Develop the Framework Conception for Hybrid Indoor Navigation for Monitoring inside Building using Quadcopter

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***Abstract*— Building security is crucial, but guards and CCTV may be inadequate for monitoring all areas. A quadcopter (drone) with manual and autonomous control was used in a trial mission in this project. Generally, all drones can stream live video and take photos. They can also be adapted to assist better decision-making in emergencies that occur inside a building. In this paper, we show how to improve a quadcopter's ability to fly indoors, detect obstacles and react appropriately. This paper represents a new conceptual framework of hybrid indoor navigation ontology that analyzes a regular indoor route, including detection and avoidance of obstacles for the auto-pilot. An experiment with the system demonstrates improvements that occur in building surveillance and maintaining real-time situational awareness. The immediate objective is to show that the drone can serve as a reliable tool in security operations in a building environment.**

Keywords—semi-autonomous quadcopter; indoor navigation; object detection; image processing; ontology

I. Introduction

Buildings, such as schools, universities building, office buildings, or shopping malls, etc. are guarded by staffs who monitor both inside and outside the buildings. They are concerned about preventing all dangerous situations. Some buildings need to be high security and may require much investment in guards and technologies. Such buildings will have Closed-Circuit Television (CCTV) and an operations room for monitoring and controlling the situation. However, the CCTV may not cover all area of the buildings, or there may be blind spots in the CCTV coverage. Technology to check the blind spots is needed to increase building security.

A quadcopter or drone [1] is a popular technology for taking photos and video, usually used for outdoor missions. The quadcopters can fly under user control or be autonomous. Although normally used outdoors they can be adapted for indoor missions. However, an indoor environment presents difficulties, especially where the building has many floors, and each floor has many objects, both static and moving. The quadcopter should be able to fly to a given destination anywhere in a building while avoiding obstacles (people, furniture) in its path. A hybrid or semi-autonomous approach for controlling the quadcopter may be appropriate.

In this paper, we discuss the indoor use of a quadcopter for patrolling a building. A quadcopter's route inside a building may be different from a person's; it can fly above head-height and can fly to different floors of the building. However, to increase the speed of quadcopter to arrive in the situation area, it needs an indoor navigation route which we have developed using an ontology method which can provide a more accurate, robust flight path. Furthermore, it needs to detect the properties of operating stability. Our approach is beneficial for the building guards as well. If they see a suspicious situation on CCTV in the building but have not enough information, they can send the quadcopter to that location to view the situation in order to decide on a future course of action. They do not need to learn how to use and control the quadcopter; they can use our application.

We propose a hybrid approach leading to an improved real-time situational awareness, as shown in Figure 1. Firstly, we have developed an analysis of the best route for the quadcopter in the building with indoor navigation ontology providing the optimum flight path. As GPS does not work inside the building, a Bluetooth Low Energy device (BLE) [2] is adapted for calculating the current position of the quadcopter. Secondly, while the quadcopter is flying, it detects some objects which may affect its flight mission. Our approach includes obstacle detection by using image processing for identifying the objects and avoiding them. While the quadcopter is in flight, it can communicate and receive real-time flight information from the control room via Wi-Fi in the building. We believe that our approach may improve security analytics and threat intelligence, enhancing the security of the building.

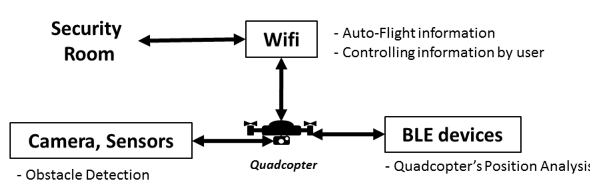


Fig. 1. Overview of the hybrid framework of the quadcopter

The section of this article is as follows. In Section II, we review the literature on quadcopters, ontology and obstacle detection. In Section III, we show hybrid indoor navigation for an indoor quadcopter. In Sections IV, we detail our conceptual approach. Section V presents our experiment. Part VI discusses our results and proposes future research directions.

II. Relate Work

In this section, we discuss some relevant related work on indoor navigation involving indoor quadcopter, indoor ontology, and obstacle detection.

A quadcopter or quadrotor [1] is a helicopter with four rotors. They are used for surveillance [3], construction inspections, or mission in the farms [4-6] etc. A quadcopter was developed to inspect the vertical infrastructure of building [7] but is limited to inspection of the exterior of the building. An AR-Drone was adapted for robotic research [8], discussing technologies on position stabilization, autonomous navigation, etc. However, it was not developed for an indoor situation. I. Sa and P. Corke detail quadcopter for use indoors and outdoors [9], but the user needs to learn and attain the skills to use it and also needs to know the structure of the building in which the quadcopter will be flown. SmartCopter is a technique for controlling a quadcopter without GPS; it can automatically fly both outdoors and indoors by using vision-based tracking [10], but vision-based tracking may not be sufficient for autonomous flight. A Camera Measurement Algorithm was used for estimating distances in a building [11]. However, this approach may be too slow for processing for indoor navigation where the requirements of the mission need a fast response.

Ontology is developed within many research fields [12]. J. Scholz and S. Schabus propose an Indoor Navigation Ontology which is used for movement of production in an indoor environment [13]. They designed the elements of the ontology for representing the indoor space. However, their article focused only on the indoor production for autonomous navigation in the indoor space. Web ontology can be combined in an indoor navigation system called OntoNav [14, 15], in which both the navigation paths and the guidelines are presented to users to develop an Indoor Navigation Ontology (INO) [16]. Nevertheless, in this article can find the route for the specific user profile for the recommendation the best route to them, which need to collect the user profile, if it applies to our research, may need to maintain the quadcopter attributes for being suitable.

Obstacle Detection is applied to many techniques for navigation such as using image processing for the autonomous micro aerial vehicles [17]. This article detail that it did not focus on indoor navigation. Obstacle Detection and the 3D indoor model are developed for indoor navigation by using the laser scanner [18], this method may difficult to collect the building planning information for creating a route from the building structure. Similarity, the 3D model is designed for navigation for autonomous vehicle [19], but his approach focuses on the outside navigation. Computer vision was used for indoor autonomous drone racing, but this article needs more information with using Deep Learning technique [20]. Imaging geometric relationship [21] is used for obstacle detection to navigate inside the building by using four cameras based on the bird's eye view images; we will apply this approach to our research.

After a literature review, we found that the semi-autonomous quadcopter will be used for our research, because it can be automatic fly by it after the user selects the destination inside the building and can control by the building guards, especially, controlling the camera on the quadcopter when arriving the target location. Our conceptual framework consist of two contributions are analysis the indoor route and the obstacle detection.

III. Hybrid Indoor Navigation for Indoor Quadcopter

This study, we describe the hybrid indoor navigation model monitoring indoor security by using a semi-autonomous quadcopter. While the quadcopter is flying on the mission, it will communicate with the security room via the internet by Wi-Fi network in the building. It can send to images, VDO and position information back to guards. The quadcopter's position can lead to present to the current position on the building map. The quadcopter begins and finishes the mission at the security room.

In section includes Indoor Quadcopter Position, Indoor Navigation Ontology, and Obstacles Detection.

A. *Indoor Quadcopter's Position*

Global Positioning System (GPS) for calculating the position is not working inside the building. We use Bluetooth Low Energy devices (BLE) for analysis the quadcopter's position [22]; these devices are called "iBeacon." These BLEs will be installed in the building, and one each will be set on the quadcopter, they are used for distance measurement and help to us for calculating the quadcopter's position in the tower as shown Figure 2.

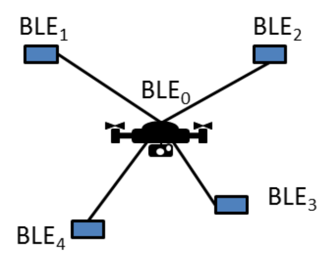
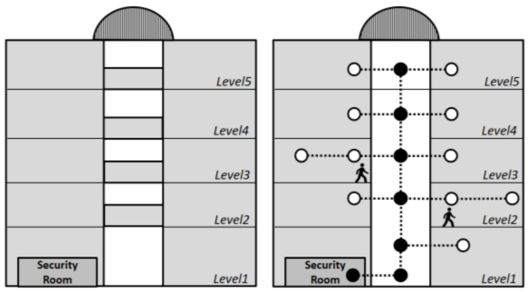


Fig. 2. BLE for analysis the quadcopter's position

B. *Indoor Navigation Ontology*

The building has some different floors plan and some levels. Normally, almost towers have the corridor for people walking inside the building, and some buildings have the lift and escalator. In this research, we focus on the flying route of the quadcopter. Therefore, the route will use any airspace for flying direction in the building. We develop the coordinate on the airspace for linking to another, vertical view, as shown in Figure 3 and map view on the floor as illustrated in figure 4.

The quadcopter's direction is not similarity with human way. Therefore quadcopter path will be designed in the position where it can fly and can link o different floor. The indoor navigation ontology is applied to creating the path of flying. The ontological foundations are used to a model of navigation on indoor space. This technique can increase the speed of quadcopter for flying the destination. Guard will set the target before quadcopter going. The quadcopter will fly follow on the coordinate and follow up until reaching the target location, which all coordinate will be set value as flight information for travelling to the next coordinate.



(a) (b)

Fig. 3. Example of (a) the instruction of indoor building where has any airspace (b) indoor route of semi-autonomous quadcopter inside the building

This approach is flexible for maintenance because all routes are set on the ontology as a dynamic database. If the building was renovated, the user could change data on the ontology for updating the fly direction. The example of primary attributes on the ontology is designed as shown in Table I.

TABLE I. TERMINOLOGIES FOR SOME ATTRIBUTES IN INDOOR ONTOLOGY FOR INDOOR QUADCOPTER

Name	Description
ID_dro	ID is a unique label for a coordinate for quadcopter (droBLD1.lev1.cr01)
x, y, z	(x, y, z) in Euclidean air space inside buildig (x=1500,y=560,z=195)
Defualt_direction	The default position of quadcopter when arriving this coordinate, the quadcopter will be set the direction about inspecting point as same as compass degree (352)
Building	Building Name (Bld1)
Level	Level of building (level3, level5)
Status	Status of a coordinate on the map (On, Off)

C. Obstacle Detection

Commonly, most quadcopters have the sensor for protecting when flying nearly some objects, but not enough for it. In the building, some properties are caused by flight problems, especially humans or cabinets. These obstacles are over control because they can move to anywhere in the building. Although the flying route is set for auto-pilot, these objects may affect the quadcopter and lead to decreasing speed and have accident flight. Therefore auto obstacle detection on the real-time is critical for the semi-autonomous quadcopter.

All level of the building, the flight route will be designed on the map of the construction plan, as shown in Figure 4. The quadcopter can fly on the flight line with the typical situation. However, it needs to get the object detection for instantly stabilized flight. The obstacle detection recognizes the objects for getting the size and dimension of them by using image processing. This research focuses on the detection of object colour.

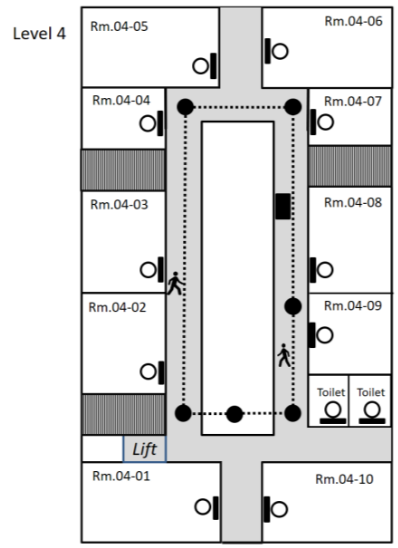


Fig. 4. For an example of direction and coordinate in the building

IV. THE CONCEPTION OF AN ALGORITHM FOR INDOOR QUADCOPTER

Our approach is using the quadcopter to fly inside the building for the indoor mission. We describe the step of an algorithm for monitoring indoor security. The building has different information for a guide to indoor travel; design should follow the real indoor space which focuses on the quadcopter flight. Figure 5 is an example of a building.

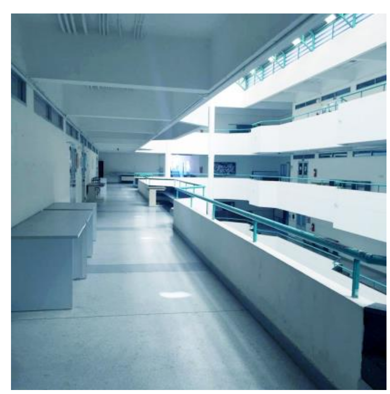


Fig. 5. Example, inside the building

The flight mission will analyze the route by the algorithm and then send information to the quadcopter. The flight information will set as the array; it consists of the coordinate information. Each coordinate has an attribute for supporting the fight until to the destination; this approach can help the speed of the flight, as shown in Figure 6. It is a drone route in the building, and it starts from the security room on level one to room number *Rm.04-07*. It will follow node of route. However, the calculation of quadcopter's position is crucial for stable flying. Our algorithm uses four BLE devices for calculating the current quadcopter's position [22, 23]. This approach looks like finding the position of the satellite, which can lead to development to show the current position of the quadcopter on the application.

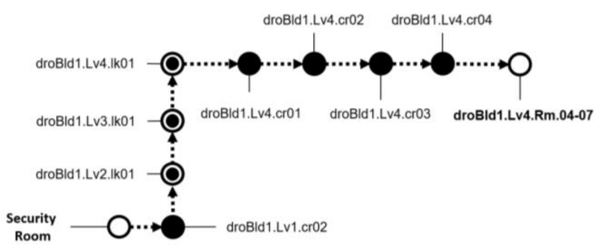


Fig. 6. The direction of quadcopter's flight

While the quadcopter arrives at each coordinate, it will get the value of attributes; this information can provide analysis for flight controlling data, for still flying to next coordinate in the direction mission. This information can help to control the flying for the *front, back, left, right, up, down, clockwise and counter-clockwise*. This controlling data communicates between the guard room and quadcopter via the internet with Wi-Fi technology.

Finally, our approach includes obstacle detection, while the quadcopter is flying on the route; we improve flight stability by using image processing for object detection. It analyses the dimension of objects for avoiding them. After that, it will fly back in the same mission route until the destination area. Also, finished task, it will use the same path for the flight back to the security room. This research develops the simple web application for controlling and monitoring with our algorithm.

V. Experiment and Discussion

We design the experiment for validation, analysis the route and obstacle detection with the simple web application. This research, we use the Quadcopter or AR-Drone 2.0 in our research, as shown in Figure 7. It flies high precision control and automatic stabilization features which be suitable for development to the indoor building. We separate to be two testings, consists of auto flight on the route and obstacle detection.

The "Estimote Location" devices [22] are Bluetooth Low Energy devices which can use to support to measure the distance inside the building. We use the stick on the wall in the building where they can send the signal to BLE on the quadcopter.

Fig. 7. Indoor quadcopter, model is AR-Drone 2.0 (*Image reference: https://www.parrot.com*)

The indoor route is designed with indoor navigation ontology. In the programming of the algorithm, the route will be set in the array. Our experiment, we set three coordinates for every route with five routes for testing. For example, the first path includes *droBld1.LV1.cr02*, *droBld1.Lv2.lk01*, *droBld1.Lv3.lk01*, *droBld1.Lv4.lk01*, *droBld1.Lv4.cr01*, *droBld1.Lv4.cr02*, *droBld1.Lv4.cr03*, *droBld1.Lv4.cr04* and *droBld1.Lv4.Rm.04-07*. The algorithm will use coordinate information for flight navigation which the values will be sent to quadcopter for flight control. Python was developed to be the simple application for controlling the quadcopter with auto-flight. Our validation uses the quadcopter to fly to a destination for one way direction. After that, we determine from the distance of closely flying the coordinates, where is set up on the route. The result is shown in Table II. The quadcopter can fly to pass all three coordinates on five routes.

TABLE II. The Result of the Flight on the Route

Routes No.	The distance of Quadcopter with Coordinate(meters)		
	Coordinate No.1	*Coordinate No.2*	*Coordinate No.3*
1	1.5 meters	1.3 meters	1.5 meters
2	0.8 meters	1.5 meters	1.2 meters
3	1.5 meters	1 meters	1.5 meters
4	2 meters	1.5 meters	2 meters
5	1.5 meters	2 meters	1.5 meters

Indoor flight has narrow space for flying, with the result in Table II; the precision of position on the route is not 100%. The result show flight of quadcopter missing from coordinate around 0.8-2 meters. Therefore, the autonomous flight of quadcopter needs to use some approach to be stable fly.

On the other hand, although AR-Drone 2.0 will include sensors for objects detection, it may not be enough for a quick flight in the environment. This research, we present that increase a part of obstacle detection, the object is detected by the camera on the quadcopter with the colour analysis by using the image processing technique as shown in Figure 8. We set the distance between camera and object for photos collection around 0.5, 1, 1.5, 2, 2.5 meters respectively. After that, they have recognized the colour in green, red and blue five times. The result shows in Table 2.

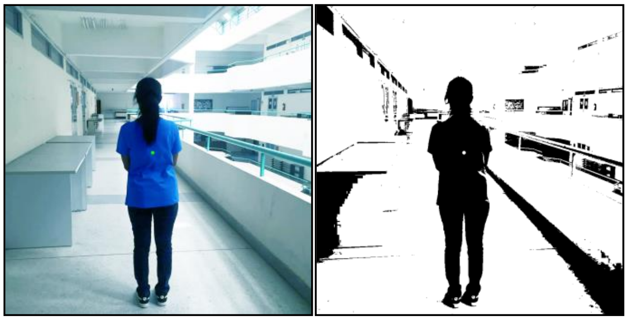


Fig. 8. Detecting the colour with an image processing technique

TABLE III. THE RESULT OF COLOUR DETECTION

Colour	Percentage of Color Detection in Different Distances				
	0.5 meters	**1 meters**	**1.5 meters**	**2 meters**	**2.5 meters**
Green	100%	100%	96.66%	96.66%	86.66%
Red	80%	40%	10%	0%	0%
Blue	96.66%	93.33%	50%	33.33%	13.33%

Table III presents all colour can analysis the colour is extremely precision in the distance 0.5-1 meters. Green got to high accuracy detection, more than 80%. Red cannot detect the colour in the distance more than two meters.

Also, these experiment results, we think that they can be adapted to use in the Hybrid Indoor Navigation for inspection inside the building by using the quadcopter.

VI. CONCLUSION AND FUTURE WORK

In this research, we developed the framework conception for hybrid indoor navigation of the quadcopter for supporting the building security. Our method focuses on selecting the best route and obstacle detection. Firstly, Multi-level Indoor Navigation Ontology is applied to our framework, which can design to support the quadcopter indoor route. All coordinates on the map used to be the information for navigation. After the design, we evaluated some routes which the result is right, can lead to developing to autonomous flight. Secondly, object detection is designed for our research. However, we just validated the colour detection with the camera on the quadcopter. The result can detect the colour object inside the building, and it can extend to being object detection.

In future research, we will work on the auto-flight of quadcopter for improving the efficient model. Our design may create to being air squadron or using many quadcopters on the mission, which can get video or photos information to supporting for deciding on building security. Nevertheless, the object detection should add the other techniques for helping to auto-pilot of the quadcopter as well.

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