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# Simultaneous Localization and Mapping in Navigating Multiple Quad-Copter Under a Dynamic Environment

Constance Nneka Eze[1], Ifeanyi.I.Ene[2], Princewill.C.Ene[3]
[1]Department of Computer Engineering in Enugu State Polytechnic Iwollo Ezeagu
[2,3]Department of Electrical and Electronic Engineering in Enugu State University of Science and Technology Enugu State
Email: nnekaeze713@yahoo.com

***Abstract***— *Simultaneous localization and mapping methodology in quad-copter navigation operation under a dynamic environment is proposed in this work. Tremendous and remarkable achievements have been recorded in the area of multiple drones under a dynamic environment. Appling the simultaneous localization and mapping algorithm, this research used two-point research objective in which the principal aim was to characterize an already existing drone system. With a reliable result, an algorithm based on the simultaneous localization and mapping technique was proposed. In executing the proposed algorithm a 3D environmental data and information were converted to 2D information for ease of mathematical computation. The SLAM process was utilized in this research work shows that when the drone starts, the controller initializes the two dimensional light detection and ranging 3D map on board sensor making them ready for data collection operation. After the initialization of the sensors, follows the running the modes which were the SLAM algorithm was Written in python programming language, then the Data visualization script (RViz) was implemented to run in order to display the obtained map of the perceived data for the data collection action for the four drones was remotely moved round the dynamic environment to collect the dataset. The python program written was used continuously to check if the multiple drone was closer to each other or not. If the drone was still closer, measurement and logging of the sensory data continues if not, the generated map will be saved in a file.*

***Keywords***— *Simultaneous Localization and Mapping, Drone, Quad-copter, Robotic Operating System, Dynamic Environment.*

## I. INTRODUCTION

### *1.1 Background of the Study*

In a global world, Navigating and mapping of more than one directional remotely operated navigation equipment (drone), under dynamic environment Has been one of the complex problems for autonomous groups of drones. Some popular approaches to autonomous navigation used combination of different intelligent navigation techniques and algorithms to autonomously navigate drones in both static and dynamic environments However, real time navigation still holds challenges for drone navigation in complex crowded environment. The major interest in drone's navigation under dynamic environment is to find a collision free path from a given start position to a predefined target point in the work space, collision-free route and path planning is one of the vital challenges in achieving navigation in an unstructured environment. The problem of simultaneous localization and mapping for navigating multiple drones under dynamic environment includes the search for a path which a drone has to follow in an environment. Navigation is a serious challenge for autonomous system in an unstructured and complex environment due to irregular shape of the environment and this required real-time planning. In other to improve the planning of multiple drone, system models that can provide solutions to localization, map building planning and control should to be developed. The three questions that need to be answered in any autonomous system are, "where am I?" "Where do I go"? And "How do I get there?". The solution to these questions gives rise to the tasks of self- localization, map building, path planning and collision free route. Drone navigation system is basically made up of navigation involving global path planning and local path planning. The navigation involving global path planning (deliberative approach) uses global information/data obtained from a completely known environment with a statics terrain to create a directed path for the drone to reach the goal. The global path planning can find an optimized, path to reach the goal when some objectives cost function is considered. While on the other side, the local path planning navigation (reactive approach) generates a feasible path through which the drone can move in an unknown and dynamic environment as the drone is currently moving, Prior to the beginning of the drone motion, the global path planning algorithm has to generate a complete path that runs from the source to the destination point, local path planning is more flexible in an unknown time-varying environment. Algorithms for path planning can either be an off-line algorithm or on-line algorithm. Off-line algorithms are used for global navigation while on-line algorithm is used for local navigation, off-line algorithm generates the model of an environment and entire path or trajectory to the target location prior to the start of the motion whereas for on-line algorithm, the model of the environment is partly or totally unknown and the trajectory path to the target location is generated incrementally. The navigation cost in off-line algorithm or global navigation is likely to be higher than that of on-line algorithm or local navigation because of the process of supplying new map to the drone due to the dynamic nature of the environment. Consequently, more attention has been on local navigation since it does not require model of the environment in advance, rather, it detects the environment, updates itself and generates new map for navigation in real time Path planning using the online algorithm begins with off-line algorithm before changing abruptly to online on the discovery of new changes on the obstacle location in the environment. Usually the information about the environment is obtained in real-time through the onboard sensor in form of sensor data, and the control laws are updated in order to achieve the online path planning. This means that successful navigation in a dynamic environment depends on the sensory data input and intelligent controller in order to handle the dynamic changes in the environment.

*Aim and Objectives of the Research*

The aim of this research is to navigate multiple quad-copter under dynamic environment using simultaneous localization and mapping. To achieve the aim stated above, the following specific objectives are proposed.

i. To characterize an already existing drone system.
ii. To characterize dynamic environment in which the drone operate.

## II. Materials and Methodology

The material used in this research are as presented below:

1. Stop watch- time measuring instrument
2. Simultaneous Localization and Mapping (SLAM)
3. Physical drone
4. Flow chart
5. Graphical presentations
6. Laptop computer
7. Wireless Router
8. Robotic operating system (ROS)

The methodology for simultaneous localization and mapping drone in a dynamic environment, it started with extensive characterization of the already existing drone as well as the dynamic environment in which it operates. The characterization of an already existing drone system which means directional remotely operated navigation equipment (drone). But the type of drone that was characterized in this research work was called quad-copter which is the type of drone with four rotors.

TABLE 1: Characterized Parametric Values, with Units, of a Quad-Copter with Four Rotors.

| Quad-copter parameter | Units |
|---|---|
| Electronic speed controller | 1 |
| Flight autonomy | 13-15min |
| Weight of the quad copter | 550g |
| Thrust per motor (**) | 521g |
| Size of the frame | 260mm (205x160) |
| Propeller size | 6X45 inches |
| Degree of freedom | 6 |
| GPS Antenna | 1 |
| Number of blades | 4 blades |

The reason for the study was to evaluate quad-copter performance. This research was achieved by examining the operational characteristics of a quad-copter. The table1 shows that this type of drone proves to be the best because its processes multiple movement that is rotational and translational movement. The characterization of the dynamic environment was done by translating the 2D point cloud map of the drone's environment into a 3D map. This was done using sensor fusion of the data obtained from the laser scanners, encoder and gyroscope that is from the two drones operating on unknown environment which was used to know its correct position relative to its co-ordinates frames in order to know how to get to the target location. The flowchart in Figure 1 presents the method of carrying out this task.

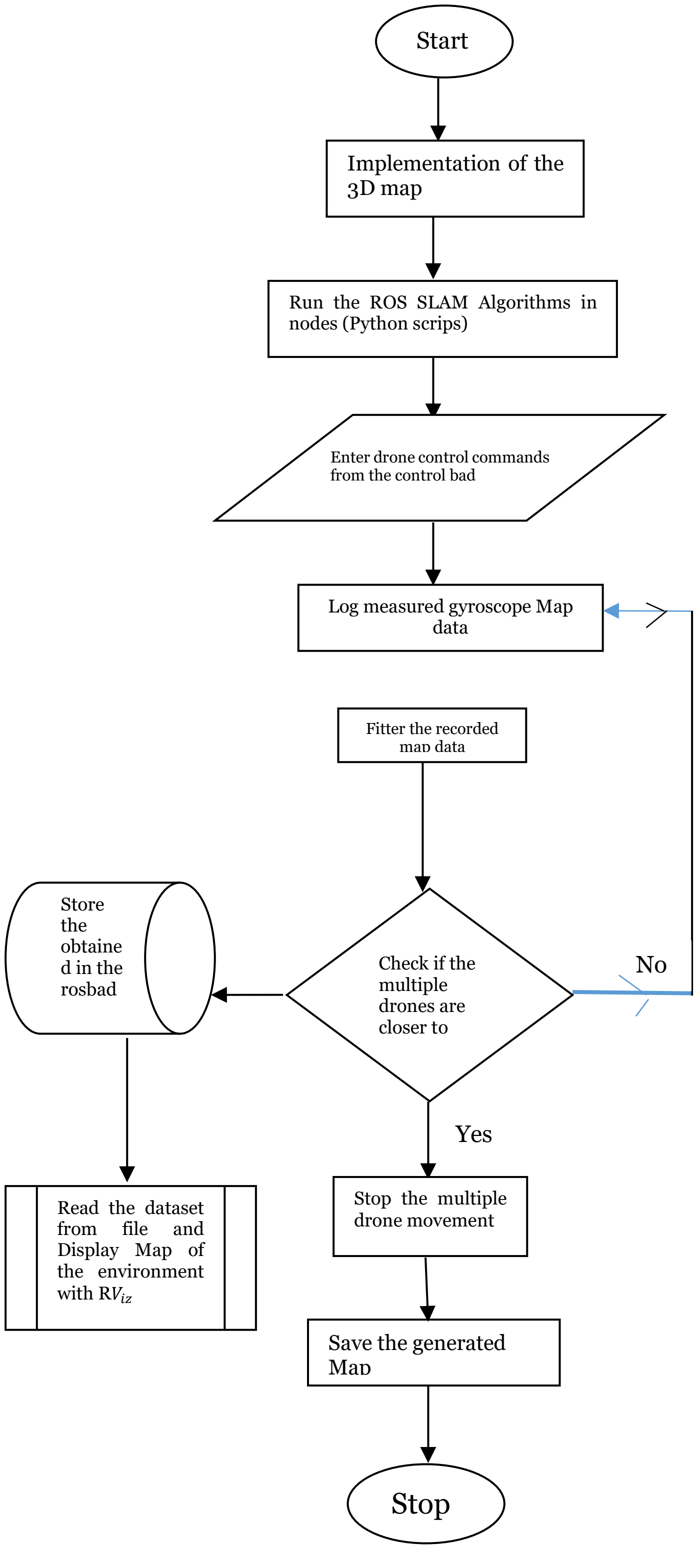


Fig. 1. Flow-Chart for SLAM Operation



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The Algorithm below shows the parameters which were used to govern the movement of the drone.

Step 1: initiating movement: the closed obstacle from the laser scan data was extracted and then four drones move towards it so that it stabilizes keeping the obstacle at a fixed preset distance.

Step 2: Check if there was no obstacle lower than d in the forward direction, meaning that the front was clear and forward movement was safe.

Step 3: Although the algorithm follows the left wall, the right wall needs to be looked at so that collisions can be avoided while entering narrow passage and to allow for enough space for the drone to turn when turns are required.

Step 4: If front was clear and right was clear, turns are not required. Hence, keep moving forward.

Step 5: If front distance was less than or if going forward will result in a collision while making a left turn or if there was no enough space to make a right turn if the four drones moves any further forward, set right turn require flag to turn. Turn clockwise until the condition for right turn completion is met.

Dynamic Environment characterization was achieved by the implementation of following steps:

Step 1: By implementing SLAM which was based on computer vision

Step 2: By installing ROS in the computer Laptop for the purpose of visualization of the sensor data 2D and 3D

Step 3: the characterization was done by using computer vision inputs to perform location and mapping of the drone.

Step 4: at that point the multiple drones was trained at that dynamic environment in other for the drones to learn and know the path that could lead to collision, obstacles and human accident.

Step 5: At this particular stage when the drone is undergoing this training data collection is been made because once the drone met an obstacle or human it will stop and it will be recorded. And when it starts again it takes another route that may be free, will also be recorded.

Step 6: The training of the drone on the dynamic environment will go on still the multiple drones has mastered path on which to Navigate from the source to the destination.

Step 7: The length and width of the environment in which the drone operate was measured from 20 feet – 98 feet.

Step 8: Which enables the multiple drone to be trained within its operational environment.

Step 9: A per existing map of a given environment was first built.

Step 10: The drone was made to operate within the existing map, which was programmed.

Step 11: Variation of this map was made as the drone moves within the environment. The data collection from the environment was done through SLAM following flow-chart sequence given in figure 1.

## III. RESULTS AND DISCUSSION

In objective one, it was required to characterize both an already existing drone system as well as the dynamic environment in which the said drone operates. The figure 2. Below shows a detailed structure of a quad-copter drone with four rotors.


Fig. 2. A Detailed Structure of a Quad Copter Drone with Four Rotors.

During the characterization, it was discovered that quad copter propeller create more lift and provide smoother flight than its counterpart. Meaning that it was discovered that this quad-copter drone possesses six degree of freedom, the six degree of freedom means that six variables are needed to express its position and orientation in space ($X,Y,Z,\varphi,\theta$ *and* $\emptyset$). The X,Y and Z are the Variables representing the distances of quad-copters center of mass along the X, Y and Z axes respectively from fixed reference frame and which is also known as the translational direction. The other three variables are the Euler angles which represent the quad-copter orientation. ($\varphi$) Is the angle about the x axis and is called roll angle, ($\theta$) is the angle about the y axis and is called pitch angle and ($\emptyset$)is the angle about z axis and is called yaw angle. Resulting from table 1 and some of the characteristics of quad-copter with four rotors.

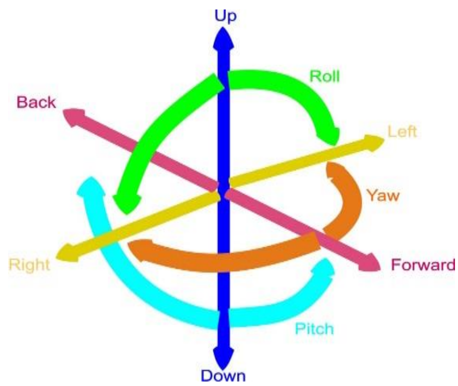


Fig. 3. Six Degrees of Freedom of a Quad Copter Drone

From the diagram above it was observed that quad-copter uses four propellers for thrust and has them configured in either a cross or plus format. The quad-copter robot can take off and land vertically which is a big advantage as the lower the requirement for a landing platform it allows the quad-copter to hover in place with considerable stability. Hover stability prevents the quad-copter from crashing in the event of strong



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wind or due to its weight. In the six degrees of freedom of a quad copter, x and y represents the translational motion along the x and y-axes respectively and $\psi$ represents yaw, the rotational motion about the Z- axis while the (frontal view) $\theta$ represent roll, the rotational motion about the x-axis, $\phi$ represent pitch, the rotational motion about the y-axis and z represents the translational motion in the direction per appendicular to ground. With a hover control unit, the quad copter can hover at a constant height z, where its roll and pitch angles stabilized by the gyroscope. To the effect it was finally observed that the person at the command base will only need to control the quad copter motion along the x- and y axis. Also, it has the ability of rotation about the z-axis so as to turn from one corner to the other thereby reducing the degree of complexity from six to only three.

The system characterization and data collection were based on SLAM operation and the multiple drones was achieved as expected from the design below, after executing the command-line given. The first window was the Rviz a 3D visualization application. It was used to observe and view all the perceived data that the drone was able to get from the environment as shown in Figure 4.

Fig. 4. Indoor Map Visualization using Simultaneous Localization and Mapping.

The area of the dynamic environment by which the drone would operator was take into consideration in this case, the length and width of the environment in which the drone operate were measured, this enables the multiple drone to be trained within its operational dynamic environments. Thus, multiple drones would be used to perform factory operations which were earlier undertaken by many industries and commercial services. The overall aim was to increased output and final productivity level of the company. From the indoor map visualization using simultaneous localization and mapping, it was proofed that the area of environment where the multiple drone operate between three meters under radio frequency. The process of representing the environment in a way that captures the connectivity and topology of the environment instead of creating an accurate geometrical map of the environment was called mapping which was implemented in the system using flow-chart and a simultaneous localization and mapping (SLAM) algorithm which happen to be used to produce a map of dynamic domain and to establish the locality of the quad-copter inside the map. SLAM was installed by using a variety of sensors which includes IMU, GPS, laser scanner, camera etc. The process for the SLAM process utilized in this research work shows that when the drone starts, the controller initializes the two dimensional light detection and ranging 3D map on board sensor making them ready for data collection operation. After the initialization of the sensors, follows the running the modes which were the SLAM algorithm was Written in python programming language, then the Data visualization script (RViz) was implemented to run in order to display the obtained map of the perceived data for the data collection action for the four drones was remotely moved round the dynamic environment to collect the dataset. The python program written was used continuously to check if the multiple drone was closer to each other or not. If the drone was still closer, measurement and logging of the sensory data continues if not, the generated map will be saved in a file.

## IV. CONCLUSION

The research was undertaken with the aim of simultaneous localization and mapping of multiple quad-copter under dynamic environment. The research work shows the characterization of both an already existing drone system as well as its operating dynamic environment was carried out. Analysis showed that drones operate in a six-degree of freedom phenomenon described as Up – Down, Back, Forward, Left, Right, Roll and Yaw. Technically, these are Light, Down, Thrust, Drag, Roll and Yaw. Angular and translational movements were also clearly examined. The dynamic environment in which the drone operates was characterized. Map visualization was essentially highlighted using simultaneous localization and Mapping (SLAM). Which was used convert a 3D environment in the air to a 2D environment for ease of localization of both stationary and dynamic obstacles as well as environmental landmarks.

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