AVALON: definition and modeling of a vertical takeoff and landing UAV

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Abstract. Unmanned Aerial Vehicles (UAVs) have been used in numerous applications, like remote sensing, precision agriculture and atmospheric data monitoring. Vertical takeoff and landing (VTOL) is a modality of these aircrafts, which are capable of taking off and landing vertically, like a helicopter. This paper presents the definition and modeling of a fixed-wing VTOL, named AVALON (Autonomous VerticAL takeOff and laNding), which has the advantages of traditional aircrafts with improved performance and can take off and land in small areas. The principles of small UAVs development were followed to achieve a better design and to increase the range of applications for this VTOL. Therefore, we present the design model of AVALON validated in a flight simulator and the results show its validity as a physical option for an UAV platform.

1. Introduction
Unmanned Aerial Vehicles (UAVs) are aircrafts that can fly autonomously or controlled remotely by a human pilot. These vehicles can be used in several applications, like remote sensing, precision agriculture and atmospheric data monitoring. Different configurations of aircrafts were created to supply the requirements of all these applications. One example is the class of Vertical takeoff and landing (VTOL) UAVs, which can take off and land in small areas and whose more representative archetype is the helicopter. However, aircrafts based on rotary wings suffer penalty performance regarding speed of operation, which reduces the area covered in a mission.

In this paper, we present a VTOL definition and design with a configuration called tailsitter, which has the benefits of VTOL and fixed-wing aircrafts. The tailsitter configuration is characterized by a fixed-wing aircraft, capable of reaching higher velocities, and that can also take off and land vertically in small areas without a runway. Our tailsitter UAV, named AVALON (Autonomous VerticAL takeOff and laNding), is a small electric aircraft with only one propeller and a structure to keep it in the vertical position during the takeoff and landing. The AVALON definition and modeling is demonstrated here with simulation results that show its physical appropriateness as an UAV platform.

2. Related work
Different configurations of VTOLs can be found in the literature, however they are usually based on complex mechanical structures like tilt rotors [1, 2], thrust vectoring [3] and ducted-fans [4, 5]. Other examples of VTOL adopt rotary wings, but can only operate at low velocities...
[6, 7]. Tailsitters with simpler designs were also explored before as an alternative more suitable for small UAVs, such as in the T-Wing [8] and C-Plane II [9]. However, these aircrafts have contra-rotating propellers to avoid the torque effect from the thrust, which increases the design and cost of the platform. Differently, AVALON design rests on the premises of simplicity to achieve a low-cost and easy to maintain vehicle, which are desirable characteristics for small UAVs.

3. AVALON definition

The operation of a tailsitter UAV is divided in five stages: vertical takeoff, transition from vertical to horizontal position, horizontal flight, transition from horizontal to vertical position and vertical landing. The platform definition must be able to encompass all stages, with hover for short periods and cruise flight for a longer range. Hence, our tailsitter UAV was designed following these criteria.

AVALON is a small electric UAV with fixed-wings and a structure to keep it in the vertical position, as seen in Figure 1 in different perspectives. It has just one propeller, two ailerons, two elevators and one rudder, as a typical fixed-wing aircraft. The design is symmetrical in the xy plane with a wingspan of 1.74 m, height of 1.7 m and weight of 2.5 kg. The airfoil of the main components is the flat plate, again chosen due to simplicity.

Figure 1. AVALON design in different perspectives: isometric view in the top right, top view in the top left, front view in the bottom left and right view in the bottom right.

4. AVALON modeling

To validate the aircraft design, we used the flight simulator X-Plane, which is considered the flight simulator with the higher physical and functional fidelity between simulator engines [10]. The AVALON model was constructed using Plane Maker, a software that is part of X-Plane, and each part was designed separately, resulting in the model seen in Figure 2. During the simulation, X-Plane calculates the dynamic and kinematic effects according to blade element analysis, which
is influenced by aerodynamic coefficients related to the components airfoil. AVALON flat plate airfoil coefficients for lift, $C_L$, drag, $C_D$, and moment, $C_M$, for different angles of attack can be seen in Figures 3, 4 and 5, respectively.

5. Simulation results

The desired trajectory was simulated with a vertical takeoff, then a transition between vertical position and horizontal position, followed by a new transition to the vertical position and an attempt to land. The latitude, longitude and altitude were retrieved from X-Plane and converted to the navigation frame represented as North-East-Up using MATLAB. The resulting trajectory of AVALON test can be seen in Figure 6.

The results show that AVALON design allows it to behave as a manoeuvrable VTOL during the vertical position and the transitions. They also illustrate the possibility of using a flight simulator as a tool to the development of UAV platforms and its capabilities to represent the dynamic and kinematic effects of UAV models.

6. Conclusions

This paper presents AVALON, a tailsitter UAV that can take off and land in small areas and does not suffer performance penalties during horizontal flight. The results in a simulation environment show that AVALON design enables the platform to act as an UAV during all operation stages.
Figure 6. Resulting trajectory represented in the navigation frame North-East-Up.

As future work, we expect to use the AVALON modeling to perform autopilot tests and validate control laws for each flight operation. Afterwards, we plan to use the simulation process to perform tests of multiple platforms and their communications in a mission scenario.

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