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INVESTIGATION INTO CONSTRUCTING AN EFFECTIVE DISASTER RELIEF NETWORK USING SMALL DRONES

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Summary
Autonomous navigation of a Drone and innovation of a sensor module made a sensor network possible. Since people cannot control the practice of the Drone, GPS-based autonomous navigation that allows the Drone to make it to its destination is being constructed. For the drone at its destination to drop a sensor module itself and remain still to obtain information of the destination with the sensor module, the battery consumption should be minimized to extend the range of activities. Utilizing a short-distance network between the drone and sensor module, a wireless sensor network between the sensor module and Drone that is able to return to the starting point with the extracted data from sensor module will be implemented. This research on the embodiment of autonomous navigation and sensor network was tested and verified through experiments. This article can be applied to information acquisition of disaster, discovery and battle areas where neither humans nor ground robots can approach.

I. INTRODUCTION

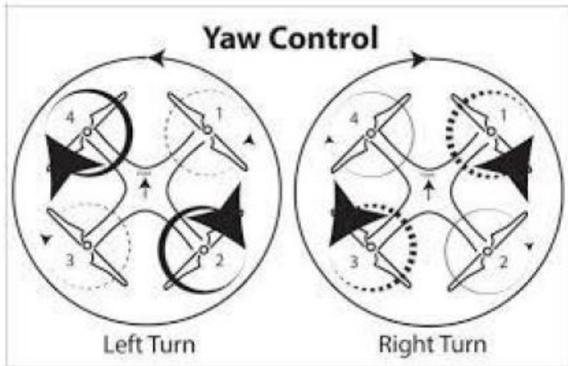
Observing bulk flow of radioactivity from the big earthquake in the east region of Japan in 2013, I have noticed that a Drone is necessary in unapproachable locations to people for real time measurement of radioactivity, proper measures for radioactive disaster and refuge decision-making. Real-time radioactivity information acquisition of the spill site per distance unit is essential. One of the shortcomings of the drone is that the duration of its running time is quite short because of high electricity consumption from its limited capacity of battery and motor rotation. So drone's stay at the destination for data collection is a loss when power efficiency and collection time are considered. With that being said, gathering information for a long time in an extensive area had become difficult and it was concluded that research and exploitation are required in order to solve the problem. For a solution, the Drone loaded with many sensor modules was directed to the destination, dropped a sensor module and extract data. How to return and collect data after a while were considered next. Therefore, this study aims at information acquisition about the specific GPS coordinate.[1]
Theoretical background

1. AR Drone (Augmented Reality Drone)

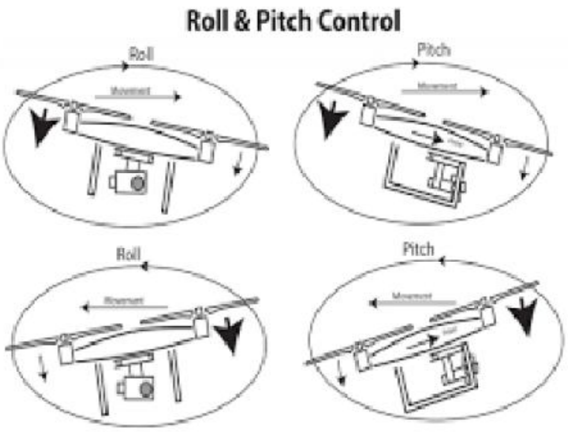
An AR Drone, cheap, small unmanned quad-armed aerial vehicle that was innovated by the company Parrot, is used in this study since it reveals SDK(Software Development Kit) so that the innovator could easily invent and make applications depending on purposes of the program.[2],[3]

2. AR Drone mechanism

The AR Drone controls flying attitudes and directions with momentum from rotations of 4 propellers. The exercise forms of the drone are Roll, Pitch and Yaw. Roll, Pitch and Yaw moments affect the rotations in the x, y, z coordinates, respectively.



[Image 1] : Yaw control



[Image 2] : Roll & Pitch control

The two of the four wings are looking at each other. Their rotors' rotation directions are constant. Total strength applied to the four rotors is the momentum of origin of drone ascension. Drone flight is feasible from generating the ascending ability in the direction heading towards the skyon a y-axis. 100% of the total power of 4 rotors wouldn't be delivered, however. In order to get a pure momentum, the gravity that is plummeted on the ground should be deducted.

3. AT command

Hayes command, the control command of Startmodem of Hayes microcomputer company, is called AT command since the command starts with letters ‘AT’. [4],[5]AT command for AR Drone control consists of 8-bit ASCII and uses UDP protocol (UDP port 5556).[6] Control commands have to consist of those below. All control commands start with ‘AT’ and distinction between command and factor value is ‘=’. Distinct sequence (seq) that increases as it sends orders and factor value with regard to each command compose a factor. At last, <LF> code is inserted to differentiate every command. The size of a command at a time cannot exceed 1024 [7]

[Chart1] :Commanddescription

AT commands	Parameter	Descriptions
AT*REF	input	Take-off/landing/scram/
AT*PCMD	Flag,Roll,Pitch,gaz,Yaw	Drone movement
AT*FTRIM	-	Reference setting for a horizontal plane
AT*CONFIG	Key,Value	Drone's setting components
AT*CONFIG_IDS	Session,User,Application ids	AT*CONFIFG Identifier for commands
AT*LED	Animation, Duration, Frequency	DroneLED Animation setting
AT*ANIM	Animation, Duration	Drone flight animation setting
AT*COMWDG	-	Communication monitor (watch dog) Reset
AT*CALIB	Device Number	Drone magnetic force sensor control

AT*PCMD, especially, is a command for Drone’s parallel translation or rotation. The drone has values from -1 to +1 so its exercise form changes depending on the chance in those values. Drone’s flight patterns with regard to specific variable values are as follows below.

Differences in AT*PCMD Drone’s flight patterns with regard to command variable values.

4. Sensor Network

Wifi communication broadcast section: Drone and Arduino Mega 2560

Arduino Mega 2560 synchronized device
- GPS Sensor
- SD Card Reader
- Drone side -ZigBee module

ZigBeecommunication broadcast section: Sensor sideZigBee module andDrone sideZigBee module

5. ZigBee

ZigBee is an established IEE 802 which allows a private network communication using low-powered digital radio. Communications protocol made based on 15 standards allows communication between many devices.[8]

6. Autonomous drive

Autonomous drive is a technique which a controller drives to an initially set destination without any direct controls.[1] Drone’s autonomous flight methods are image processing based and GPS-based. The research made GPS-based autonomous navigation possible. The GPS obtains time and location information from more than 3 satellites to calculate a coordinate. However, it may cause the risk of errors in the matter of aerial situations and cannot be used while indoor travelling which blocks GPS network.[5] This study aims for constructing sensor network in outdoor disaster areas; therefore, upon consideration of exceptions of impossibility to control through RC(Radio Control) and PC, an autonomous navigation system that separated the Arduino and GPS was constructed and developed emergency landing.

7. UDP(User Datagram Protocol)

Protocol is a communication contract about computers that have information interchangeability and a commitment for two entities for exchanging data. The immediate transmission of data typifies UDP; however, the data may be lost or damaged. Since AR Drone supports only UDP, a UDP socket is used.[9]

Chapter 2: research procedures and methods

This study set the direction of autonomous navigation using an AR Drone which issues Drone’s flight orders in relation to an autonomous navigation algorithm with an Arduino and enables making any programs with a revealed SDK. Communication interface between a sensor module of a sensor network and an Arduino of a Drone concluded that ZigBee, with a wide communication range and a simple connection, is the most suitable means of communication for the project.

[chart3] Processing flow chart of the research

AT Command program drawing up

⇓

Drone and Arduino communication

⇕⇦Wificommunication

Sensor Network construction

⇕⇕

Drop moduleZigBeecommunication

⇕⇕

Code drawing up for drone's autonomous navigation

⇓

Autonomic navigation initiation

Details of work that is necessary for this project are as follows below.

- Drawing up of an autonomous algorithm which calculates Drone's flight path based on GPS data from an Arduino and enables the Drone to navigate based on the SDK [10]

- Way of dropping a sensor module and study of how to protect it from dropping impact

- Way of sensor module's data acquisition and programming for transmission through ZigBee communication using an Arduino attached to a Drone.

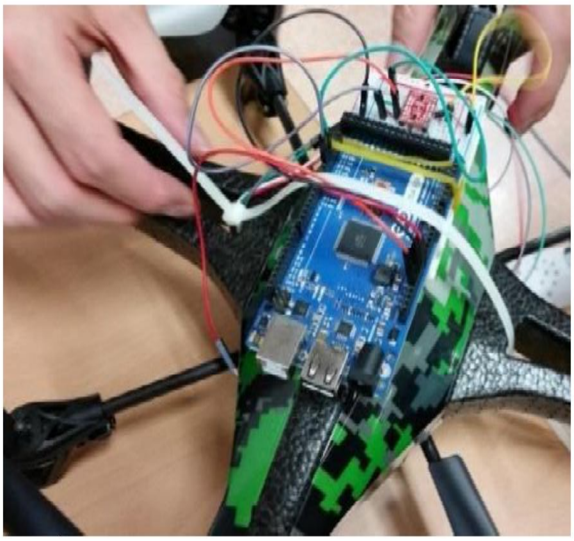
Based on the goals above along with the chart 3, the AT Command to control the AR Drone was materialized as an Arduino function on the basis of the SDK first. After studying ways of sending those commands to an AR Drone next, dropping method of sensor module which composes sensor network and data acquisition and transmission method of sensor module were researched and an autonomous algorithm was written. At last, a sensor network including all the precedent procedures was demonstrated through an experiment outdoors to verify accuracy and practicality of sensor network. Details of each step are as follows.

1.AT Command Programming

Sending an AT Command to an AR Drone enables controlling a Drone. To make the Drone autonomous, therefore, requires programming for the Arduino to send the Drone a suitable AT Command for specific situations. The AT Command is delivered to the AR Drone, thereby allowing direct control of the Drone. For the sake of an autonomous Drone, therefore, it should be programmed into a way of the Arduino being able to sendthe suitable AT Command depending on situations to Drone. Arduino compatible C++functions which send the AT Command to the Drone following the rules were drawn up to control Drone at Arduino easily based on SDK. This applies to the AT Command transfer functions for take-off, landing, advance, reverse and hovering.[12],13],[14]

2. Means of communication between Drone and Arduino

Communication viaWiFi was chosen. Since a Drone autonomously provides AP, essential for WiFi communication, communication is possible if a WiFi shield is attached to anArduino. Its communication method, however, became wholly different than that of the Drone so codes were modified accordingly. Wifi communication codes were made, answering research purposes, based on sample codes provided by an open source platform, Arduino, itself. Drone's landoff was a success due to those communication codes. Besides, control commands of various flight patterns such as advance, reverse, hovering and descent successfully worked. For Drone's autonomous navigation, a program which delivers commands from appropriately utilizing functions that send commands controlling WiFi communication built on GPS information and movement of the Drone mentioned above was designed.[15],[16]



[Image3]: Drone with Arduino attached

3. Sensor Network construction. Sensor Module

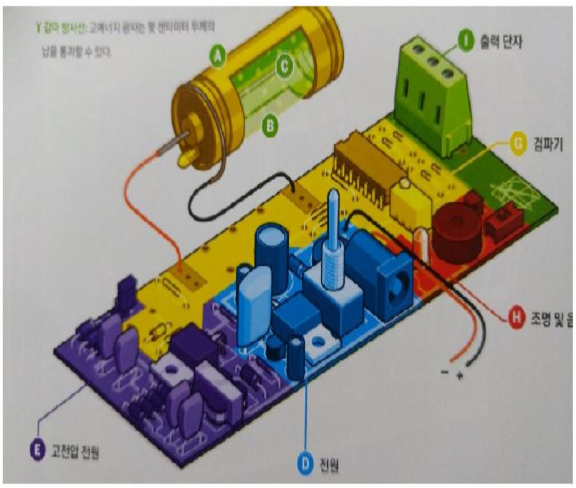
Sensor module, used for collecting radioactivity data from releasing Drone, was built on an ArduinoFio. ArduinoFio itself has a built-in module socket for ZigBee communication, works even with low voltage and makes adhering small LiPo batteries easy; these are suitable conditions for miniaturizing volume and weight. With sensor module, the component of sensor network, equipped with radioactivity sensor, was designed allowing radioactive concentration measurement in real time. The sequence action of the sensor module - from atmospheric condition to data collection to transmission to ZigBee to atmospheric condition – repeats the cycle. In other words, sensor module stands by until activation signal is received, collects radioactivity information of nearby area until requested signal is transmitted and saves it ArduinoFio first. Once signal is received, collected data is sent to drone. Meanwhile, since ZigBee is a very frank communications system, all sensor modules within the range of communication receive commands when drone sends commands. Therefore, each module definitely needs a factor that discriminates whether the commands were issued to it. That is to say each sensor module has to use a different command due to the characteristics of the ZigBee communication. If not, the Arduino side which sends data from a sensor module gets problems with differentiating kinds of radioactivity(alpha, beta, gamma).In order to solve this problem, processed data were sent not as it is and so requisite information could be drawn from the Arduino from the Drone, the data sender, and saved on SD card.[17],[18]

When the Arduino of the Drone sends measured values from each sensor module that is dropped at every vertex of a square of an assumed location of radiation leaksintactly, there is trouble with discriminating which sensor module each of the measured values is from.

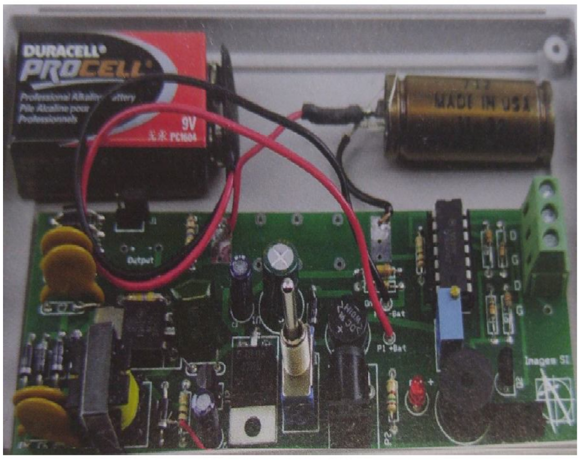
Hereupon, assigned serial numbers of sensor modules and collected data with respect to radiation values from sensor modules at vertices are recorded in a chronological order and, at the same time, are sent to the SD card to check for any errors.

4. **Sensor Network Construction –Drop(Sensor Module)**

In order to construct a sensor network, steps of supposing regions where radiation leaked, selecting measure points and dropping sensor modules at every point have to be gone through. The most crucial purpose is to find ways of landing the sensor modules safely on the ground. A radioactivity readings standard for an Arduino equipped with the Geiger-muller tube which was produced by Images Scientic Instrument and being sold online is used as a radiological measuring unit.[11]

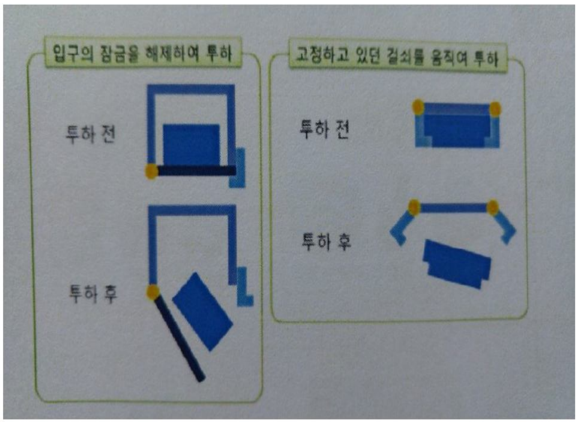


[Image4 ;three-dimensional summary chart of radioactive detection organization for Arduino



[Image5]: Radioactivity sensing device for Arduino

A device that can drop several small sensor modules (aka dropper module) is necessary to build sensor network. There are several means of dropping an object from an aircraft but the most typical ways are dropping after unlocking a box and moving a fixed lash.

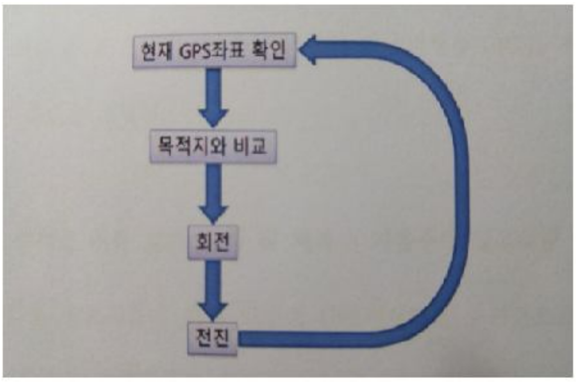


[Image6 :Two representative methods of dropping objects from existing aircrafts

At least more than one motor per object are required. This experiment used a small Drone for information collection and two big Drones for sensor module drop. The big ones could carry an object of about 5kg. They carry to and drop sensor module at a measurement spot. Radiation detector so fragile that when received huge external impact, it damages or disconnects its cord; therefore, the sensor module has to be covered with 3 layers of shockproof wrappers that are often used in delivery companies before being sent to big Drones. Once big Drones equipped with the sensor module box flies and get to the target spot, the big Drones are commanded to run the motor that unlatches the box. The sensor module device wrapped with shockproof vinyl, then, drops to the ground. Monitoring starts since then. To facilitate radiological monitoring, a small hole is made on a part of a Geiger counter in the process of shockproof vinyl wrapping, to let inradioactive matter with ease.[11],[19]

5. Code plans and production for small autonomous Drone - GPS

Because the purpose of the research is to drop sensor module at a previously set coordinate using GPS and to collect information from sensor module, an algorithm that flies to its destination was prepared. Tiny GPS, the library which provides functions that are processed into proper forms for projects from data obtained from GPS sensor, was utilized. The first algorithm made based on functions of Tiny GPS library is as shown in the image 7.



[Image7] :Autonomous navigation algorithm flow chart

This algorithm is a repetition of rotating the body of Drone to fly shortest path between current location and destination and moving forward. The algorithm does not consider obstacles on a straight route and depends solely on Drone with built-in obstacle recognition so this was tested by running Drone in a relatively safe school playground. Code that tests GPS was written first and the experiment to see whether realization of autonomous navigation is possible was executed. The image 8 below is a map which indicates log with GPS coordinate marking function provided from http://www.gpsvisualizer.com/.

[Image8] :GPS data from actual Drone driving test

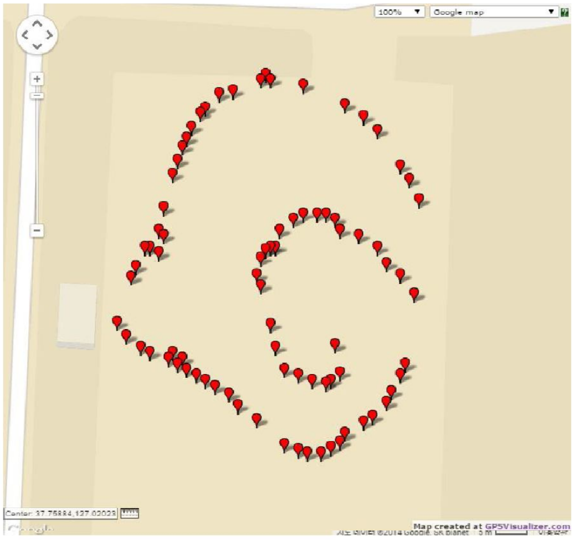
It was corroborated that the received GPS coordinate shows the actual route as it is in reality with almost unerring accuracy. Therefore, it was concluded that Drone's autonomous drive is feasible on the basis of GPS.

6. Code plan and production for Drone's autonomous navigation – autonomous navigation algorithm

A program which sends AT Command to Drone so that it flies to a destination autonomously based on GPS data that Drone periodically receives per autonomous algorithm was written. [Image 8] shows a flight path that indicates conspicuous problem of SD card flight log during a flight after the initial code above was uploaded to the Arduino. The Drone departedfrom the 8 o'clock position, moved in a S-path, and kept going to the 2 o'clock position. The destination was marked as'goal[37.000089(longitude),127.000087(latitude)]'. The Drone went by the destination and headed towards a different place in the following image. The cause of this phenomenon was analyzed as incapability of bringing GPS data when passing through the destination even though Drone flew to the goal point on the basis of real-time GPS data.

[Image9] :flight record of drone that just passed by destination

It was judged that the cause of the Drone going straight through the destination is its constant flight speed even in close proximity to the destination and the Drone was induced to arrive at destination safely by inputting values of decelerating flight speed as the separation distance between the destination and current Drone which was measured based on GPS data decreased. In particular, the code that determines a destination was revised. A 1m radius with a destination as the centre was previously entered as the destination but it was thought to be very narrow so the radius was extended to 10m. The dropping accuracy of the big Drone which carries sensor module was made sure depending on such code operation. Its minuteness was further added by designing an algorithm to receive as many coordinates that the Drone passed through as possible.



[Image10] :flight record of drone that approached destination by going in a wide circle

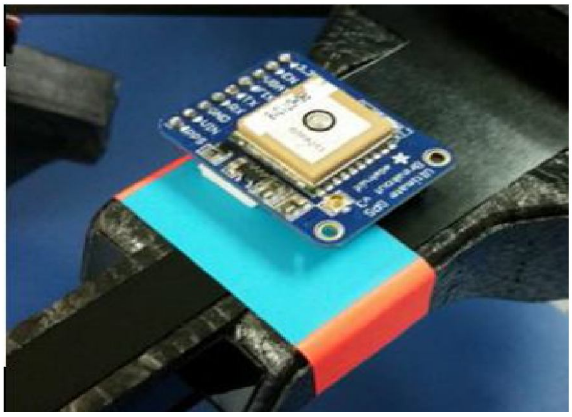
Chapter 3Conclusion

[Image11] :Compact Drone armed with Arduino

Autonomous navigation of a Drone was demonstrated based on GPS data withthe Drone attached with an Arduino, WiFi Shield and GPS sensor according to the study's autonomous navigation implementation plant. Following the sensor network construction plan, sensor module device, composed of a sensor and ArduinoFio, was sealed with shockproof plastic wrapper, latched, and dropped at the destination. For the Drone to collect data that the dropped sensor modules measured, duplex ZigBee communication was materialized. As a result, a product that fulfilled research purposes was earned. A sensor module was manufactured by adhering a radiation detector and ZigBee communication module to the ArduinoFio. A latch was made and attached to the ArduinoFio to suit the environment for dropping.

[Image12] ZigBee communication module attached to Drone

The ZigBee communication module was adhered to an ArduinoFio of a sensor module and Arduino Mega of a Drone as demonstrated in the image 12 so that it could send commands to sensor module and data collected by the sensor module to the Drone.



[Image13] : GPS Sensorattachment

In the view of problemsof reception rate decline when attached on the bottom of the Drone, GPS is attached on the top of the Drone. The Geiger-Muller counter is used as a radiation detector. When so much radiation is emitted from high-level radioactive region, peculiar sound effects are produced and values of the CPM, count per minute, rise.[11] The Geiger-Muller counter that was prepared for the experiment, could not be used for measuring radiation values in reality since it measures not natural radioactivity but high level radiation. The experiment was confined to verifying the procedure of collecting radiation value information from sensor modules in real time from the target point that the sensor modules were dropped.[20],[21],[22].23]

Chapter 4:My opinion after the research

This study realized an autonomous drone and constructed a sensor network through the module throw. This focused on proposing a new method for collecting data for handling of the disaster in catastrophic regions where humans' direct exploration and existing unmanned robots do not work, especially areas of radiation leaks. Raising degree of completion of autonomous navigation assisting with a GPS through image processing using a more efficient and exact autonomous navigation algorithm design, GPS quality improvement and the Drone with on-board camera is crucial from now on. Furthermore, extending the scope of sensor network by embarking many more sensor modules and bigger batteries using more remarkable Drone and diversifying types of sensor for data acquirement to serve the purpose are likely to increase practicality and capability of the research. It is no doubt that the outcome of the research that establishes wireless communications system via compact sensor modules is instrumental in strategy establishment of disaster relief by providing radioactive level of human-unapproachable areas in real time and, particularly, is a useful tool for saving precious lives by gauging the range of evacuation of nearby residents.

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