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RESEARCH ON SWARM DRONE USING WIRELESS NAVIGATION NETWORK IN PERFORMING BIRD MODEL SWARM DRONE

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Abstract

This research presented the preliminary research about swarm algorithm for simple maneuver of drones using wireless navigation network as a locator and communication. A simple and efficient solution to synchronize and orchestrate a swarm of drones lies in the RF communications to position drones where we can try a simple swarm algorithm. The communication control among drones used transmitter and receiver placed on each of the drones' wireless navigation network (WNN). The mechanism of drone motion can be directed into swarm motion where random motion is done by each drone without collation and leader which called as Apus Model Swarm Drone (AMSD). It can also be directed in the kind of following motion where the leader drone followed by other drones which completely autonomous which called Boid Model Swarm Drone (BMSD). The results obtained by placing the vertical obstacle randomly. The AMSD, although not perfectly in finished entire the swarm motion, given a promising result in the next ongoing research as a new novelty of experiment in swarm drone with adding extremely random motion in speed.

Keyword: Swarm, drone, algorithm, wireless, navigation.

1. Introduction

In nature, societal faunas such as ants, bees, fishes, and birds can do group coordinated motion [1]. These animals can collaborate in order to complete tasks that were impossible to do alone, even with the full-extent of their abilities. Invisible communication happened among them to create a performance that appears from decentralized self-organizing systems. If the main control or sense of resolve did not exist, Self-organization may occur as individuals only interact with each other and with the situation which created global patterns. Swarm robotics was a unique method. Drones used in many cases, the most noticeable benefit of a drone is to bring a camera and making landscape photos from the sky. This was for single usage, but recently the trend of drones was shifted to swarm drone which is a group of drones doing manoeuvres without colliding with each other. They seemingly knew its position like other drones and doing swarm motion like birds in the sky. To do this, minimally we must have position detection control in spatial and communication control among drones or at least between each drone which connected to the control centre in the ground. It was the proper communication technique among them. The problem can become more complicated when the motion is random like Apus bird and also the speed of the individual drone is doing the sinusoidal like motion when Apus is in the partner or group condition.

2. Research Methodology

The problem of this research was how to make the Apus Model Swarm Drone which can mimic Apus bird motion. The drones also needed to have some common ability in Impact evasion the ability to record the action itself so they can perform the trajectory in recorded data. This recorded trajectory data can become one element of the wireless navigating network. The swarm drone was tested by doing BMSD action with six drones involved and also AMSD action with the same number of drones. The Communication in doing the action for BMSD was using Ring Topology and communication for doing for AMSD was using Wheel Topology. The success criteria of the experiment were only on Impact evasion criteria.

2.1. Wireless navigating network

Previous research used at least two techniques to know the position of drone in the swarm. The first was marking visual method where video recordings are placed above some area in which grid marking is placed on it [2]. The second method was by doing initial preparation like a grid setting and put all the ground in a grid configuration. In the first method, the position was detected by the video and recorded by the control station. However, in the second method, each drone knew their position relative to the initial position like the experiment done by University Pennsylvania in 2012 without GPS [1].

Wireless Navigating Network is a network built by each drone in the swarm. All the positions and position changes among the followers were recorded by the drones themselves. The main task of WNN are:

a. The leader drone moving or hovering the swarm to the target location with a specific speed and broadcast his position to the nearest drone

b. Follower drone determining the relative distance between the nearest drone and calculate position with the leader drone, making follower and co-leader relation between drone

c. The follower and the co-leader establish a relation in the wireless navigation network. The task determines in each follower and co-leader relation.

d. When the leader moving or command the followers to move to a location, each moving drone should do Impact evasion to other drones or the environment.

e. Together, the swarm drone should maneuver seamlessly in the group with updatable WNN by recording motion data by themselves.

The position of the main leader could be located using GPS, but the position of each drone in the swarm must not depend only on the GPS they carry with. An infra-red sensor like PIR sensor and ultrasonic sensor can be used to determine the relative location to the nearest drone [2]. But it is not enough, the time response to determine the position was not compensated with the speed so it should be made intelligent by predicting the algorithm to help the accuracy position of each drone in the network. That was the challenge in making wireless navigation network. This paper proposed some visual sensors when applying in a daylight experiment to detect the presence and position of the nearest drone.

2.2. Flock simulation

According to Craig W Reynolds in Skattman thesis, he pioneered in making simulation of bird flock [3]. Boids was the name of these animated birds. In order to create a flock simulation, he started by creating a boid that supported flight geometry with the fundamental actions such as preventing impact, maintaining unity, and flock separation. The boids must follow three rules specifically:

i. Impact evasion: dodging accident with adjacent flock-mates and obstruction.

ii. Alignment: try to balance the speed with adjacent flock-mates.

iii. Unity: try to keep the distance with adjacent flock-mates.

Impact evasion and position supported each other and they can guarantee that the followers of the flock can fly freely without crashing into each other. The Impact evasion was determined by the location of adjacent flock-mates. It was the stationary space that makes sure the boids keep a minimum distance. Equally, the position was based on speed and direction, not the location. By matching the speed, the separation among the boids remained invariant for the flight geometry. Unity instructed the boids to stay near its flock-mates, or in the middle of those around to it. If a boid is inside the flock surrounded by flock-mates, the mass will be the same to every direction and the centering tendency is small. If the boid is on the flock border, most of its adjacent boids can realign. The boids center is located the the flock's body and the flight path stays adjusted following the flock center. The boid model style grants separation in difference to the chosen leader models. If an obstruction appears, a boid did not stop when the flock is separated, as long as it stays near its flock-mates. The model has some difficulties with separated flocks that cannot perceive each other until they are inside a certain distance. If the three rules were not arranged, they can force themselves to a different direction with acceleration, made a contact with each other, disrupt each other and become a potential risk of collision to the boid. Therefore, the rules were prioritized, if an emergency situation occurred, the acceleration would be distributed to the most vital need first.

2.3. Boid-drone model

Apus Nipalensis is the Latin name for house swift bird, this kind of birds moves with high agility in a single and rare swarm. This bird can maneuver very fast without colliding with the other or the environment. The Apus drone should be the drone with high agility and somehow designed in metastable control. The hard maneuver was involved in this swarm drone. tilt sensor was inserted to map the position into static and dynamic reference. In reference to boid algorithm, the Apus algorithm can be the modification of Reynold flocking was shown in Algorithm 5.

```
Data: A group of apus.
Result: Simulates flocking behaviour with an animation.
foreach Frame do
        foreach apus do
expansion (apus)
separation(apus);
contramovement(apus)
contraUnity(apus);
        end
        foreach apus do
                apus.x ← cos(apus.course) ∗ b.velocity ∗ dTime;
                apus.y ← sin(apus.course) ∗ b.velocity ∗ dTime;
           recorded (wnn); approximate(wnn)
                when collision do
                        anticollision;
         wnn ← approximate(wnn);
                end
                when wnn is off
                wnn ← approximate(wnn)
                end
        end
end
```

We named it contra movement, because swift bird naturally passes the other bird in contra direction without collision. The movement of the center swarm is called contra Unity.

2.4. Apus-drone model

Many previous types of research regarding formation flight applied several different control techniques and methodologies to achieve the goal of maintaining a formation of robots while in motion. The incorporation of a “leader” into the formation was a common approach in which the motion of the lead robot is planned. In addition, the robots have minimal sensing capabilities and communicate to at least one other robot. In swarm drone, the control station only communicates to the leader drones, and other drones were set to follow the leader drone after mapping position was done. Follower robot intended to move seamlessly in Unity and maintaining the flock formation without collision to other and the environment every time. The communication between leader the control station can be done in radio frequency or IP based [4]. But, the communication between nearby follower drones was done using two ways, namely using a sensory systems-based and approximation of positions. Each drone recorded their velocity (speed and direction) and the swarm direction in order to fly without real-time data. They recorded the data of position, velocity, and target movement before and while moving [3].

2.4.1. Model of swarm drone

The neighborhood structure in the original algorithm was the global topology, where every boid connected to every other in the swarm. Therefore, accessing the best solution found so far by any particle. This may lead to a rapid loss of diversity (implosion), which in turn may result in premature convergence to a poor suboptimal solution. While this can be controlled to some extent by setting the coefficients in the trajectory equation, numerous neighborhood topologies have been proposed to reduce the connectivity distance, thus delaying the propagation of information throughout the swarm. A few neighborhood topologies are shown in Fig. 1 [5].

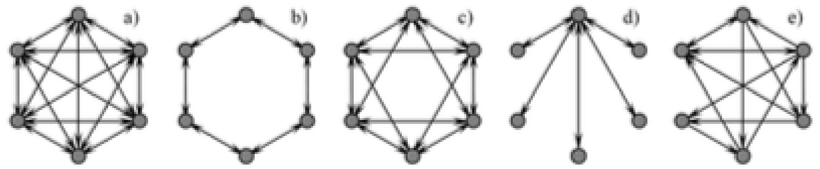

Fig. 1. a) global topology; b) ring topology with two neighbours; c) ring topology with four neighbours; d) wheel topology (global for one particle and two neighbours for the rest); e) random topology.

Two models were proposed in this model. In the first 3 models of drones, the leader is located in the center and the two are on the above or the below of the flock while maintaining the radius of the swarm. The second 5 models were four side shapes; a drone placed in every corner and in the middle. The drones were doing all the motion in Unity format and maintain the distance when the swarm center moving into different areas.

2.4.2. Speed of swarm formation

In swarm, the speed is very important. Besides maintaining the formation, they also maintain the speed in which they move. The center of swarm moved in linear, parabolic, or even twisted formation. Twisted formation is unique formation that combined the circle motion with elevation motion.

2.5. Leader-follower formation control

Communication system between leader to followers and among followers was made from fast RF Transceiver and Receiver in 433 MHz and 315 MHz. The communication between leader and follower drones used 433 MHz radio frequency, but communication system used 315 MHz among the follower drones. The digital modulation used Amplitude Shift Keying with <9.6Kbps (at 315MHz and -95dBm). For the processing unit, it used Arduino Uno. You may find the simple algorithm to process this transmitter and receiver in web made by Rawashdeh [6].

2.6. Communication systems

The Impact evasion system equipped with Forward, Backward, Downward and Lateral Vision Systems including Upward and Downward Infrared Sensing Systems [7]. These systems provided omnidirectional obstacle detection, only if lighting conditions are adequate. The main components of the Forward, Backward and Downward Vision Systems were six camera sensors located on the nose, rear end, and underside of the quadcopter. The lateral Vision System used 2 cameras with one camera on each side of quadcopter. The main components of the Upward and Downward Infrared Sensing Systems were two 3D infrared modules located on the top and underside of the quadcopter. The Downward Vision System and Infrared Sensing System helps the drone maintain its current position and hover in place steadily. The Vision and Infrared Sensing system allowed the drones to fly indoors where GPS signals are unavailable [8].

3. Results and Discussion

The model of the drones allowed them to maneuver and maintain the formation at the same time. The Apus motion should become a consideration as a novelty factor [9]. However, it needed more practice and formulation to do that. The Unity movement of the swarm drone can be the first requirement in making swarm drone. The two experiments used Boid Model Swarm Drone (BMSD) and Apus Model Swarm Drone [10, 11].

(a) Plan formation swarm drone moving using ring topology communication without random vertical obstacle

Using ring model, Fig. 1(c) with 6 drones, which 1 drone become leader and 5 drones become follower, the description related recording of swarm drones can be seen in Table 1.

Table 1. Recording of swarm drones in BMSD with ring topology communication without obstacle.

No.	Step of moving and recording condition	Successful action	Drones who are saved the recording data
1	Hovering position Between leader and nearest drones	Success	Leader Drone
2	Hovering position between leader and two-level far drones	Success	Leader Drone
3	Between followers	Success	Each follower
4	Leader command to separate	Success	Leader, and follower
5	Hovering after separation	Success	Leader and follower
6	Unity movement triggered by time	Success	Leader and follower
7	Doing maneuver movement: moving to separation to Unity	Success	Leader and follower
8	Doing maneuver of half followers with swarm motion (3 back drones doing contra movement among each other, while the drones as group doing forward movement	Success	Leader and follower

(b) Plan formation swarm drone moving using ring topology communication with random vertical obstacle

The drones illustrated with six-side polygon in Fig. 2 and the vertical obstacle is illustrated with black circle. The distance between two vertical obstacles is placed randomly about 2 to 3 metres. If shown from above (as depicted in Fig. 2), the swarm drones were moving to the left to the right. The successful result was shown in Tables 2 and 3 for each condition of vertical obstacle. Condition A is where there is only single vertical obstacle, condition B is only one single vertical obstacle placed in left of motion lines of swarm, Condition C is quite similar with B but the position of vertical obstacle is on the right side of swarm line motion. The condition of A to B is designed to represent of partial Unity and separation movement during swarm motion. The condition of D is only allowed for one drone to enter so there is queueing process in pass through the vertical obstacle. In position of E, the swarm hovers with the same configuration with initial.

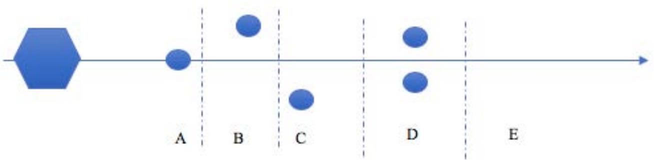

Fig. 2. The movement of swarm drones through vertical obstacle in Ring Topology Communication

(c) Moving forward with random motion using Apus-Drone Model

Using wheel topology six drone are followed the leader move in swarm through random vertical model like in Fig. 2. Each of drone are doing sinusoidal motion horizontally or vertically when approached the vertical avoidance. The follower speed of transversal motion of sinusoidal is 40 cm per second and the amplitude is 60 cm for horizontal and 50 cm for vertical. The trajectory of one of follower in Apus-Drown Swarm Model can be shown in Table 2.

Table 2. Recording of swarm drones in BMSD with ring topology communication with random vertical obstacle.

No.	Condition	Action	Successful action	Drones who are saved the recording data
1.	Condition A	Leader is moving without hitting the obstacle, and the follower doing separation	Success	Followers
2.	Condition B	Leader is moving without hitting the obstacle, half left sided of the swarm are moving left to avoid the obstacle	Success	Followers at the half side of the swarm
3.	Condition C	Leader is moving without hiting the obstacle, half right sided of the swarm are moving right to avoid the obstacle	Success	Followers at the right side of the swarm
4.	Condition E	Leader stopped, followed by the followers and they regroup to initial formation by response to the data	Success	Leader and followers

Two drones which located in face-to-face position did pair motion simultaneously. The leader did not save every trajectory position, but trajectory positions are recorded by the followers for angle-accelerator sensor. Somehow, the Impact evasion system is not perfectly good for speed above 3 m/s. It needed more comprehensive improvement in time detection of Impact evasion. The result of swarm motion can be shown in Table 3.

Table 3. Recording of swarm drones in Apus-drone model with wheel topology communication with random vertical obstacle.

No.	Condition	Action	Successful action	Drones who are saved the recording data
1.	Condition A	Leader is moving without hitting the obstacle, and the followers separate	Success	Leader and related followers
2.	Condition B	Leader is moving without hitting the obstacle, left side of the swarm are moving left to avoid the obstacle	Success	Followers at the left side of the swarm
3.	Condition C	Leader is moving without hit to obstacle, half right sided of the swarm are moving right to hindering the obstacle	Success but some followers almost collided	Followers at the right side of the swarm
4.	Condition E	Leader stop, followed by follower and they regroup to initial formation by response to data	Success	Leader and follower

4. Conclusion

The result of the moving swarm simulation in this experiment is not done by pre-recorded data, the drones are adaptively doing the Impact evasion motion according to the random appearance of the obstacles. Each of the drones recorded the data when Unity and separation happened. In condition where only half side of the swarm doing Unity or separation motion, only the drones who are doing that and the leader who recorded the data. The data needed to be recovered to initial formation. The motion for Apus model was not perfectly done but this model looks promising for further continuing the research. As a preliminary research, the ongoing research will be focused on Apus model swarm drones.

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