MINIMIZING THE IMPACTS OF WIND GUSTS ON A QUADROTOR MINI-UAV

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ABSTRACT

UAVs are very useful in the current era of technology. Several studies have been conducted to optimize and improve the functioning of these systems. These aerial vehicles are very often used in the field of photography. However, they are sometimes sent on dangerous missions as a war machine or to deliver medicines in unfavorable environments. It is essential that the commands sent to the UAV are accurate and that it can be adapted to different environments.
In some countries, it can be very difficult for cars or people to move freely from one place to another when the wind gusts are very strong. It also happens that when there is heavy rainfall, some neighborhoods are flooded. In this case, a solution to these problems is to use a flying device that can fly back and forth without difficulty. UAVs can be adapted to this type of situation. This study is based on how to ensure that the capacity of the UAV is always optimal despite the presence of wind. In other words, we try to get signals close to the initial signals despite the wind gusts. This is the continuation of a previous work based on the effects of external disturbances on a quadrotor mini-UAV. To carry out this analysis, MATLAB and SIMULINK were used. A human-machine interface has been created to facilitate the use of the designed software. The initial curves and those after exposure to wind gusts were then obtained. Finally, we have integrated a corrector allowing us to have signals approaching the initial signals. This means that the drone will be able able to adapt to gusty winds.

Keywords : - *Mini-UAV, quadrotor, gust wind*

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1. INTRODUCTION

UAVs are nowadays indispensable devices in various fields, whether for civil or military use. They can be used for medicine transport, endemic species surveillance, or photography. However, drones are sometimes forced to encounter gusty winds. In this case, they will be disrupted and this could have an impact on their operations.
This study was initiated to minimize the impact of these disturbances on the drone. In this article, some of the parameters essential to the functioning of the drone will be presented. Then, the results of the simulations performed will be given. The research is based on how to get a better performance of the UAV despite all the gusty winds.

2. PRESENTATION OF THE QUADROTOR MINI-UAV

In principle, a UAV is a flying device designed to perform various tasks. They are autonomous or semi-autonomous. The number of motors it has depends on the type of device. For the quadrotor, there are four engines. Two propellers rotate in one direction and two others rotate in the opposite direction.

The four movements used by the quadrotor mini-drone are yaw, roll, pitch and vertical. The yaw movement is used to turn the drone on itself. It is obtained by increasing the speed of normal-pitch propellers and decreasing the speed of inverted-pitch propellers proportionally. Roll and pitch are fairly similar movements designed to tilt the drone on one axis or another. This movement is obtained by increasing the speed of a propeller and proportionally lowering the speed of the opposite propeller (propeller of the same torque). The vertical movement simply corresponds to the rise or fall of the quadrotor. The climb is obtained by increasing the speed of the four engines. The descent, which is more difficult to measure, is obtained by reducing the speed of the engines. [1] [2]

3. MATHEMATICAL PARAMETERS

When you want to operate a drone, it is necessary to know how to take into account Euler's angles (ψ, θ, φ). [3] These angles are important in describing a rotation in a three-dimensional space. The passage of a coordinate system to a coordinate system is carried out by 3 successive rotations :

- precession (gradual change of orientation of the axis of rotation of an object), around the axis O_z, move from O_{xyz} to the referential O_{uvz} ;
- nutation (periodic swing of the axis of rotation), around the O_u axis, passes O_{uvz} from to $O_{uwZ'}$;
- the clean rotation around the axis O_{zo}, from O_{uvz} to the axis system linked to solid $O_{X'Y'Z'}$.

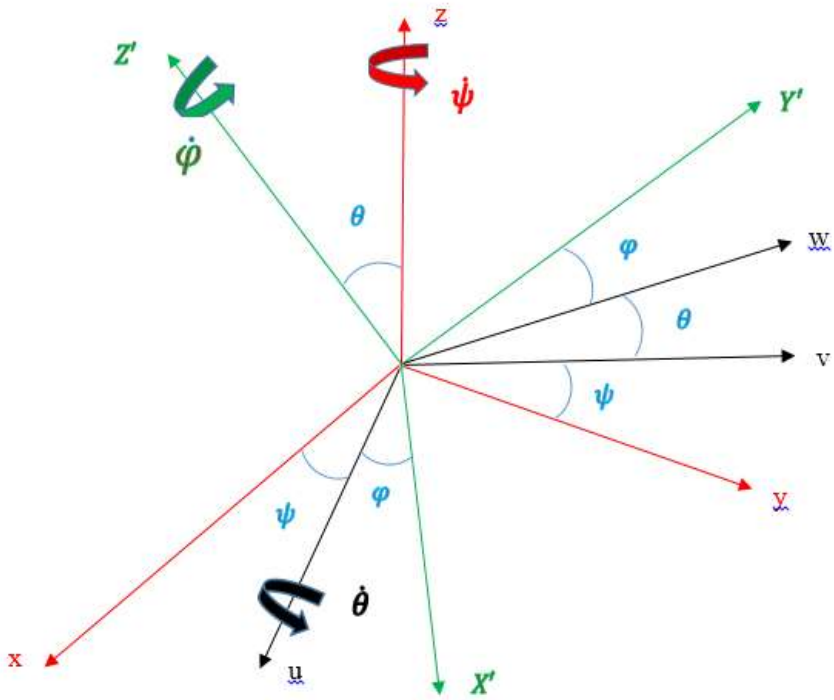

Fig -1 : *Angle of Euler*

4. CONTEXT OF MINIMIZING IMPACTS

The main objective is to simulate the sending and receiving of signals from a quadrotor mini-drone that encounters wind gusts and then minimize the impacts of these gusts on the mini-drone. To do this, the mini-drone must first be modelled by taking into account the appropriate parameters in relation to the motors and sending it control signals.
Then, this model will be subjected to gusts of wind, taking care to see the difference between the order results. And finally, a corrector will be integrated into the model to minimize the effects of gusts. The parameters to be taken into account in the chosen model are resistance, cyclic inductance, number of pairs of poles, electromotive force constant, rotor flow, moment of inertia, dry friction, viscous friction.

The concerned engine contains integrator, several gains, adders and subtractors. This is the SIMULINK model of the motor. We send signals of command to the input. This signal will be added to the rest of the model. As we can see, there are many loopbacks. [4] [5]

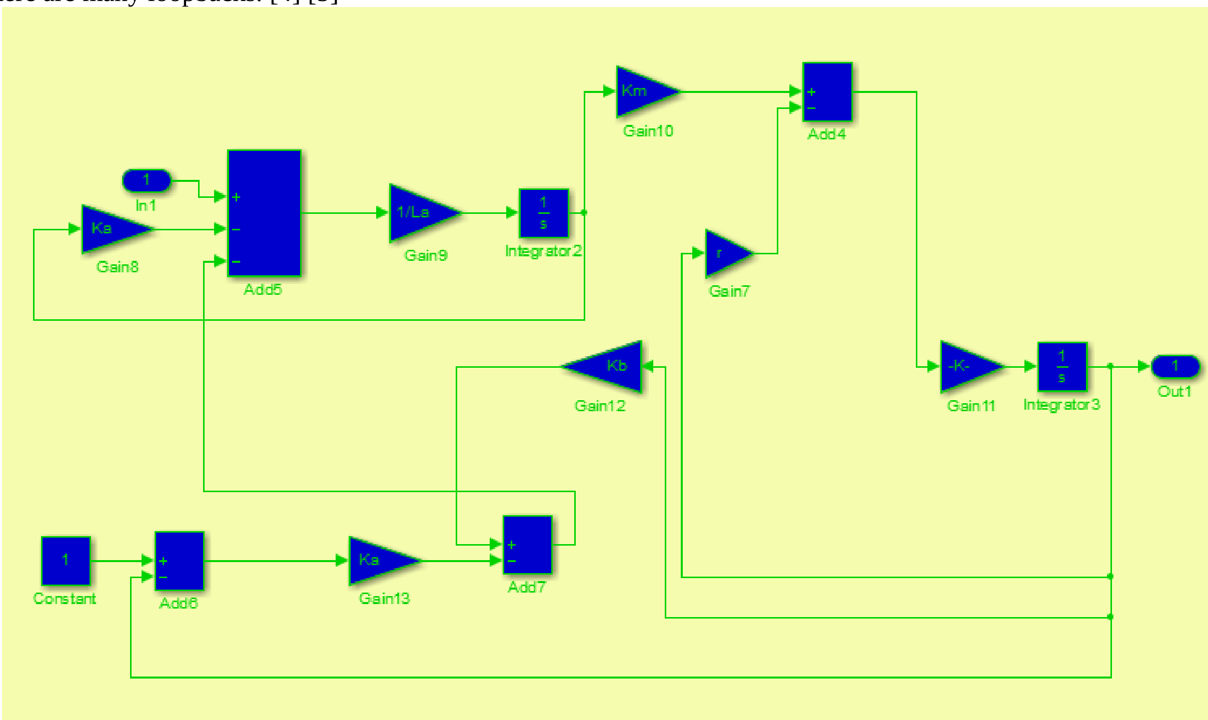

Fig -2 : *Simulink Model of the Motor*

5. SIMULATION AND RESULTS

An application was built in MATLAB to simulate the different operating steps. After several researches and comparisons, these are the appropriate values of each parameters of the motor. [5]

$$\begin{cases} R = 0{,}39 \\ r = 0{,}5 \end{cases} \quad (1)$$

These are the values of the resistors used in the motor. Then, we have the different inductances.

$$\begin{cases} L = 49{,}5 * 10^{-6} \\ L_d = 49{,}5 * 10^{-6} \\ L_q = 49{,}5 * 10^{-6} \\ L_a = 0{,}035 \end{cases} \quad (2)$$

Finally, we also use different values like rubbings and pulsations.

$$\begin{cases} P = 7 \\ P_{hir} = 0{,}012 \\ J = 1{,}5 * 10^{-5} \\ f_s = 2{,}098 * 10^{-3} \\ f_v = 1{,}181 * 10^{-4} \\ E_{psc} = 0{,}8 \\ w_c = 2\pi * 2000 \\ w_{cv} = 2\pi * 200 \\ p_{ej} = 2 \end{cases} \quad (3)$$

This is the first interface of the program. We use the GUIDE command to build this interface.

Fig -3 : *First interface of the application*

On the one hand, we have the different engine parameters mentioned in the previous paragraph such that Kpc,Tic, Kpcv and Ticv are calculated using the following equations. [5]

$$Kpc = 2 * Epsc * L - Rbe \tag{4}$$

$$Tic = \frac{Kpc}{wc * wc * L} \tag{5}$$

$$Kpcv = 2 * Epsc * J - fv \tag{6}$$

$$Ticv = \frac{Kpcv}{wcv * wcv * L} \tag{7}$$

On the other side, we have access to the various menus, the most important of which are: the "INITIAL MODEL" menu, which gives access to the model of the mini-drone, which is not yet subjected to gusts, the "Disrupted MODEL" menu, which gives access to the model, which is subjected to gusts of wind, and finally the "Corrected Disrupted MODEL" menu, which gives access to the model, which has been corrected.

5.1. Initial model

Since the mini-drone contains four engines, it was decided to send four control signals that act on yaw movement, roll movement, pitch movement and vertical movement respectively. This is the model in question under SIMULINK.

Fig -4 : *Quadrotor mini-UAV model under SIMULINK*

At the exit, there are oscilloscopes corresponding respectively to the Euler angles, the altitude of the mini-drone and the body speed of the mini-drone. In this article, it is the speed of the body that will be treated. We therefore simulated over a period of 100 s. And here is the result.

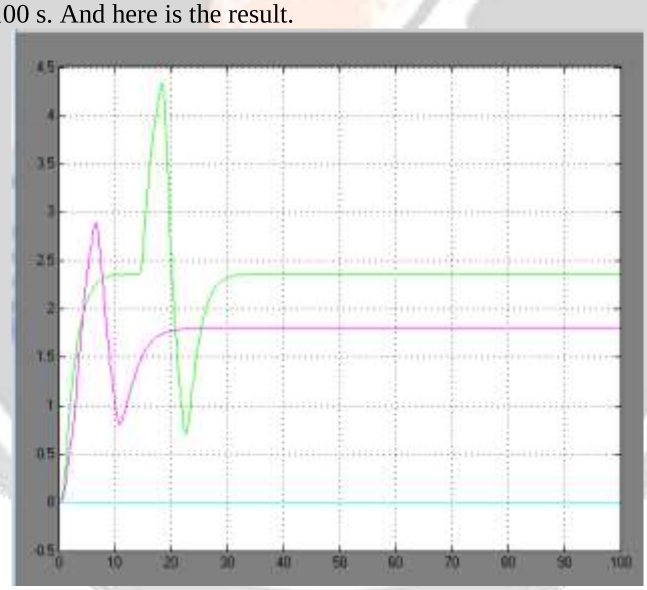

Fig -5 : *Mini-drone body speed without disturbance*

These curves represent the speeds of the mini-drone on the x, y and z axes when the model is not subjected to disturbances. It can be seen that the user first tries to vary the signals by considerably increasing the speeds and then decreasing them abruptly to then have constant speeds.

The objective is that even under wind conditions, the curves should be similar to those in this figure. Before seeing the model disturbed, it is necessary to specify that the mini-drone contains several subsystems.

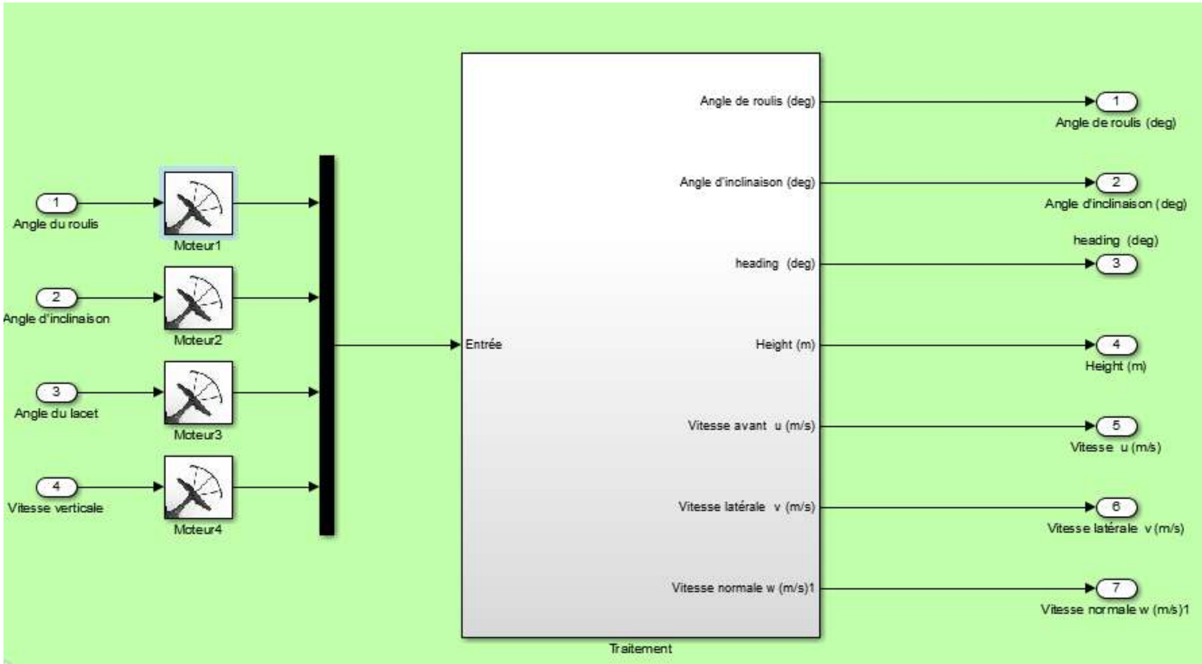

Fig -6 : Mini-drone subsystem

This figure shows the subsystem of the mini-drone in which the four engines and the information processing system can be seen. The motor parameters have already been processed.

5.2. Model subjected to wind gusts

In the "Processing" section of the previous model, a few parameters have been added to ensure that the drone is subjected to gusts. This is the part in question.

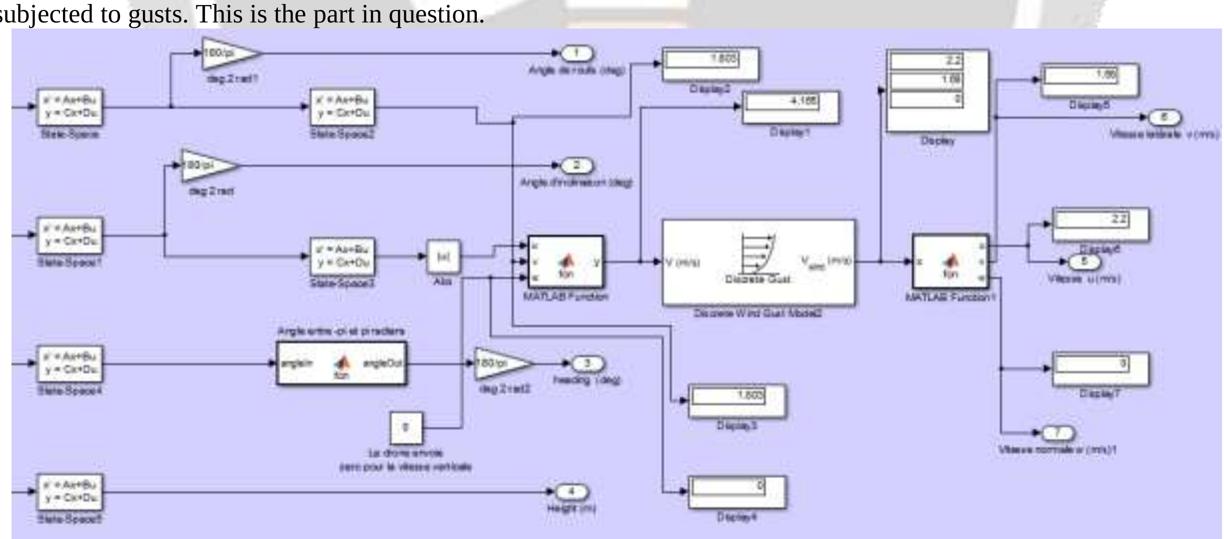

Fig -7 : *Treatment of the model subjected to wind gusts*

The mathematical model of the wind gust for a mini-drone is defined by the following relationship. [6] [7]

$$V_{raf} = \frac{V_m}{2}\left(1 - \cos\left(\frac{\pi x}{L_u}\right) t\right) \tag{8}$$

Where Vm represents the amplitude of the wind gust (m/s), Lu represents the length of the gust in (m) and x is the distance travelled in (m). The length of the Lu gust is traditionally taken equal to 25 times the aerodynamic chord of the main rotor blade of the UAV. And here is the curve corresponding to the different speeds of the mini-drone after disturbance.

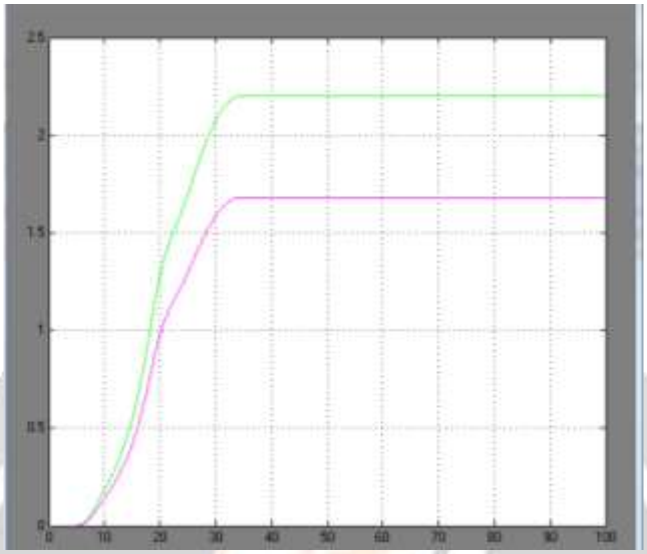

Fig -8 : *Speed curve subject to disturbances*

First of all, it can be seen that these curves differ significantly from the curves obtained when the drone was not subjected to gusts. Then, we see that drones take a long time to have a stable speed. Between 0 s and 34 s, the signals try to reach a constant value.

5.3. Corrected model

For the corrected model, a function has been integrated to evaluate the signals sent into the device. Then, the extent of the disturbance caused by wind gusts is assessed. The corrector contains a program that connects the mini-drone and the gusts. Thus, functions are integrated in MATLAB as in the following model.

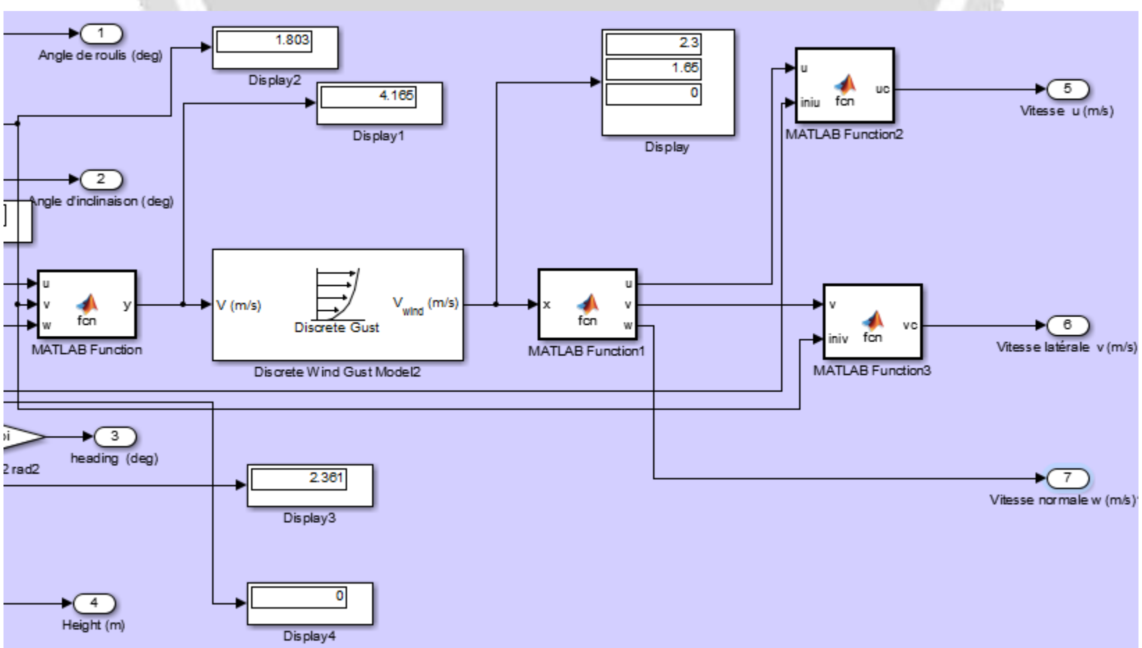

Fig -9 : *Processing the corrected model*

And here are the curves obtained. We can see that these are very close to the curves obtained without wind gusts.

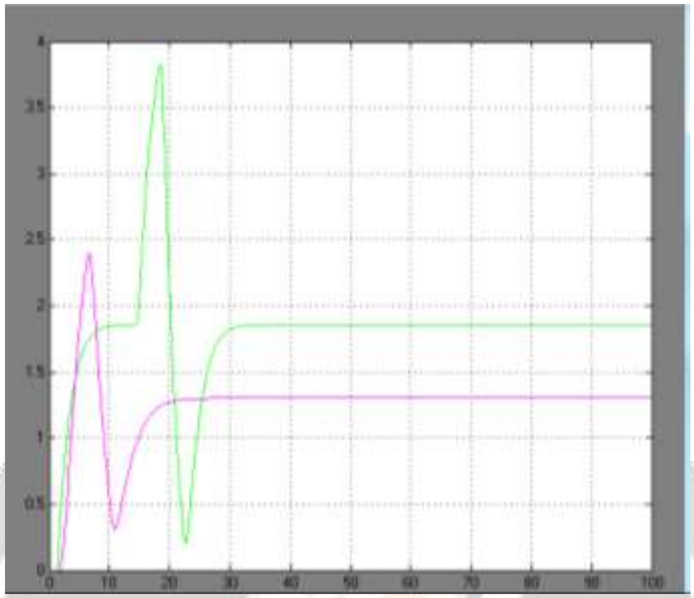

Fig -10 : *Corrected curves*

Before both curves reached constant values, we can see that they are very similar to the original curves. The only difference is about the amplitude. Indeed, the maximum amplitude of the velocity is near 3,7 m/s. In the original curves, the maximum amplitude is superior to 4 m/s. However, despite that little difference, the UAV will be able to adapt to wind gusts.

6. CONCLUSION

This research was based on how to counter the effect of wind gust on a quadrotor mini-UAV. The simulation was in the MATLAB Software. An application was designed so we can interact with the SIMULINK Model. Many subsystems have been treated. We had Model of the mini-UAV without any perturbation, a model perturbed by a discrete gust wind and a corrected model. Even if the model is not perfect yet, it can already support gusty wind. The objective in the future is to ameliorate this model so it can adapt to any type of disturbances.

7. REFERENCES

[1]. T. Hamel, *« Modélisation, estimation et contrôle des drones à voilures tournantes »; National Day of Robotic Research,* 2005.
[2]. A. Walid. *« Bounded error estimation and design of guidance and control laws for small UAV's in presence of atmospheric perturbations »*, february 2018.
[3]. P. Michel, *« Commande d'un minidrone à hélice carénée : de la stabilisation dans le vent à la navigation autonome »,* april 2006.
[4]. A. Jordan, C. Wossler, M. Beekman. *« A scientific note on the drone flight time of Apis mellifera capensis and A. m. scutellata »*, january 2018.
[5]. K. Valavanis,. *« Advances in unmanned aerial vehicles: state of the art and the road to autonomy»*, 2007.
[6]. M. Adnan, G. Abba, *« Modélisation et commande de vol d'un hélicoptère drone soumis à une rafale de vent »*, France, 2008.
[7]. D. Bacar,. *« Etudes des lois de pilotages des véhicules aériens »*, september 2017.