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Target Tracking by Flying Drone with Fixed Camera

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Abstract**—**This paper presents the software conception of a quadrotor UAV, named SKYWATCHER, which is able to follow a target. This capacity can at a long turn time permit to follow another drone and combine their performance in order to military missions for example.

From a low-cost architecture constructed by five students we implemented a software and added a camera to create a visual servoing. This project demonstrates the possibility to associate the technology of stabilization and the technology of visual enslavement.

Keywords**—**Quadrotor, visual servoing, student project, image processing, Unmanned Aerial Vehicles, stabilization.

I. Introduction

THE word "UAV" names an unmanned aerial vehicle, also named "drone". There are several types of drones: micro-drones, short, medium and long-range drones, aquatic or high altitude drones… Their use has truly started during the Vietnam War, where they had a scouting role. Drones had initially a military use. Technological advancements allow them to become more and more efficient and consequently to fulfill more complex objectives.

In recent years, UAVs are no longer only confined to the military domain, but have civil applications, like supervising, endangered people rescue, etc. Moreover, entertainment drones are now commercialized, such as the Parrot AR Drone, but this one tends to have closed source software which cannot be recovered or modified. Moreover, drones have a strong popularity in the domain of model aircraft where many projects flourish.

Current drones range from micro-drones, with a lesser wingspan than 0.5m, to drones of the size of small airplanes or helicopters. Majority are equipped with optical sensors to ensure at least a video feedback.

We noticed that the main challenge of these drones is a compromise between accuracy, response time and board weight. In fact, these three performances are linked. If you want to improve one, it has an impact on another.

We analyzed the performances of drones uses nowadays. Three categories appeared:

One type has a high response time and a board weight but few accuracy like the Predator, which killed many innocent people because of his lack of accuracy [8], [9].

Another type has a high response time and accuracy but a board weight limited like the Ar Drone, which is impossible to embark a projectile.

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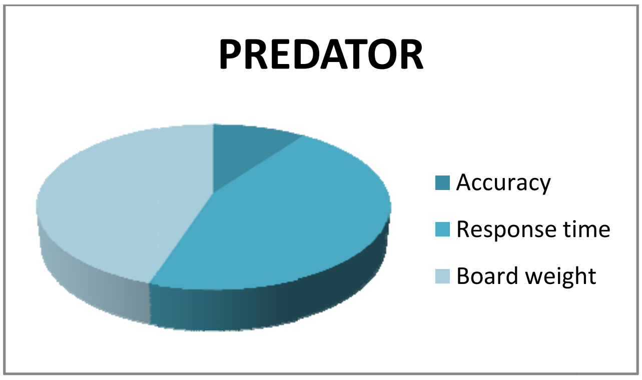

Fig. 1 Performances of predator drone

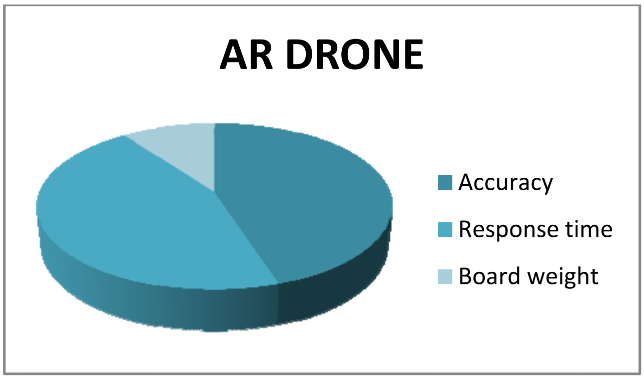

Fig. 2 Performances of AR drone

The last type has a high accuracy and board weight but has a long response time like the CL-289, in fact it takes pictures and it is exploitable only at the end of its flight.

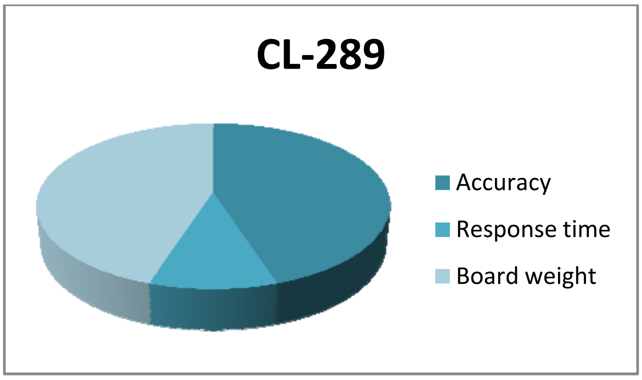

Fig. 3 Performances of CL-289

Thanks to this overview, we pointed out a real lack of drone with an equal repartition of performance.

Therefore, we decided to concept a drone with these characteristics:

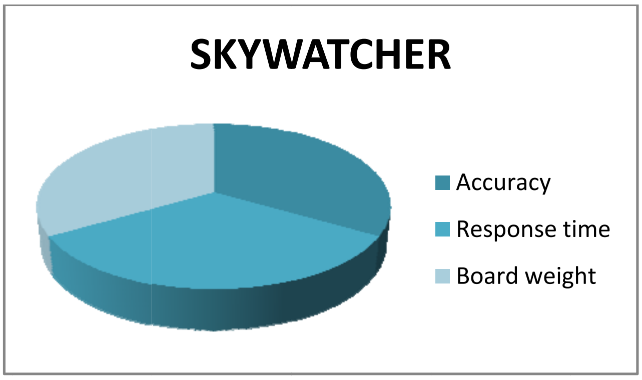

Fig. 4 Performances of our drone

This goal leads us to make different technical choices in our research to visually enslave an already built drone.

We want it can follow in an autonomous way a moving target on the ground and able to recognize a simple form from its camera (image processing) and able to follow it.

Besides, we took up this challenge under certain conditions: an inexpensive academic environment and a short period.

II. Image Processing

First, to have a picture we have to choose the sensor. In order to answer to our goal of a good response without decrease accuracy and board weight time we chose a fixed camera.

Usually sensors are embedded according to two different principles: either the sensor is placed in a mobile device, for example, a rotary turret, or the sensor is fixed and integral with the drone [3]. These two arrangements each have their advantages and disadvantages. If a mobile support allows the sensors to observe a target regardless of the position or the direction of the drone, it requires the additional servo control of the support, which must then take the movement of the drone into account. A stationary sensor has then the advantage of the response time, since there is only one enslavement: the one of the drone.

The purpose of the image processing is to identify a target depending on its shape and color. Detection circle was chosen for its ease and reliability. The color is selected by the user or pre-recorded.

The program receives an image directly from the camera. It is then treat by a Gaussian blur to reduce artifacts created by the camera during capture. An optional step can be performed: the values of the pixels are changed by an affine function. It allows having artificial colors, but these colors differ better from each other to prevent from color confusion.

Next the image is converted from a conventional BGR (Bleu Green Red) basis to a HSV (Hue Saturation Value) basis. This conversion is done in order to work only on the hue and saturation components and thus to let free the value component. This method allows retaining some flexibility in color detection.

Once again to improve the response time without impacted the accuracy the image is binarized. A new image is created in which all the elements of the hunted color (with a tolerance value and by only considering the H and V components) are white, the other colors become black. Pure black and white mask is obtained (not a grayscale one). This mask is then subjected to dilation and erosion to remove possible noise pixels. The number of iterations of these operations may be changed if required.

The final step is the application of the generalized. Hough transforms to detect the circles on the mask resulting of the binarization. The coordinates of the center of the circle and its radius, so the position of the target and its relative size, are thus recovered.

The detection is a chain of low-complexity operations. Its reliability is nevertheless ensured by a joint detection of shape and color. The accuracy of the result depends on the value of various parameters, such as color tolerance, power of applied filters … These parameters should be set according to the chosen target and the UAV environment to have the best result.

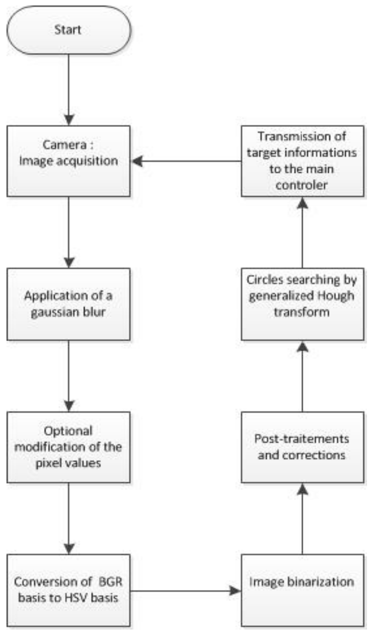

Fig. 5 Image processing algorithm

III. Visual Servoing

It is an indirect enslavement [1]; actually the visual servoing is in a higher layer than the horizontal stabilization of the drone. This layer acts on the target tracking.

To ensure the visual control of the drone, a camera is embedded and connected to a microcontroller [4]. The image processing is done by a specialized library, OpenCV. This process seeks to recognize a predefined target (defined by the user or already registered). Once the target is locked, the drone aims to follow it until another order is given [5].

The image processing has been previously described so let see how it actually works. The servoing runs as follow: relative coordinates of the target are measured on the image and return to the drone processing unit. Depending on these, the drone tries to align itself with both pitch and roll axis, and to move closer to the target. For this purpose, threshold values in pixels are set in the picture to create a frame that should not be passed beyond. The maximal distance to the target, representing by the detected radius of the target on the picture, is also set. If the radius is lower than the value of reference, the drone moves, otherwise it stops. Cf. Figs. 7 & 8. In this graphics the target go away in front of the drone and it is apparent that, proportionally to the distance traveled by the target, the drone reacts to realign itself [6], [7].

The standard stabilization is still on, but it only keeps the drone stationary and not interacts against the chase. More precisely, it attempts to correct the roll to hold the UAV on the trajectory to the target and the pitch angle to ensure the drone to move forward its target [2].

As we can see in the Fig. 8 a displacement of the target triggers a fast reaction of the UAV. In approximately 40ms the drone starts to follow the target and the more the UAV is far from the target the more it increases its speed and its compensation. Finally when the target is close enough, it stops the compensation as quick as it begun and stays stable above the target. We remark that the time to start the target following is equal to the time to stop. It allows the drone to stay at range and to continue to follow the target if it moves again. And without lose the target. This specification of our drone allows gives it balance between the three arguments we talked about in the introduction.

The tests were done in the best possible conditions without wall, wind or trees, and by moving ourselves the target to examine the effect of the servoing on the motors and the drone placement.

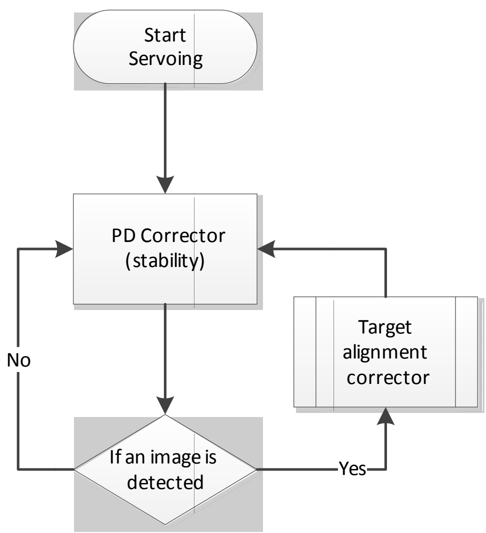

Fig. 6 Enslavement algorithm

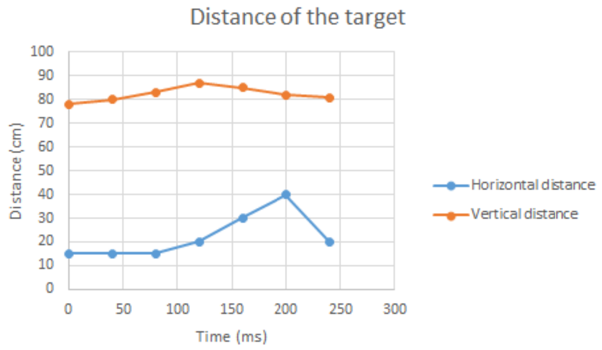

Fig. 7 Distance of the target

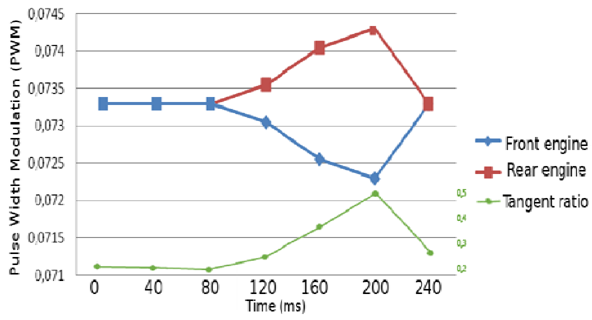

Fig. 8 Relation between power and offset angle

IV. Conclusion

In this project, members of a student team developed the visual servoing of quadrotor UAV, SKYWATCHER. Through a color and shape processing, an embedded and fixed camera, a control and efficient stabilization algorithm that can compensate the immobility of the camera, the UAV is capable of tracking a target.

The SKYWATCHER project shows that it is possible to create an operation UAV that is capable of tracking a target while having a fixed camera. An improvement axis of this drone is the maximization of its autonomy by embedding all the processing. This, combined with the fixed camera, would significantly reduce the response time and increase the autonomy of the UAV.

This improvement is realized with the goal of have a well response time and accuracy

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