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Report on Work in Progress of Small Insect Tracking System using Autonomous UAV

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Abstract—**In this paper, we will introduce an appropriate solution for tracking a small flying insect such as wasps. The existing approaches face difficulties such as weight of transmitter, accuracy, cost, capability of keeping tracking range covers target. Our method includes the use of autonomous UAV and an easy-finding tracking devices that are adaptive for the targets such as wasps. Finally, a path planning algorithm for UAV is provided to guarantee the operation of these devices.**

Keywords—**insect tracking, autonomous UAV, Signal Strength, positioning, distance estimation.**

1. Introduction

1.1. Animal tracking system: development and issues

In literature, the following techniques are commonly applied for animal tracking:

- Global tracking system: An integrated GPS module is attached on the target to be tracking, which allows the monitoring of the trajectory in global space with high accuracy (can reach one meter or less). Moreover, the cost of GPS devices is on the decline and depends on the quality of the service provider. However, GPS has certain disadvantages such as dependency on service provider and high energy consumption, which leads to a bulky battery and increased weight.

- Harmonic radar system: Radar technology can be applied for the detection of metal-alloy materials. In this case, a diode or non-linear junction is mounted on an animal that automatically sends harmonic responses to the Radar system. The diode is sufficiently small to enable a small insect to carry it. It also can work without a power supply at long range distances of more than one kilometer. While a stationary radar system has long range, it also is very expensive to build. Several handheld versions of radar with lower cost and shorter range have been used for security applications such as RECCO Rescue Systems. In practical application, however, harmonic radar systems have a serious drawback; every other object in the operational environment that is fabricated using metal or alloy, may be mistaken as a target with the same frequency response.

- Device using radio signal: Radio Frequency (RF) transmitters are cost neutral, and have comparably less size than a GPS and Radar. While the range of RF transmitters is the same or less than that of a harmonic radar, the transmitter and receiver of the RF system are cheaper and bigger in size. An RF transmitter can be recognized by the RF receiver based on a specific frequency for tracking (in Very High Frequency band commonly)) or by coded data.

- Visual tracking: The development of computer vision techniques has enabled the tracking of target without requiring any attachments. However, only detecting the target's contour and target motion correctly under various light environments is a difficult task. Moreover, it is impossible to detect an object that is very small in outdoor backgrounds, and the distance and motion velocity of object that the camera can recognize are limited even for a large object. Visual tracking has been applied for some targets such as humans, vehicle, and large animals.

1.2. Tracking wasp, a small flying insect

For searching a honeycomb, we approach the tracking problem of a wasp based on its behavior; the wasp returns to the hive after working. By using the localization system on the UAV that tracks the wasp, we are able map the vespiary location on a computer at the station, as shown in Fig.1. While GPS module is too heavy considering the load capability of a wasp, the wasp's size renders it infeasible to use visual tracking systems for outdoor-based long distance tracking. Harmonic radar was considered for this task; however, it seems that there are many metal-alloy objects in the tracking environment (university campus). Therefore, we finally adopted a RF device. However, there are many obstacles in the tracking environment and the range of the RF device is limited, which may result in the tracking system to lose the target because the tracker must take a detour in case it encounters an obstacle. We recommend using an autonomous UAV that bears an RF device for tracking; it is not only avoids obstacle but also reduces the human effort required. Previously, an eight-rotor platform was successfully implemented to track the trajectory of an animal [1]. However, the mean error of distance of the experiment reached 20 meters approximately, causes a trouble to accurately locate honeycomb. Moreover, this system uses a complicated antenna array, and the information about its cost was not provided, given that it is difficult to manufacture or purchase. Our solution for tracking wasps using UAV

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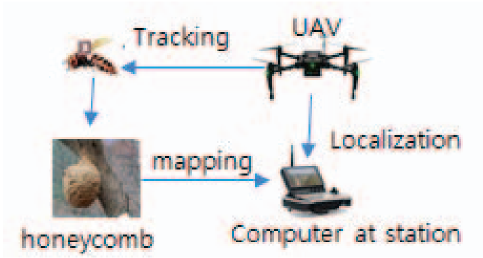

Fig. 1. Searching vespiary based on tracking wasp.

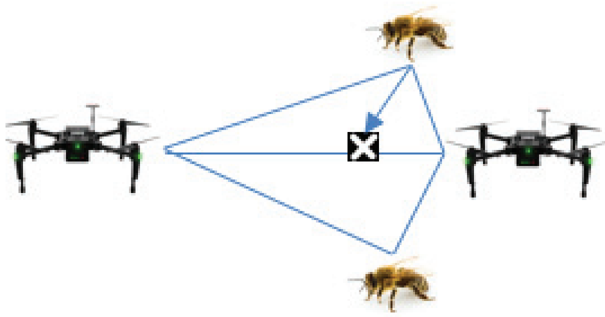

Fig. 2. Two symmetric positions of the wasp can be inferred from distances. The basic idea of this method: do not allow the wasp to cross the line linked between two UAVs during tracking.

includes easy-finding RF devices with accompanying tracking algorithms, which are adaptive for tracking a wasp.

2. Method

A 150-MHz RF receiver, Australis (from TITLEY SCIENTIFIC) and its corresponding transmitter weighing 0.2 grams (from Advanced telemetry system) tested well on a wasp. In addition, we also tested that Australis receiver can recognize signal from transmitter well. Our solution comprises two steps. First, the distance between RF receiver and transmitter (attached on bee) based on RSSI (received signal strength indicator) is estimated. Second, the position of the transmitter is estimated using optimized algorithms.

2.1. Estimation of distance based on RSSI

RSSI has a relationship with distance following logarithm; however, practical measurement is easily affected by multipath fading and shadowing in a cluttered environment [2]. Because of this probabilistic characteristic, in every distinct environments, it requires on-site adaption to find the relationship between RSSI and distance [2]. We conducted experiments to collect data of the receiver (Australis) and ran the program to find the estimated relationship between RSSI and distance.

2.2. Positioning Methods

A. positioning with only one reference point and directional antenna: The basic idea of this method is to ape the operation of human who using a RF receiver to track animal. The RF receiver accompanies a directional antenna, which is very sensitive to the direction of received signal. The user can rotate this antenna to find the direction, which indicates the best signal strength, along the direction of transmitter. Generally, path planning of UAV comprises the following steps:

Step 1: Rotating the antenna
Step 2: Moving towards the direction that gives the best RSSI
Step 3: Checking if the RSSI is increasing or not. If not, returning Step 1. If yes, keep moving.

B. positioning with two reference points: Australis accompanies a directional antenna, which is expensive (2000 USD approximately). Therefore, we propose another algorithm, using a cheaper RF receiver and an omni-directional antenna. The positioning entirely depends on the distances between the two receivers and the transmitter.

In practice, if we only consider the distance from RSSI between the transmitter and the two receivers, there will be ambiguity when there are two positions of transmitter that are symmetric along the axis, which is the straight line linking two UAVs. However, in the beginning of our action, we clearly know the position of wasp before it is released. In other words, if during tracking, the wasp does not cross the symmetric axis, it will be possible to infer the wasps position based on distance between the wasp and the two receivers. For this purpose, UAVs must stand back if the bee is very close, as shown on Fig.2. Then, we determine the critical distance between UAVs and the wasp for stepping back. The critical distance should be sufficient for the UAVs to react on time and deal with error of estimated distance. The value of critical distance will be defined during the experiment. It depends on many factors such as error of estimated distance, velocities of wasp and UAVs.

3. Conclusion

We introduced devices and algorithms for a new approach to the small insect tracking problem. Compared with previous researches, we strongly believe that our system is more appropriate for tracking a wasp. In our subsequent work, we hope to conduct the following:

- Testing algorithms on the real UAVs
- Comparing the obtained results with those of previous researches
- Applying different methods for distance estimation

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