Flying Wing Drones based on Cricket Antennas

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Abstract: Drones represent an important part of the shipsets' domain. There are different application areas and depending on the field of application, problems of stability, trajectory correction and autonomy arise. The flying wings drones are one of the drones' categories inspired from birds flying technique. This category of drones has several problems quite different from the classical drones. Among these problems we can identify the drone hunter issue. To solve this problem, we propose a solution inspired from the wood crickets. In fact, the crickets are extremely fast as they can process information locally. They have a kind of "back brains" that process the information locally and control the movement of their legs. Unlike human who strictly send all information to the main brain that treat them and make a reaction, the cricket has several brains inside the body, so that it can send the information about the airflow to small brains behind its legs. These little back brains not only process the information about the airflow that comes from the crests and their multiple hairs, but also controls the movement of the rear legs. This unusual performance of the crickets' crests hair was the origin of our research contribution. We therefore propose a biometric flow camera based on several electronic hairs connected together. We have selected REMANTA as a winged drone to implement our proposed solution. We will integrate our micro-sensors in this 10 cm dimensions drone to solve three problems: trajectory correction, stability, and enemy avoidance.

1 INTRODUCTION

Nowadays, the performance of embedded electronics is increasing in a regular way, going hand by hand with a more and more advanced miniaturization. Consequently, a great interest is today given to "mini or micro-drones" based on miniaturizedsensors and embedded systems. These kinds of drones have major advantages when used in congested environments or small spaces (urban) in which larger rotorcraft are not well suited. Several rotorcraft architectures are available dependingon the number and arrangement of rotors.

Numerous devices have been developed in recent years in robotics. These devices are equipped with different on-board sensors and used in several application fields such as: civil security, police, customs, military, agriculture, medicine, transport, control, surveillance, etc. Among these devices, we mention drones, smart cars, industrial robots, etc. The navigation of these devices is only possible thanks to the location and realtime orientation using onboard sensors. In this paper, we enumerate the diverse problems facing flying-wing drones and present a solution to avoid the enemy. The solution aims to provide a good and efficient motion estimation task regardless the disturbances in the field. This solution is based on the information coming from sensors, inspired from the cricket antennas.

2 RELATED WORK

A drone is a small device that does not exceed the dimension of 50 by 50 cm and weighting between 300g to 500g (see Figure 1). The drone includes 4 engines and a Lithium Polymer battery rechargeable every 980 minutes (Hayat et al., 2016, Gupta et al., 2015, Motlagh et al., 2016, Mozaffari et al. 2019).

Figure 1: The drone.

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The heart of the drone is an electronic card, such as ARDUINO or STM32Fx, which ensures different actions (see Figure 2):

- Read the flight parameters.
- Read the detector data that describe the rotations and displacements in three dimensions: This is the role of the accelerometer and the gyroscope.
- Provide speed correction to each motor (Motlagh et al., 2016, Khawaja et al., 2019, Khuwaja et al., 2018, Zeng et al., 2016, Kumbhar et al., 2016, Kelly, 2017).

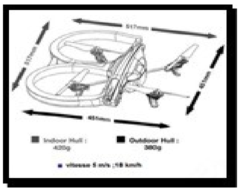

Figure 2: Drone characteristics.

A drone or quadrotor has four rotors. The role of these rotors is to rotate the drone around the vertical axis and modify its vertical acceleration. To ensure the stability of the drone, two propellers must be turned in one direction and the two others in the opposite direction.

There exist several types of drones, among them we can find:

- Fixed wing drone: The fixed-wing drone can reach 80 km/h and can fly for 45 minutes. In addition to its light weight (it weighs 700 grams), its two wings are removable. It was designed to ease manual transport. In addition, it allows to capture photos as it has a camera equipped with a high-resolution sensor of 14 mega pixels and an optical stabilizer (Sebbane, 2015, Korchenko and Illyash, 2013).
- Rotating wing drone: They are miniature rotary wing drones that perform propulsion and lift separately (reactor or propeller, and fixed wing). Rotary wing drones use the same body for propulsion and lift (rotors). Thanks to this feature, this type of miniature UAV is capable of vertical landing and takeoff, as well as hovering or quasi- stationary flight, opening a wide field to new applications (Al-Hourani et al., 2014, Valcarce et al., 2013, Reynaud and Rasheed, 2014, Tozer and Grace, 2001).
- Flying wing drone: A micro-drone or micro-aerial vehicle is a craft less than 15 cm and even 1 cm in length, width and height, capable of flying. Recently, research has focused on the development of swing-wing micro-drones (see Figure 3). In fact, progress in microelectronics has influenced the manufacture of micro actuators, sensors, communication systems, batteries, processors, and so on, favorizing the evolution of this type of drones (Chmaj and Selvaraj, 2015, Zuckerberg, 2014, Gettinger, 2016).

Figure 3: Remanta flying wing drone.

3 DEFINITION OF A FLYING-WING DRONE

Swinging wings are an alternative propulsion system for mini and micro-drones. The flapping of wings reproduces the flight of birds (see Figure 4) or insects (see Figure 5).

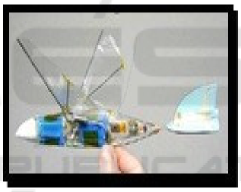

Figure 4: Micro-drones with flapping wings (birds).

An insect consists mainly of three parts (Reynaud and Rasheed, 2014): head, thorax, and abdomen. The head contains vision sensors (ocelli and compound eyes), antennas (sense organs: smell, touch, taste) and mouthparts (to pierce, suck, suck, or chew). The chest consists of three parts (pro, mesa, and meta-thorax) to which are attached the legs, wings and dumbbells.

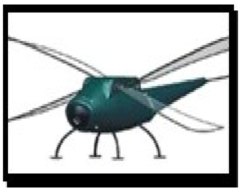

Figure 5: Micro-drones with swinging wings (insect).

3.1 The Flying Wing Movement

The wing of an insect has several degrees of freedom: beat, rotation, orientation of the beat plane (deflection), frequency and other degrees more difficult to model such as bending andtwisting. In this work, the degrees of freedom considered are the amplitudes of the angles of beat and rotation, the wing is supposed to beat in the plane of median beat, with a frequencyof 100 Hz.

- Degrees of freedom: The wing of the micro-drone isconsidered as a rigid body which has three degrees of freedom in rotation: the beat, the rotation and thedeviation.
- Para-measurement of the wings: The control of the micro- drone is done by acting on the corners of its wings.Indeed, the flapping of the wings creates the aerodynamicforces which is generated following the movement of the machine (Mazur et al., 2016).
- Decomposition of the movement of a flying wing: There are different variants of the flying theory, but in general, the theory is only highly simplified because the calculation of the equilibrium forces remains difficult. The aerodynamics of swing wings is more unstable than othertypes of wings (see Figure 6).

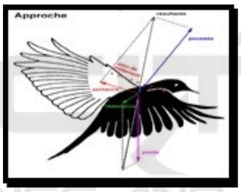

Figure 6: Representation of forces exerted during a flight.

A flying wing is an aerodynamic machine with two working times, the flapping of the wing in elevation and its slaughter.

- Elevation: The air hits the wing rather than coming from the top during the beat.
- The slaughter: the air hits the wing coming from thebottom.

Swinging wings have two roles: lift and thrust. Lift is the component of the force the device experiences when moving in a fluid and acting perpendicular to the direction of that movement. The thrust, meanwhile, is the force exerted by the movement of the air and which allows the displacement.

3.2 Types of Forces

There are 3 types of forces:

- Stationary aerodynamic force: The stationary aerodynamic force is generated by the air pressure exerted on a flapping wing. It is oriented in the opposite direction to the speed of the wing.
- Strength of added masses: Considering that the wing is formed of a single slice, the intensity of the force is dueto the effects of added masses during the rotation of the wing.
- Rotational force: The wings are supposed to be rigid and present only movements of flapping and rotation. Bendingphenomena, difficult to model, are not considered.

3.3 Examples of Flying Wing Drones

3.3.1 Remanta

It is the first French project on micro-drones with swinging wings. It was conducted by ONERA: Office Nationale d'Etudes et de Recherches Aronautiques between 2002 and 2006. Its goal was to deepen the knowledge in aerodynamics, flight mechanics, control, actuators, materials, and structure (see Figure 7).

Figure 7: The REMANTA micro-drone.

3.3.2 Delfly

Started in 2005 in the form of a student project at the Technological University of Delft, Netherlands. The drone, weighing 16 g, has two pairs of wings of 28 cm wingspan, uses a DC motor and is equipped with an onboard camera. It can fly horizontally, stationary, and even backwards.The next phase of this project would be the Delfly microaiming for a 10cm wingspan and a mass of 3g. The final objective is to reach at the end the Delfly nano by further minimizing the size and the energy consumption of the craft (see Figure 8).

Figure 8: Micro Delfly.

3.3.3 Micro-robotic Fly

This project is carried by the Micro-robotics laboratory at Harvard University, USA, and is also supported by DARPA. A first prototype, 3 cm wide, took off in 2007, only in vertical flight with an external power supply and without control. This machine also uses a piezoelectric actuator, but a much more flexible structure than that of the MFI, especially with regard to the amplification of the displacement transmitted to the wings (see Figure 9).

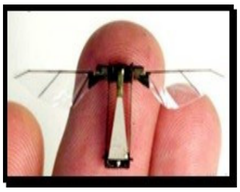

Figure 9: Micro-robotic.

4 FLYING WING DRONES' PROBLEMS

4.1 Flying Wing Drone Range

Flying drone autonomy depend largely on the wind. Depending on the wind strength, it can sometimes greatly reduce the flying drone autonomy. On the other hand, flying in the wind direction, can sometimes prevent you from returning your drone. The risks of loss or crash are then important (Reynaud and Rasheed, 2012).

4.2 Flying Wing Drone Flight Speed

Indoors, these machines can fly from 70 to 80 km/h, but can exceed 170 km/h outdoors. They can reach an average speed of 265.87 Km/h, with a peak at 288.07 Km/h. Acceleration requires perfect control of the machine. It is sure that the weight /power ratio is largely to the advantage of drones. High speed flight, but stable, is less problematic than acceleration. Especially since it is made with blades that must move while maintaining the gear.

4.3 Flying Wing Drone Hunters

One problem that could face a flying-wing drone is drones-hunters. A Hunter drone rely on a set of sensors and attack tools "including a net" to secure an area. In practice, the drone will spot an intrusion into its coverage area, take off, locate the target, throw a net, and bring the enemy to its base (see Figure 10).

Figure 10: Swing wing drone fighters.

There is also a new method such as training eagles to chase a flying-wing drone (see Figure 11). The flying-wing drones should therefore be able to avoid drones' hunters.

Figure 11: An eagle hunting a flying-wing drone.

5 PROPOSED APPROACH: SOLVE THE FLYING WING DRONES HUNTER PROBLEM USING CRICKET ANTENNAS

The wood cricket lives in the edges or holes and it feedson dry leaves. When attacked by a predator, it is able toescape in a lightning way (see Figure 12). We think that it could be interesting to understand the reasons for this extreme sensitivity and use it to support the flying-wing drones.

Figure 12: The wood cricket.

Figure 13: The antennae of the wood cricket.

When the cricket is attacked it will perceive the flow of air thatis caused by the attacker by two organs at the back of the bodycalled creches (see Figure 13). These organs look like antennason which there are a lot of hair. The hairs on these antennasare used to perceive the tiny vibrations of the air. Each of these hairs is extremely powerful, it needs a tenth of the energy of a photon to react and the insect will combine all this informationto escape before being reached by the predator. The sensory hair of the cricket is quite unusual because it is very simple and at the same time extremely powerful, it is nothing but a simple tube that will not bend when the air arrives on it, itgoes to move to its base. There is only one neuron at the base of this hair, which is also unusual, and it is this simplicity that makes these sensory hairs so effective.

The cricket therefore has a kind of “back brain” that processes the information and controls the movement of its legs. Unlike human, who strictly send all the information to the main brain that will treat them and make a reaction, the cricket has several brains inside the body, so that it will be able to send information about the air flow to a small brain just behind its antennas. This little brain not only processes the information that comes from the crests and their multiple hairs, but also controls the movement of the legs. That’s why over millions of years, crickets have been able to escape predators. They are extremely fast because they process information locally. The understanding of the extreme sensitivity of the cricket hair is a source of inspiration from a biomechanical and electronic point of view, in order to imagine high performance micro-sensors. The unusual performance of the cricket hair has motivated the objective of our research (see Figure 14).

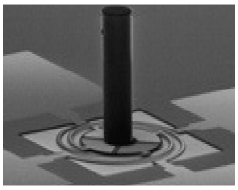

Figure 14: Micro-sensors.

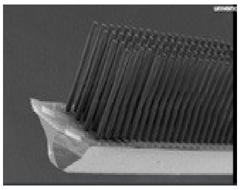

Figure 15: Gathering the micro-sensors.

We have therefore imagined that we can connect several electronic hairs together and this gives birth to a biomimetic flow camera (see Figure 15).

In other words, instead of the pixels found on the usual cameras, we will have micro sensors (similar to cricket hairs). We will therefore have a series of micro sensors that measurea flow image. This work, which has a long-term or even medium-term scope, will be useful in the context of future flying wings drones. In fact, in this kind of systems, it is necessary that the movement of the wing is controlled in continuous time. The wing does not always have the same movement, so we must be able to measure what the wing does, especially in the case of turbulence. And here our hairs are absolutely ideal as they are small and can be put everywhere (see Figure 16). We have selected REMANTA as a winged drone to implement our proposed solution. We will integrate our micro-sensors in this 10 cm dimensions drone to solve three problems: trajectory correction, stability, and enemyavoidance. We will afterward reduce the size to reach a drone of 2 cm using other materials that have reduced size.

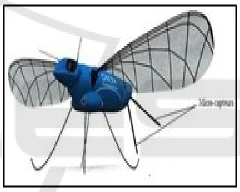

Figure 16: Micro-sensors in REMANTA.

6 CONCLUSIONS AND ONGOING WORK

In this paper, we have presented the technological advances and the growing interest in aerial robotics over the past ten years. The different types and forms of air targets created by the great utility, allow to accomplish the required tasks in complex environments. Since the perception of the environment is a necessary process in these tasks, the majority of the moving drones are connected by different sensors used to navigate and detect obstacles during their journey. Our studied system the flying wing drone is among these drones, that requires sensors to control and monitor its attitude. In this paper, we presented an overview of the different stages of development of this project. Indeed, after presenting the state of the art, defining the drone, their flight mode, the different types of drone, we focused on the flying-wing drone problems. We presented our idea to solve the course correction and enemy escape problems, inspired from the wood cricket. The solution consists in adding micro-sensors placed in the rear of swinging wings drones. We plan to reduce the size to reach a 2 cm drone using other materials.

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