MISSION MANAGEMENT FOR AN AUTOMATED PILOT SYSTEM MOUNTED ON A FIXED-WING TWIN-ENGINE AIRPLANE UAV

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Abstract: *UAV systems used automated pilots which can be configured based on the mission. The entry level market for this type of systems is not focus mainly on fixed-wing configurations. On this paper we asses, develop and simulate missions for an automated piloting system, built on a Cube Orange architecture. The flight controller is mounted on a fixed-wing twin-engine airplane built using additive manufacturing technologies. For the management and simulation of UAV mission we use Mission Planner, and open-source software from ArduPilot. The missions is simulated to obtain an improvement of the automated piloting system, evaluate the terrain from the flight path, avoid dangers, keep out of restricted areas and find the optimal routes.* .

Keywords: *Aerospace, Fixed-wing UAV, Automated Pilot, UAV Mission Planning, Additive manufacture*

1. INTRODUCTION

Unmanned Aerial Vehicles systems have become more affordable to build, but still, there is the need for careful planning, designing and implementation. The research is focused on a couple of directions: UAV quad-copter development [1,2,4,5,7], UAV fixed wing development [6], UAV automated system integration [1,2,3,4,5,6], Communication interfaces [3,8,9], Simulation, Navigation, Stability and missions types [1,2,3,4,5,6,7].

The UAV community is expanding each day with products and solution reigning from underwater to ground and air vehicles. In the near futures they're numbers will increase as prices go down, this will lead to crowded sky's and communication band. On these premises an autopilot with flight instructions on board that does not need ground guidance in achieving is goal is crucial. Such a possible mission (mapping an area) was developed in the present paper.

When making an autonomous flying vehicle, one of the most important factors, is the flying path of the aircraft. Based on the mission profile this flying path needs to change sometimes even during flight.

On the present paper, we used a 3D printed airplane, with 3D printed engines, which has implemented an automated control system built around a CubePro Orange processor mounted an PixHawk motherboard.

The airplane was manufactures using additive manufacturing technologies, more exactly, for the fuselage and wings we used Fused Deposition Modeling and as material reinforced composite with short fiberglass for the fuselage and reinforced composite with short carbon fiber for the wing. The parts were manufactured on a Zortrax M300 Dual, used for composites with fiberglass, and Ultimaker S5, used for composites with carbon fibers.

On the airplane were mounted two brushless motors, manufactured using Selective Laser Sintering method from A6 steel on a 3D System SPRO 60 SD. The manufactured motors develop 10 kgf each and are equipped with 15 inch counter rotating blades.

FIG. 1 Simulation of the model aircraft made from 3D printed composite materials [10]

The CubePro Orange controller was mounted on the airplane using as interface a PixHawk motherboard. We are using this controller to command the servos in flight (engines, flaps, ailerons, stabilizer and direction) but also to send telemetry to the Ground Control station using a wireless 8GHz transmitter. Alongside telemetry we send video signal from a Tau 2 Longwave Infrared Thermal Camera Module using a 5GHz analog video transmitter. The video signal has over imposed the telemetry information gather during flight.

When computing the flying path one of the major influencers of the outcome is the Tau 2 Longwave Infrared Thermal Camera Module. Exposure time, focal length and objective dimensions are parameters that directly influence the altitude of the airplane and the flight speed.

The flight path is based on aircraft mission, and each mission has two repeating segments of the flight path, takeoff and landing. We need to define each path segments as a single path, saved it and append it each time we need to take off and land.

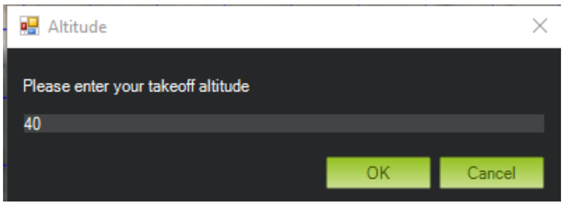

FIG. 2 Takeoff altitude

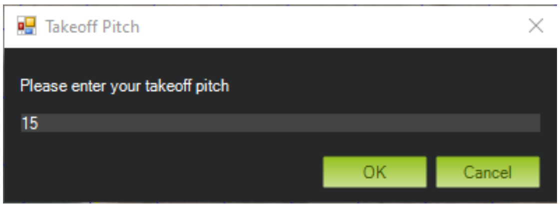

FIG. 3 Takeoff pitch angle

To define the takeoff segments the first step is to study the terrain and select an appropriated take off runway, the runway needs to be straight and have sufficient length in order to reach takeoff speed flight. In Mission Planner we select first the home location and define a takeoff with the following parameters, takeoff altitude 40 m and pitch 15 meters (Fig.2 and Fig. 3). This two values depend on the airplane design and were computed when we first calibrated the aircraft [10]. The automatic takeoff means that the throttle is to maximum and the airplane climb to the designated altitude with the designate minimum pitch angle (how steeply the aircraft will climb during the takeoff).

The designated altitude, during takeoff, defines the altitude, above the home location, that the airplane needs to reach in order for the takeoff to be considered complete. Takeoff direction is set from the direction the plane is pointing when the automatic takeoff command is started.

Automatic landing is part of the mission. In order to land the aircraft, the autopilot needs to know the latitude and longitude of the touchdown pot along with the altitude which will be 0 this time. The last step in the landing procedure is the flare point, is the stage were the autopilot cuts off the throttle and raises the pitch in order to increase drag a slow down the aircraft to touchdown. The flare point is defined by two more parameters the time in seconds before the aircraft would hit the ground if it continued with is current descent rate and the second parameter is the altitude above ground, in meters, at which the aircraft will flare, not taking into account the value of the first parameter.

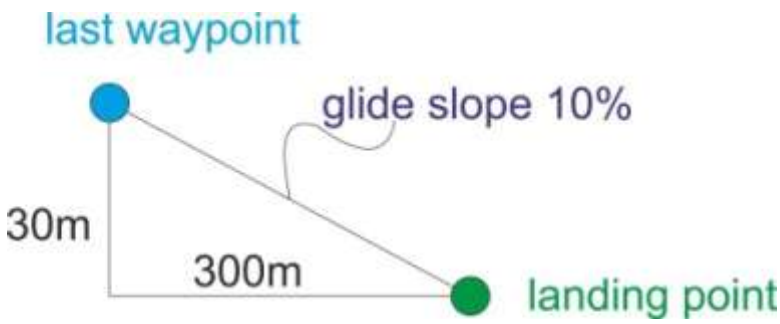

FIG. 4 Glide slope case study

Besides the flare point on landing, at a great importance is the glide slope. The glide slope represents the ratio of the distance from the last waypoint to the landing point. The recommended value for the glide slope is about 10%, this means that the distance between the landing point and the last waypoint should be 300 m and the altitude of the last waypoint should be 30 m (Fig. 4).

Last of the parameters that we need to take in account is the landing speed. The landing speed should be a speed above the stall speed of the aircraft, but low enough that the aircraft is able to lose altitude and land in a reasonable distance.

FIG. 5 Landing path generated in Mission planner

Taking all the above parameters into account we will generate a landing path based on 6-7 waypoints. First, we will need to align the airplane with the runway and we will do an approach path with descent in order to aircraft to runway and having the necessary distance to land. If we cannot do a straight approach, we can generate a downward helicoidal path that will take us to the desired altitude with the desired slope of approach. In the present paper we took into account a sideway approach with a straight landing on the Sânpetru airfield (Fig.5). As it can be seen from Fig. 5 starting from waypoint 6 we start to descend with 30 m at each waypoint until we reach the last waypoint were we have 30 m and a distance to the landing point of 300 m.

FIG. 6 Survey grid with picture squares simulation overlap

Our final goal is to generate a survey grid for 3D or thermal rendering of the terrain to be used in search and rescue missions or mapping technologies.

When aiming for a survey grid mission, the parameters that influences the path are the ones that create a good rendering. That means that we need to accomplish at least 100 pictures, at the overlap between consecutive picture should be between 65% and 80%, but higher would be better. The altitude of the mission will depend on photographed subject, for large flat area a good detail will be achieve with a 40-80 m altitude, while for buildings flying higher the 100m will reduce distortions.

The higher the altitude of the vehicle the wider apart we can create the tracks, and because we aimed for an overlap of at least 65% then we can create a strategy with tracks between 25 and 100 m, but by increasing the altitude to 120 m and using a 40 m distance between tracks we obtained an 80% overlap (Fig.6).

To this grid we appended takeoff and landing segments and we obtained our final flight plan for our autopilot Fig. 7.

In order to reduce development times for future missions we modularized the mission and created separated segments that can be used as individual flight paths or as parts of a bigger flight path. Based on the mounted FLIR camera we generated a grid pattern that will provide around 1000 pictures of the area, pictures that will be used in future experiments to generate 3D terrain mapping, air survey data or search and rescue missions. Path optimization for distance, load and flight time is an ongoing problem which will need further studies.

FIG. 7 Defined flight path with landing, survey grid and landing attached.

CONCLUSIONS

Automatic path generation and automated pilots provide a good replacement for human pilots when doing repetitive work, but also can assist in normal flight to stabilize the aircraft.

When doing repetitive work a human can became board and make mistakes, this is not the case for automated system, they excel at doing repetitive work without error, if the environment parameters remain the same, and the system was programed correctly.

When a UAV has the capability to take off and land on its own, and also complete a mission, this create an opportunity to use multiple autonomous vehicles in order to reduce time and speed up the process. Time is at most important in search and rescue missions, and time is converted into money when surveying a terrain. Also the weather has a great impact on the flight time, and being able to do more in less time is a necessity nowadays.

By using a path generation software in conjunction with a good configured autonomous guiding system, the pilot does not need to be an experience pilot and can control the aircraft from a distance just by changing the waypoints or flight modes.

The flight time is directly linked with the battery consumption, by configuring a flight path beforehand and doing a flight simulation we know if the mission can be accomplish and if we have reserves for other unplanned objectives.

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REFERENCES

[1] Darwante, S., Kadam, A., Talele, H., Ade, O., & Bankar, A. (2019, September). *Border Surveillance Monitoring Application*. In 2019 5th International Conference On Computing, Communication, Control And Automation (ICCUBEA) (pp. 1-6). IEEE;

[2] Uddin, S. M., Hossain, M. R., Rabbi, M. S., Hasan, M. A., & Zishan, M. S. R. (2019, January). *Unmanned aerial vehicle for cleaning the high rise buildings*. In 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) (pp. 657-661). IEEE;

[3] V. Prisacariu, C. Cioacă, D. Luculescu, A. Luchian, S. Pop, *Consideration about UAV command and control. Ground Control Station*, in *Journal of Physics: Conference Series*, Volume 1297, No. 1, p. 012007, 5th International Scientific Conference SEA-CONF 2019, 17–18 May 2019, Mircea cel Batran Naval Academy, Constanta, Romania;

[4] Paul, J. K., Yuvaraj, T., & Gundepudi, K. (2020, December). *Demonstrating Low-Cost Unmanned Aerial Vehicle for anti-Poaching*. In 2020 IEEE 17th India Council International Conference (INDICON) (pp. 1-7). IEEE;

[5] Sohail, S., Nasim, S., & Khan, N. H. (2017, April). *Modeling, controlling and stability of UAV Quad Copter*. In *2017 International Conference on Innovations in Electrical Engineering and Computational Technologies (ICIEECT)* (pp. 1-8). IEEE;

[6] Enomoto, M., & Yamamoto, Y. (2015, August). *Modelling, simulation and navigation experiments of Unmanned Aerial Vehicle*. In *2015 IEEE International Conference on Mechatronics and Automation (ICMA)* (pp. 482-487). IEEE;

[7] Bhatti, D., Bhalbar, J., Chaurasiya, S., Mannikeri, K., & Iyer, R. (2018, May). *Clairvoyant Raven*. In *2018 2nd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech)* (pp. 1-5). IEEE;

[8] Allouch, A., Cheikhrouhou, O., Koubâa, A., Khalgui, M., & Abbes, T. (2019, June). *MAVSec: Securing the MAVLink protocol for ardupilot/PX4 unmanned aerial systems*. In *2019 15th International Wireless Communications & Mobile Computing Conference (IWCMC)* (pp. 621-628). IEEE;

[9] Koubâa, A., Allouch, A., Alajlan, M., Javed, Y., Belghith, A., & Khalgui, M. (2019). *Micro air vehicle link (mavlink) in a nutshell: A survey*. *IEEE Access*, *7*, 87658-87680;

[10] G.R. Buican, S.M. Zaharia, I.S, Pascariu, L.A. Chicos, C. Lancea, M.A. Pop, V.M. Stamate, Development And Implementation Of An Automated Pilot System For A Fixed-Wing Twin-Engine Airplane Uav. In *Scientific Research and Education in the Air Force – AFASES Conference*, 2022, Henri Coanda Air Force Academy. In rewiev;

[11] Ardu pilot documents and manual fro mIssion Planner software, aveilabel at https://ardupilot.org/plane/ last accesed on 25.05.2022.