a remarkable proportion of the entire population worldwide. Thus, the automated medication process has its significance in telemedicine innovation. At present, there are many designs and development to overcome medication routines and issues such as missed-dose or even overdoses [37] to which the life-saving implication should not be overlooked.

Most smart medicine devices contain components that include the pillbox, buzzer alarm, LED/LCD module, real-time clock, input and output modules, and SD card shield [35]. This way, the system can monitor and alert the users if 'missed-medication' case happens especially to children and elderly patients [6, 8]. Figure presents such smart medical devices in IoT architecture are composed of software and hardware components, which have been announced as one of the useful AAL solutions to regulate the medication practice of patients and even health monitoring [37]

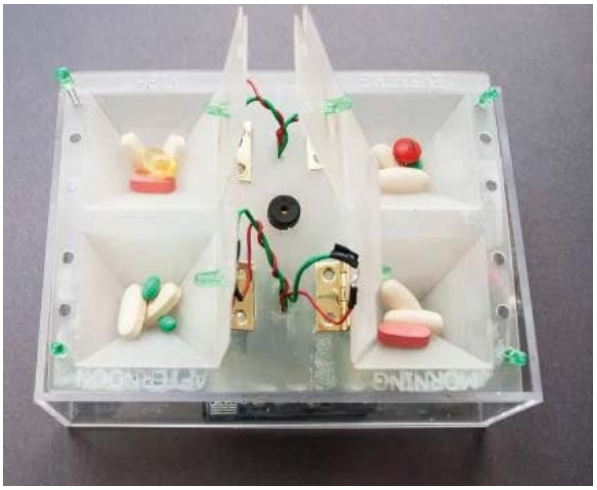

Fig. 2. The prototype of Smart Medicine Box [37].

2.3. Unmanned aerial vehicle (UAV)

UAV refers to the pilotless aerial craft powered by remote control technologies [5]. After decade years of use in the military, UAV can now be equipped for commercial and civil applications. Table 2 displays the various purposes in the utilization of UAVs which include delivery, monitoring, surveying, and mapping for different industries [38]. Drone delivery is a preferred method, especially in "last-mile" tasks, which can reduce energy consumption compared to traditional logistic approaches. After all, the implementation of drone technology enhances green and clean energy initiatives comparing to the conventional methods [39]. IoT-Collaborative drone is going to play a vital role in the smartness of a city as well as the QoL of citizens [40]. In s previous study, Scale et al. [10] used UAV in organ transportation and status monitoring. Therefore, the medical-purposes-based drone has proven its ability in first-aid mission and blood sample transportation [10]. In this case, the UAV-based delivery approach extends to other areas to reduce the manpower input.

Table 2. The review matrix of UAV.

Direction	Author(s) & Year	Results	Remarks
UAV for First Aid	Fakhrulddin, et al. (2019) [9]	An advanced First aid system powered by drone is introduced in the article to monitor the health status and apply first aid kit by drone to patients if mortality emergency happens.	However, the drone can also be used for guiding ways to dementia patients.
UAV in emergency response	Clark et al. (2018) [50]	18 interview samples were collected to determine the current rescue approach and potential of UAV use in disaster search & rescue	Research in in spatial variation of the emergency and capacity emergency rescue technology approach.
UAV for emergency medical response	Dayananda et al. (2017) [48]	UAV-powered medical emergency solution outside of hospital environment. The system also allows the control over a robotic arm to operate remotely supported by the sensing and recognition system with the security consideration.	The current research can extend for handling emergency cases in the elderly centre. A predictive model can be established for foreshadowing the wellbeing of elders in long term.
UAV Ambulance for outdoor sports	Kumar and Jeeva (2017) [49]	First aid to outdoor sport man Fire monitoring for outdoor sport activities	The system framework can also extend to the tracking of elders in outdoor environment
UAV in wildfire management	Ejaz et al. (2019) [45]	To inform the residents in disaster-affected area by using UAV, 5G, and data analytics technologies.	The system needs more experiments for its validation in different scenarios.
UAV with Wireless Navigation Network	Putra (2020) [53]	This study uses swarm algorithm for simple maneuver of drones with the adoption of navigation network as a locator and communication	The result of the study shows the drones are adaptively doing the Impact evasion motion according to the random obstacles.
UAV in organ and lab testing delivery	Scalea et al. (2018) [10]	The proposed transportation system is able to reduce the cold	The current regulation of the organ delivery requires organ needs

		ischemia time, vibration in organ delivery	to be accompanied by couriers
UAV in COVID-19	Maryanti et al. (2020) [47]	The study investigated the perceptions of students with special needs for the contagion of CoViD-19 virus particles through aerosol droplets.	This study gave information on how to treat students with special needs for protecting them during contagion problems, especially dealing with CoViD-19 conditions.
Drone-based delivery	Park et al. (2018) [39]	This research studied the environmental impacts on the new UAV delivery and also compared with the conventional ones.	New electric motorcycles can be used in comparison to UAV delivery as in the future study.
Routing Algorithm	Dorling et al. (2016) [12]	Total 6 algorithm used to determine the efficiency of the DDP model in cost reduction for multiple drone's execution including total cost (c), time cost (l), energy cost, initializing time (t), weight (y), times to destination (u), delivery time (h), and route timing vector (U).	This algorithmic model has its significance in outdoor environment rescue for lifesaving.
Routing Algorithm	Peng et al. (2019) [63]	Multiple drone parcel delivery performance enhancement in their novel Hybrid Genetic Algorithm to solve the problem of limited UAV coverage during their delivery tasks.	This algorithm is particular at the anchor nodes in the middle of the customer and facility location with the assistance of vehicles.
Drone in WSNs	Potter et al. (2019) [52]	Usage of drone based WSNs for environmental monitoring purpose using Arduino microcontroller.	Enhancement on image capturing Sensitive data gathering concerns
Map-Based Navigation	Bender et al. (2017) [60]	A map-based navigation approach introduced to minimize the distance using shortcut through unexplored areas.	Adjustment on the INS failure Real-world experiment

Architecture of Drone Control	Gharibi et al. (2016) [5]	The paper explains how the layered architecture for drone control designed and organized in order for drone to perform the different tasks planned.	Any drone architecture proposed should be able to integrated in as many types as possible drones so that they will share the urban airspace
Routing Algorithm	Bai et al. (2019) [62]	A novel routing algorithm to realize the precedence-constrained parcel by the vehicle-drone delivery	Heuristic task assignment algorithms designed can quickly achieve the goal for heterogeneous vehicle
Routing Algorithm	Boychev (2018) [61]	Two algorithms (Dijkstra's and shortest path calculation between two vertices in peaks) were tested for graphically routing the optimal path in a 3-dimensional space	As the results show, Dijkstra's has its advantages in collaborating with drones so that it can be used in direct navigation.
UAV Performance Test	Huang et al. (2018) [14]	Dual-antenna GPS/INS based flight performance test approach of UAV in positioning with high precision	Hovering accuracy and altitude can be tested in this approach
GSM/GPS for health management	Aziz et al. (2016) [54]	Remote real-time healthcare monitoring system model was introduced using sensors and data captured was used to compare with threshold predefined.	GSM/GPS module can be used in UAV and other smart devices to deliver in-time rescue to the patient in dangers.
GSM/GPS for fire detection	Desima et al. (2017) [55]	Using GSM SIM800L and Arduino uno microcontroller connecting with MQ-135 fire sensor to determine the location and level of fire hazard.	The proposed system has its potential in integration with the auto accident detection system.

2.3.1. Purpose of the UAV

Foremost, the Internet of Drones [5] depicts the fundamentals of layered architecture control for UAV to perform in the outdoor and indoor communication environments [41, 42]. By using different communication methods and even under the deep learning process [41], UAV has demonstrated its capability of civil uses for daily living purposes such as delivery [43], and video-making and surveillance in the fields

of law enforcement [44], disaster rescue [45], journalism and filming [46], and healthcare [47]. In healthcare services, UAV has been widely used for emergency care [48-50], laboratory testing and organ delivery [10], and disease/injury surveillance [48, 51]. Furthermore, the UAV solution for handling emergency accentuates its excellence in real-time monitoring and transportation of medication supplies from many research studies [44, 48, 49, 52-54].

2.3.2. GPS/INS navigation

GPS/INS-based UAV navigation is a well-planted technology that has been adopted to make the flying of drone automated. The Global Positioning System (GPS) module embedded with a microcontroller can collect the location information from the user [54, 55]. In terms of automated flight, the flight mode of a UAV can be switched in different levels of autonomy either by a human operator or via on-board CPU in the drone device [50, 52, 56].

However, the Autopilot program with the proportional integral derivative algorithm in the Inertial Navigation System (INS) will be used with GPS information to define the mission of UAV by marking the waypoint in the close and open routine of the flying path under multiple modes of rotation and expansion. In this case, by using the GPS and GSM module [56, 57], wearable devices can be used to send physiological information and GPS coordinates via the GSM network to have a connection with drone. Thus, the UAV can navigate to the destination set following the GPS coordinate received. Fakhrulddin et al. [9] developed a GPS/GSM module based first-aid kit delivery system (Fig. 3), to handle the emergency cases like in fall events and heart attack and had successfully demonstrated a 99% accuracy level of significance for the prototype.

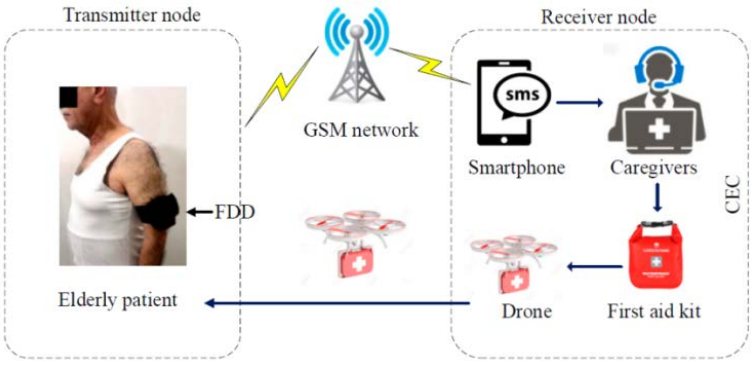

Fig. 3. First-Aid kit delivery using UAV [9].

With the increasing number of drone applications in the market, users always have higher expectations on the performance of the task drones in different industries. With the utilization of the Inertial Navigation System (INS), the drone can amend its navigation from an embedded algorithm during its navigation task. In 2019, a novel UAV-based environment monitoring model introduced blueprints for the use of wireless sensors combined with a drone. GPS/GSM module would be used with the wireless devices connected to the network infrastructure such as WSNs [58] in the indoor and outdoor environments [59] to transmit the GPS information required.

2.3.3. Drone routing

UAV may be advantageous in cost reduction and time saving for delivery and monitoring service [5, 9, 12, 39, 60]. In the drone-based delivery cases [12, 61, 62], a successful routing plan supported by a mathematics-based computing algorithm (e.g., Dijkstra's) can effectively reinforce the logic and performance of applications [61]. Dorling et al. [12] exhibit a comprehensive routing algorithm in the input variables (e.g., total cost, time cost, object weight, energy cost, initializing time, and routing timing vector) based on the consideration of the output of delivery efficiency.

In another study of a vehicle-assisted multi-drone parcel delivery to multiple customers [63], authors come up with their novel algorithm which involves the pipelines of tournament selection algorithm of frequent-use node, local search algorithm, and anchor node based child-route education to reduce the overhead of vehicle-drone delivery, to extend the service coverage in such a complicated scenario. The crossover algorithm has proved its significance of efficiency over antecedences of similar cases.

A perfect solution may not always be available to overcome various problems either from the past, present, or future. Drone homing is a concept of shortcut navigation for drone flight back to its origin automatically. With the support of the visual measuring approach using an actual camera, the altitude estimation is correspondingly computed. Simultaneous localization and mapping approach (SLAM) can solve the issues of location estimation with the variables location and a map of the environment in a shortcut route plan [60]. As the path information shows in Fig. 4, once the drone reaches the destination, it maps out way back as direct as possible to avoid roadblocks and buildings based on camera images captured. Therefore, the total flying distance can be reduced while the coverage of round-way drone service can be extended in the same battery capacity.

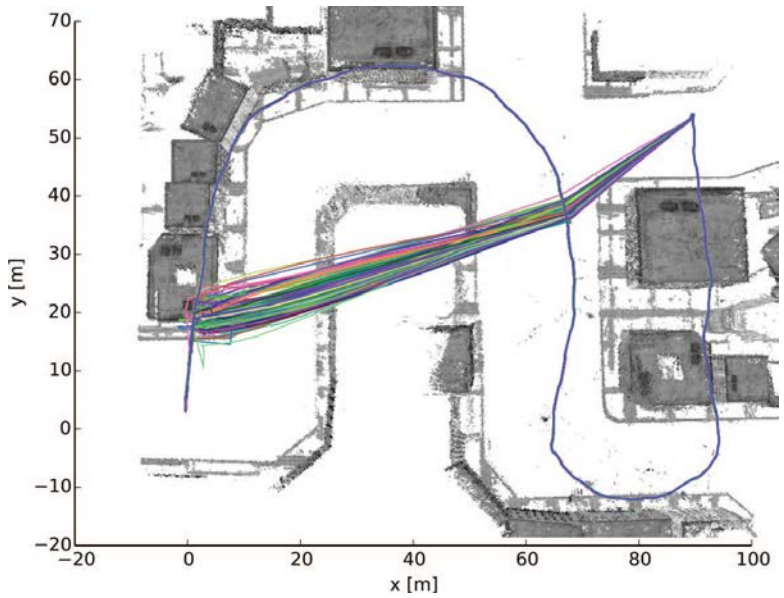

Fig. 4. Simulation of route planning for drone homing [60].

3. The Proposed Research Framework for Elderly

Most of the designs of smart medicine reminding system are aimed to schedule the single user-based medicine intake arrangement. Compared to these other system, our system is designed to assist caregivers in maintaining multi-elderly medication management and reducing the possibility of medication-intake accidents. Moreover, as drone is part of our system, it is implemented to retrieve medicines from the hospital or pharmacy on a predefined pinpoint navigation route.

Figure 5 demonstrates the framework of MMS. A prototype of the medicine case will be developed to serve and schedule medication management for multiple-elderly usage in the institutional context. In the proposed design, it contains multiple pillboxes that are assigned to elderly individuals in care centred. For each box, it has multiple portable compartments for each type of medication prescribed for a particular person.

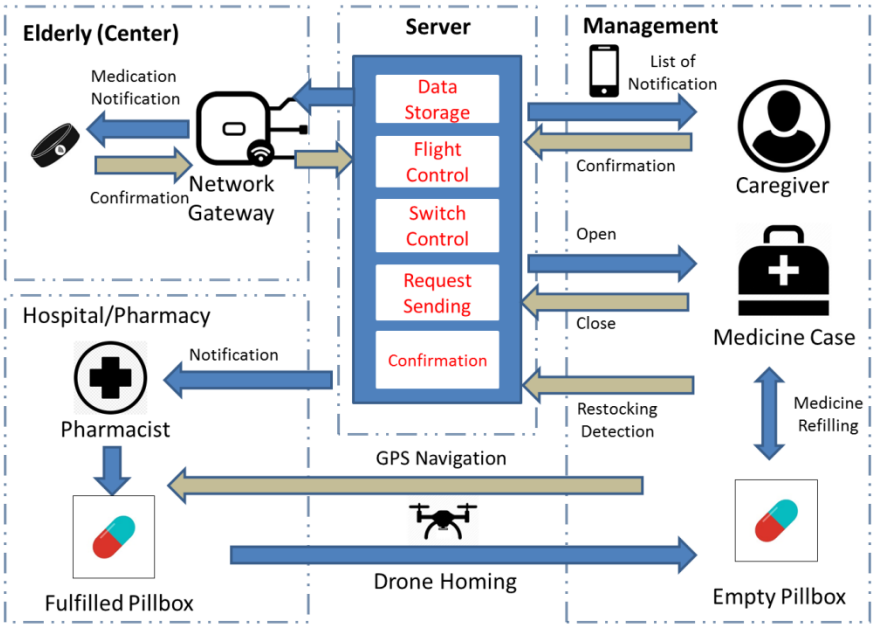

Fig. 5. The system framework of the MMS.

The central server connects with the medicine case (Raspberry Pi), wearable devices of the elderly, mobile application, the pharmacy end server, and the drone operating system. When the medication time arrives, the medicine case will acknowledge the medication information (prescription) and respond the "open" instruction to the corresponding box. Meanwhile, the elderly and caregiver will also be informed to complete the medication practice. Once every single practice is completed, the mobile application will mark down the medicine practice reference in the central server whilst the "close" instruction received by the medicine case. The pharmacy will be informed if any particular medicine runs out in the care centre and the GPS location will be synchronized to the drone operating system for the further execution of medicine delivery by the drone.

3.1. Entity-Oriented system design

With the consideration of elder-centred system design [11], the proposed medication management system is composed of entities, which could be further described as featured components contained in the Entity-Component-System for real-time interactions [64]. In this case, entity-oriented design philosophy was used to realize the system as the counterpart of the non-digital management approach in the digital world. To achieve successful centralized medication management, our system needs to be connected with the server and database for data transmission, manipulation, and storage. In this direction, the relationships among entities matter as data accessibility of the entire system design should be adherent with the reliability of the medical device contained. Therefore, we need to map out the entity-relationship model before anything else.

A single medicine case has several attributes including the boxes, working status, name of the centre, number of boxes on working, and GPS coordinates of the centre, which are used for drone-based medicine delivery. According to the Entity Relation Diagram in Fig. 6, each medicine box is assigned to an individual elder resident at the centre, and each compartment inbox collects a single type of medicine belonging to the particular elderly. In addition, each container is noted with information of the medicine details such as description, total quantity, pills per dosage, and quantity left, which are required to calculate the restocking time for a particular medicine. Medication record will be marked down accordingly with the date and time information once the elderly properly takes their medicine.

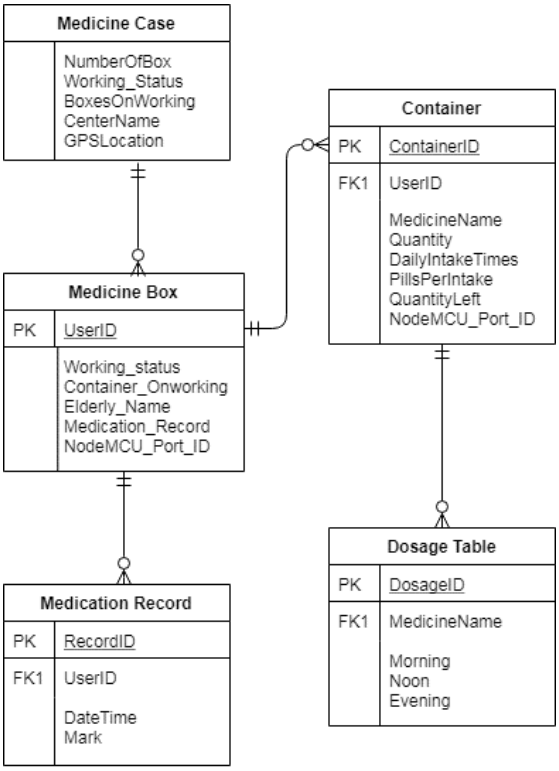

Fig. 6. Entity relationship diagram of medication management.

3.2. The design of medicine case

When it is time for their medication intake, the elder users and caregivers would be informed on their smart devices with the presentation of medication details which include the name of the medicine, time, resident ID via WIFI network. Meanwhile, the "Open" instruction would be sent directly to the caregivers via the server to the microcontroller on the device.

Figure 7 demonstrates the process after the medication intake is completed, the caregivers need to confirm the action, and the system marks down a completed process. For the periodical medication practice and delivery concerns, once a particular compartment runs out of its content, our system sends a refill request to caregivers; and if a type of medicine runs out, caregivers need to notify the pharmacists according to the medical prescriptions of an individual elderly so that the medicine delivery module can be started. The drone will then retrieve the refilled medicine box. Lastly, the caregivers need to insert the refilled medicines back into the medication box.

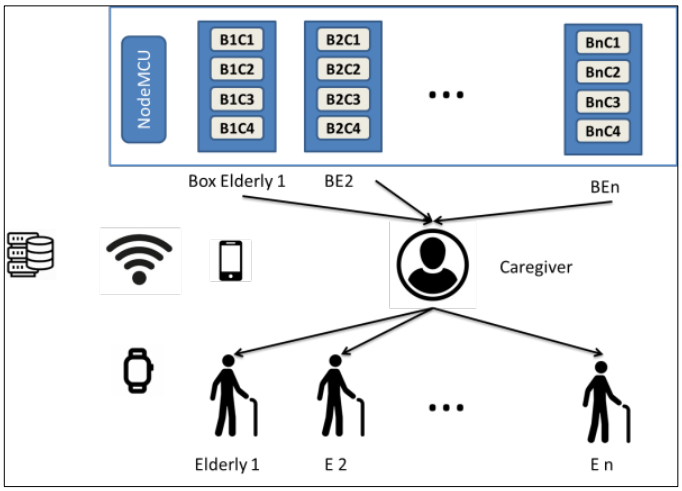

Fig. 7. The design of medicine case.

3.3. The design of a drone-based medicine delivery

In MMS, medicine delivery is based on the low inventory detection from the medicine box. In this case, once any particular medicine contained is used up, the central sever will be updated and synchronize the GPS of the corresponding pharmacy to the drone operating system for the further refilling function to be realized by the drone delivery. In Fig. 8, each of the compartments is sensitive to the restocking alert from the central server. Once the caregivers confirm the information, the drone carries a specially designed container from the centre to a pharmacy close by under the remote flight control, which pre-sets GPS coordinates with altitude to the destination. Once the drone reaches the destination, it will automatically land on the ground within the range of 10 meters. Afterward, when the medicine is refilled by the pharmacist, it automatically takes off from the venue homing back to the care centre. Lastly, the caregiver can put the fulfilled container in its designated box back into the medicine case.

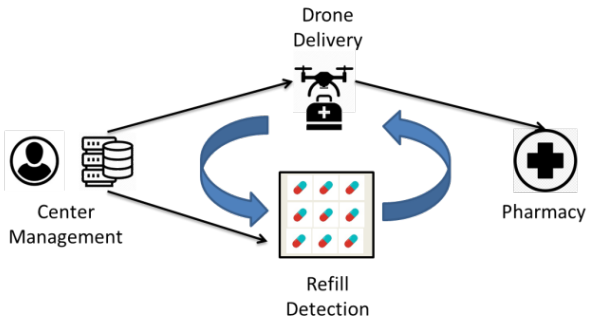

Fig. 8. The design of medicine delivery using a drone.

3.4. System architecture

From top to bottom, the system is composed of multiple layers in two modules which is explained as medicine case and medicine delivery in Fig. 9. System data is processed and stored respectively in the layers of server and database. Android Studio constructs various OS SDKs for mobile developers to customize activities based on their specific needs for both mobile and wearable application development. The application connects the system and users by using IT protocol and controls. NodeMCU ESP8266 is an open-source microcontroller widely used in IoT projects in the WIFI environment. It also enables GitHub integration to build the standard application features. Correspondingly, the Arduino IDE based C/C++ is preferable to be used as hardware programming in the system development. MQTT protocol supports lightweight messaging function so that it can be used to realize the data transmission between ESP8266 and server. By using ESP8266, hardware components (e.g., RTC, LED, etc.) can be connected, and its functions can also be realized based on predefined computing algorithms. The programmable drone allows developers to customize their system based on their needs. DJI Phantom 3 is a preferable delivery drone that is used to carry objects of 1.5kg or below within in 2KM circumference under the NAZA N3 flight control. It also supports altitude adjustment, automatic take-off/landing, and drone homing while in the flying process.

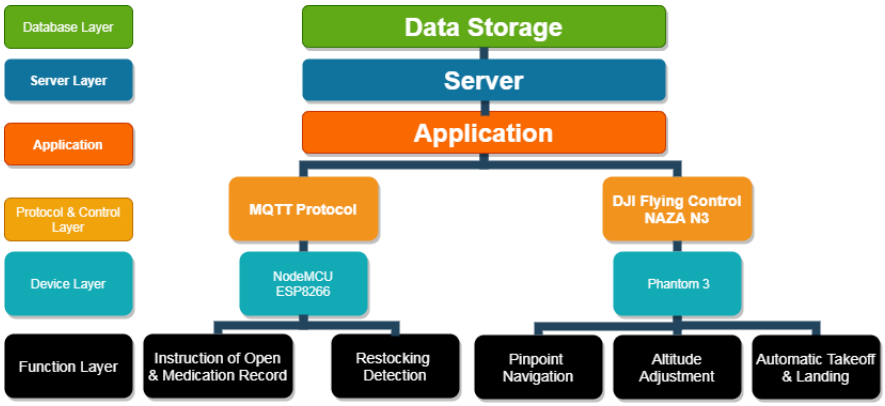

Fig. 9. System architecture.

4. Discussion

The proposed system regulates the intake of medicine for each elderly in the centre by using IoT. Likewise, it is equally important that the system effectively lessens the workload and improves the work environment of the caregivers by simplifying and automating the process of daily basis medicine practice for multiple elderly at care centres.

4.1. System flow diagram

The design of MMS strengthens the mediation management for the elderly residents at care centres. Literature review performed on articles from recent years revealed that there is growing interests for IoT solutions in the telemedicine sector especially in the designs of medicine boxes. Nonetheless, many of them emphasize the dispensation in medicine measurement, and medication monitoring process of individual patients rather than trying to handle the critical situation in a multi-user context, especially in the elderly centre.

A combination of Medical Treatment and Endowment has become a trending concept to elderly healthcare service which involves most current IoT technologies (e.g., telemedicine). Bearing this in mind, MMS focuses on the elderly-centered design principle [11] with the consideration of the primary users who are recognized as caregivers at the workplace to support the medication services to centre elderly. In comparison between MMS and cases of SMRD [6] and SMB [34] for the elderly as tabulated in Table 3, we initiated design works for independent elderly. The design focused on the functionality of medicine devices instead of nature centralized system which can display and update medication detail from references. In MMS, the system centralizes information from multi-users at care centers to assist medication management by means of multi-user medicine case for its systemic enhancement on the reliability of medication management in terms of reinforcing medication schedule for centre elderly at the same period of medication time. Essentially, the system ensures medical safety can be guaranteed for the sake of the elderly's wellbeing in care centers.

Table 3. The comparison between MMS and other similar designs.

Features	MMS	SMRD	SMB
Medical Alert	Available	Available	Available
Prescription Detail	Available	Unavailable	Unavailable
Medication Monitoring	Available	Available	Available
Multiple Users	Available	Unavailable	Unavailable
Medication References	Available	Unavailable	N/A
Medicine Delivery	Available	Unavailable	Unavailable

4.2. Medicine delivery automation

Based on care centre medication management, MMS equips UAV for medicine delivery automation purposes. With the boost of civil used UAV applications in the industry, people are benefitting from its advantage of clean energy usage, which improves the sustainability of human society in the long term. There is no doubt the drone can significantly diminish the cost of delivery in terms of energy conservation and the usage of clean energy. For medical purposes, the drone has been widely used in organ and first-aid kit delivery, which are recognized as the

inspiration of medicine restocking in MMS. The design of Advanced First-Aid System [9] delivers the first-aid kit via GPS navigation, but once the kit package reaches the location in one way.

In MMS, the drone is capable of homing with a fulfilled container with the default GPS location. With the drone homing algorithm planned, the travel distance per task will be decreased and so that its service coverage can also be increased in the same payload and battery capacity. Comparing with other medicine box designs [6, 55], MMS implements drone as its significant components in medicine restocking in which medicine can be retrieved from the pharmacy/hospital in the concept of last-mile parcel delivery [12]. Medicine containers are designed to be demountable for their convenience in drone-based delivery. As a result, in comparison to other similar projects (e.g., pillboxes or medicine reminders), we have made a contribution to telemedicine automaticity for the elderly community in the context of care centres.

4.3. Less workload on caregiver

The MMS presents a concise way of medication management and automation on the medicine delivery approach, which significantly reduces the workload of the caregiver in the elderly centre. From the angle of the employee at the institution, MMS reduces their workload and redefines their responsibility in medication services. The MMS provides higher user experience in HCI than traditional management methods based on paper forms. With its implementation, the elderly can view their medicine details on their smart devices in accordance with the prescription information retrieved from the database at every medication intake process. Finally, caregiver can operate and monitor the medication intake process on the mobile end, which will significantly reduce the error-prone and the possibility of medication accidents in healthcare service.

5. Conclusion

In conclusion, MMS can supportively administer medication management for multi-elderly residents at care centres. The Medication Management System regulates the daily medication practices of the elderly residents and its UAV-based restocking effectively lessens the workload of caregiver as well as energy used compared to the traditional approaches. Furthermore, the MMS is the evidence of telemedicine contributing to the elderly community in accordance with the United Nations Sustainable Development Goals No.3 (Good Health & Wellbeing), No.9 (Industry Innovation & Infrastructure), and No.11 (Sustainable cities and communities). However, the MMS also has its limitation where the system does not contain medicine auto-distribution function for the elderly patients, which means caregivers still need to dispense medicines according to prescription prompted from the mobile device.

6. Future Study

In the future, MMS will be developed according to the current design. Also, prescription synchronization needs to be realized throughout the web application between pharmacists and care centres administration to move a single step forward to standardized medication management for the care centres.

Abbreviations

ADL	Activity of Daily Living
GPS	Global Positioning System
GSM	Global Network for Mobile Communication
HCI	Human-Computer Interaction
ICT	Information and Communication Technology
INS	Inertial Navigation System
IoT	Internet of Things
MMS	Medication Management System
SLAM	Simultaneous Localization and Mapping Approach
SMB	Smart Medicine Box
SMRD	Smart Medicine Reminder Device
UAV	Unmanned Aerial Vehicle

Acknowledgment

Our thanks to the Taylor's Internal Research Grant Scheme - Major Funding Scheme (TIRGS-MFS) for the funding and support received for this project.

References

1. Department of Economic and Social Affairs, U.N. (2019). World population prospects 2019. Retrieved December 11, 2019, from http://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf.
2. Jing, W.; Willis, R.; and Feng, Z. (2016).Factors influencing quality of life of elderly people with dementia and care implications: A systematic review. *Archives of Gerontology and Geriatrics*, 66(1), 23-41.
3. Alshammari, S.A.; Alhassan, A.M.; Aldawsari, M.A.; Bazuhair, F.O.; Alotaibi, F.K.; Aldakhil, A.A.; and Abdulfattah, F.W. (2018). Falls among elderly and its relation with their health problems and surrounding environmental factors in Riyadh. *Journal of Family & Community Medicine*, 25(1), 1-4.
4. Volkert, J.; Andreas, S.; Härter, M.; Dehoust, M.C.; Sehner, S.; Suling, A.; Ausín, B.; Canuto, A.; Crawford, M.J.; Da Ronch, C.; and Grassi, L. (2018). Predisposing, enabling, and need factors of service utilization in the elderly with mental health problems. *International Psychogeriatrics*, 30(7), 1027-1037.
5. Gharibi, M.; Boutaba, R.; and Waslander, S.L. (2016). Internet of drones. *IEEE Access*, 4, 1148-1162.
6. Kumar, S.B.; Goh, W.W.; and Balakrishnan, S. (2019). Smart medicine reminder device for the elderly. *2018 Fourth International Conference on Advances in Computing, Communication & Automation (ICACCA)*. Subang Jaya, Malaysia, 1-6.
7. Hu, T.L.; and Qian, H.Z. (2017). Design and implementation of an intelligent medicine box capable of detecting user's medication taking state. *2nd International Conference on Materialss Science, Machinery and Energy Engineering*. Dalian, China, 123, 972-978.
8. Kader, M.A.; Uddin, M.N.; Arfi, A.M.; Islam, N.; and Anisuzzaman, M. (2019). Design & implementation of an automated reminder medicine box for old people

and hospital. *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET).* Chittagong, Bangladesh, 390-394.

9. Fakhrulddin, S.S.; Gharghan, S.K.; Al-Naji, A.; and Chahl, J. (2019). An advanced first aid system based on an unmanned aerial vehicles and a wireless body area sensor network for elderly persons in outdoor environments. *Sensors*, 19(13), 2955.
10. Scalea, J.R.; Restaino, S.; Scassero, M.; Blankenship, G.; Bartlett, S.T.; and Wereley, N. (2018). An initial investigation of unmanned aircraft systems (UAS) and real-time organ status measurement for transporting human organs. *IEEE Journal of Translational Engineering in Health and Medicine*, 6, 1-7.
11. Chang, D.; Gu, Z.; Li, F.; and Jiang, R. (2019). A user-centric smart product-service system development approach: A case study on medication management for the elderly. *Advanced Engineering Informatics*, 42(100979), 1-18.
12. Dorling, K.; Heinrichs, J.; Messier, G.G.; and Magierowski, S. (2017). Vehicle routing problems for drone delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 47(1), 70-85.
13. Ahmed, E.; Yaqoob, I.; Gani, A.; Imran, M.; and Guizani, M. (2016). Internet of things based smart environments : state of the art , taxonomy , and open research challenges. *IEEE Wireless Communication*, 23(5), 10-16.
14. Huang, J.; Meng, Y.; Gong, X.; Liu, Y.; and Duan, Q. (2014). A novel deployment scheme for green internet of things. *IEEE Internet Things Journal*, 1(2), 196-205.
15. Laplante, P.A.; and Laplante, N. (2016). The internet of things in healthcare: potential applications and challenges. *IT Professional*, 18(3), 2-4.
16. Jara, A.J.; Zamora, M.A.; and Skarmeta, A.F.G. (2011). An Internet of things-based personal device for diabetes therapy management in ambient assisted living (AAL). *Personal and Ubiquitous Computing*, 15(4), 431-440.
17. Cubo, J.; Nieto, A.; and Pimentel, E. (2014). A cloud-based internet of things platform for ambient assisted living. *Sensors (Switzerland)*, 14(8), 14070-14105.
18. Azimi, I.; Rahmani, A.M.; Liljeberg, P.; and Tenhunen, H. (2017). Internet of things for remote elderly monitoring: a study from user-centered perspective. *Journal of Ambient Intelligence and Humanized Computing*, 8(2), 273-289.
19. Almeida, V.A.F.; Doneda, D.; and Monteiro, M. (2015). Governance challenges for the internet of things. *IEEE Internet Computing*, 19(4), 56-59.
20. Smith, A. (2014). Older Adults and Technology Use. *Pew Research Centre*. Retrieved December 20, 2019, from http://www.pewinternet.org/2014/04/03/older-adults-and-technology-use/.com.
21. Pal, D.; Triyason, T.; Funilkul, S.; and Chutimaskul, W. (2018). Smart homes and quality of life for the elderly: perspective of competing models. *IEEE Access*, 6, 8109-8122.
22. Zdravevski, E.; Lameski, P.; Trajkovik, V.; Kulakov, A.; Chorbev, I.; Goleva, R.; Pombo, N.; and Garcia, N. (2017). Improving activity recognition accuracy in ambient-assisted living systems by automated feature engineering. *IEEE Access*, 5, 5262-5280.
23. Yang, H.; Lee, W.; and Lee, H. (2018). IoT smart home adoption: the importance of proper level automation. *Journal of Sensors*, 2018, 1-11.

24. Pal, D.; Funilkul, S.; Vanijja, V.; and Papasratorn, B. (2018). Analyzing the elderly users' adoption of smart-home services. *IEEE Access*, 6, 51238-51252.
25. Yusif, S.; Soar, J.; and Hafeez-Baig, A. (2016). Older people, assistive technologies, and the barriers to adoption: A systematic review. *International Journal of Medical Informatics*, 94(1), 112-116.
26. Ali, M.A.; Alam, K.; and Taylor, B. (2019). Measuring the concentration of information and communication technology infrastructure in Australia: Do affordability and remoteness matter?. *Socio-Economic Planning Sciences*, 2020, 100737.
27. Pasha, M.; and Shah, S.M.W. (2018). Framework for E-health systems in IoT-based environments. *Wireless Communications and Mobile Computing*, 2018, 1-11.
28. Hussain, A.; Razak, H.A.; and Mkpojiogu, E.O.C. (2017). The perceived usability of automated testing tools for mobile applications. *Journal of Engineering, Science and Technology (JESTEC)*, 12(4), 89-97.
29. Farahani, B.; Firouzi, F.; Chang, V.; Badaroglu, M.; Constant, N.; and Mankodiya, K. (2018). Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare. *Future Generation Computer Systems*, 78(2), 659-676.
30. Yacchirema, D.C.; Sarabia-Jacome, D.; Palau, C.E.; and Esteve, M. (2018). A smart system for sleep monitoring by integrating IoT with big data analytics. *IEEE Access*, 6, 35988-36001.
31. Zanella, A.; Bui, N.; Castellani, A.; Vangelista, L.; and Zorzi, M. (2016). Internet of things for smart cities. *IEEE Internet of Things Journal*, 1(1), 22-32.
32. Yu, L.; Chan, W.M.; Zhao, Y.; and Tsui, K.L. (2018). Personalized health monitoring system of elderly wellness at the community level in Hong Kong. *IEEE Access*, 6, 35558-35567.
33. Bhati, S.; Soni, H.; Zala, V.; Vyas, P.; and Sharma, Y. (2017). Smart medicine reminder box. *IJSTE-International Journal of Science Technology & Engineering*, 3(10), 172-177.
34. Zeidan, H.; Karam, K.; Dauo, R.A.Z.; Hayek, A.; and Boercsoek, J. (2018). Smart medicine box system. *2018 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET)*. Beirut, Lebanon, 1-5.
35. Ranjana, P.; and Alexander, E. (2018). Health alert and medicine remainder using internet of things. *2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*. Madurai, India,1-4.
36. Doshi, V.; Dey, S.; Mehta, N.; and Prasad, R. (2019). An IoT based smart medicine box. *International Journal of Advance Research, Ideas And Innovations In Technology*, 5(1), 205-207.
37. Al-Shammary, R.; Mousa, D.; and Esmaeili, S.E. (2018). The design of a smart medicine box. *26th Iran. Conf. Electr. Eng. ICEE 2018*. Mashhad, Iran, 130-134.
38. Khan, N.A.; Jhanjhi, N.Z.; Brohi, S.N.; Usmani, R.S.A.; and Nayyar, A. (2020). Smart traffic monitoring system using unmanned aerial vehicles (UAVs). *Computer Communications*, 157, 434-443.

39. Park, J.; Kim, S.; and Suh, K. (2018). A comparative analysis of the environmental benefits of drone-based delivery services in urban and rural areas. *Sustainability*, 10(3), 888.
40. Alsamhi, S.H.; Ma, O.; Ansari, M.S.; and Almalki, F.A. (2019). Survey on collaborative smart drones and internet of things for improving smartness of smart cities. *IEEE Access*, 7, 128125-128152.
41. Khan, N.A.; Jhanjhi, N.Z.; Brohi, S.N.; and Nayyar, A. (2020). Emerging use of UAV's: secure communication protocol issues and challenges. *Drones in Smart-Cities*, 2020, 37-55.
42. Maciel-Pearson, B.G.; Akcay, S.; Atapour-Abarghouei, A.; Holder, C.; and Breckon, T.P. (2019). Multi-task regression-based learning for autonomous unmanned aerial vehicle flight control within unstructured outdoor environments. *IEEE Robotics and Automation Letters*, 4(4), 4116-4123.
43. Khan, N.A.; Brohi, S.N.; and Jhanjhi, N.Z. (2020). UAV's applications, architecture, security issues and attack scenarios: a survey. *Intelligent Computing and Innovation on Data Science, Springer*. Singapore, 118, 753-760.
44. Davis, O. (2019). Theorizing the advent of weaponized drones as techniques of domestic paramilitary policing. *Security Dialogue*, 50(4), 344-360.
45. Ejaz, W.; Azam, M.A.; Saadat, S.; Iqbal, F.; and Hannan, A. (2019). Unmanned aerial vehicles enabled IoT platform for disaster management. *Energies*. 12(14), 2706.
46. Pugliese, L.D.P.; Guerriero, F.; Natalizio, E.; and Zema, N.R. (2017). A biobjective formulation for filming sport events problem using drones. *2017 IEEE 9th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS 2017*. Bucharest, Romania, 2, 639-644.
47. Maryanti, R.; Hufad, A.; Sunardi.; Nandiyanto, A.B.D.; and Al-Obaidi, A.S.M. (2020). Understanding covid-19 particle contagion through aerosol droplets for students with special needs. *Journal of Engineering Science and Technology* (*JESTEC*), 15(3), 1909-1920.
48. Dayananda, K.R.; Gomes, R.; and Straub, J. (2017). An interconnected architecture for an emergency medical response unmanned aerial system. *AIAA/IEEE 36th Digital Avionics Systems Conference*, San Antonio, USA, 1-6.
49. Kumar, G.D.; and Jeeva, B. (2017). Drone ambulance for outdoor sports. *Asian Journal of Applied Science and Technology (AJAST)*, 1(5), 44-49.
50. Clark, D.G.; Ford, J.D.; and Tabish, T. (2018). What role can unmanned aerial vehicles play in emergency response in the Arctic: A case study from Canada. *PLoS One*, 13(12), 1-17.
51. Bravo, G.C.; Parra, D.M.; Mendes, L.; and De Jesus Pereira, A.M. (2016). First aid drone for outdoor sports activities. *2016 1st International Conference on Technology and Innovation in Sports, Health and Wellbeing (TISHW)*. Vila Real, Portugal, 1-5.
52. Potter, B.; Valentino, G.; Yates, L.; Benzing, T.; and Salman, A. (2019). Environmental monitoring using a drone-enabled wireless sensor network. *2019 Systems and Information Engineering Design Symposium (SIEDS)*. Charlottesville, USA, 1-6.

53. Putra, Y.H. (2020). Research on swarm drone using wireless navigation network in performing bird model swarm drone. *Journal of Engineering Science and Technology 2nd International Conference on Informatics, Engineering, Science, and Technology 2019*. Bandung, Indonesia, 45-53
54. Aziz, K.; Tarapiah, S.; Ismail, S.H.; and Atalla, S. (2016). Smart real-time healthcare monitoring and tracking system using GSM/GPS technologies. *2016 3rd MEC International Conference on Big Data and Smart City (ICBDSC)*. Muscat, Oman, 1-7.
55. Desima, M.A.; Ramli, P.; Ramdani, D.F.; and Rahman, S. (2017). Alarm system to detect the location of IOT-based public vehicle accidents. *2017 International Conference on Computing, Engineering, and Design (ICCED)*. Kuala Lumpur, Malaysia, 1-5.
56. Fakhrulddin, A.; Al-Humairi, A.; Al-Mhanna, N.; and El Asri, H. (2019). Mobile robot detecting elderly falls: representing aesthetic technologies, theory, software, and hardware. *2018 International Conference on Computing, Electronics & Communications Engineering (iCCECE)*. London, UK, 257-261.
57. Zheng, Y.L.; Ding, X.R.; Poon, C.C.Y.; Lo, B.P.L.; Zhang, H.; Zhou, X.L.; Yang, G.Z.; Zhao, N.; and Zhang, Y.T. (2014). Unobtrusive sensing and wearable devices for health informatics. *IEEE Transactions on Biomedical Engineering*, 61(5), 1538-1554.
58. Hussain, R.H.; Jabr, Z.F.; and Saleh, S.R. (2019). Improved localisation algorithm for wireless sensor networks by using XBee. *Journal of Engineering, Science and Technology (JESTEC)*, 14(6), 3470-3480.
59. Borle, V.S.; and Kulkarni, P.S.N. (2016). An enhanced fall detection system with GSM and GPS technology. *International Journal on Recent and Innovation Trends in Computing and Communication*, 4(7), 345-348.
60. Bender, D.; Koch, W.; and Cremers, D. (2017). Map-based drone homing using shortcuts. *2017 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems*. Daegu, Korea, 505-511.
61. Boychev, I.Z. (2018). Research algorithms to optimize the drone route used for security. *2018 IEEE XXVII International Scientific Conference Electronics-ET*. Sozopol, Bulgaria, 1-4.
62. Bai, X.; Cao, M.; Yan, W.; and Ge, S.S. (2019). Efficient routing for precedence-constrained package delivery for heterogeneous vehicles. *IEEE Transactions on Automation Science & Engineering*, 17(1), 248-260.
63. Peng, K.; Du, J.; Lu, F.; Sun, Q.; Dong, Y.; Zhou, P.; and Hu, M. (2019). A hybrid genetic algorithm on routing and scheduling for vehicle-assisted multi-drone parcel delivery. *IEEE Access*, 7, 49191-49200.
64. Lange, P.; Weller, R.; and Zachmann, G. (2016). Wait-free hash maps in the entity-component-system pattern for realtime interactive systems. *2016 IEEE 9th Workshop on Software Engineering and Architectures for Realtime Interactive Systems (SEARIS)*. Greenville, USA, 1-8.