Dynamic Soaring

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TMAL02, Linköping University, 2017

1 Introduction

The technique of dynamic soaring utilized by the albatross has been observed over many years as an efficient alternative approach to long distance flight regimes typically used by aircrafts in the current era.

The albatross exploits the phenomenon of wind shear over the surface of the ocean in order to maintain flight. Wind shear is defined as a difference in wind speed over a relatively short distance in the atmosphere. Directly above the surface of the ocean, the wind speed is almost zero, whereas going higher in altitude, there is an appreciable value of wind speed, which leads to a region of wind shear above the surface of the ocean. The albatross extracts energy from this wind speed gradient by ascending in the windward direction, and by descending downwind, continuously gaining a net increase in the value of its ground speed. It is an awe-inspiring flight mechanism which allows albatrosses to sustain flight over large distances, for large periods of time and without having to flap their wings a lot, as seen in Figure 1. Dynamic soaring, which is therefore based on the difference in air mass velocities, must not be confused with slope soaring that simply uses the wind which is forced upwards over an obstacle like a hill.

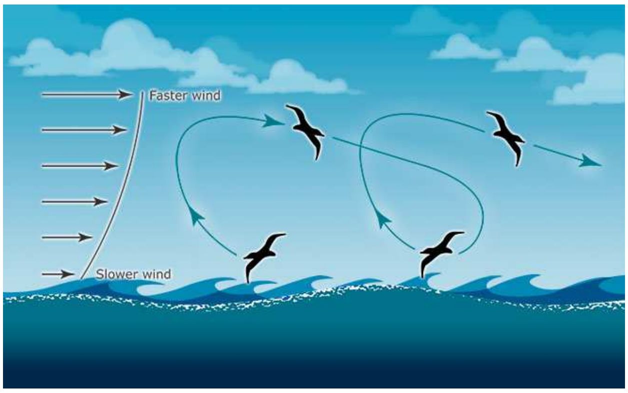

Fig. 1 . An illustration of the typical flight path of the albatross.

2 Definition

In order to fully understand the principle of dynamic soaring, we first need to make sure that the definitions of groundspeed and airspeed are unambiguous.

- Groundspeed: The groundspeed is the speed of a body by taking the ground as referential.
- Airspeed: We can define the airspeed as the difference between the groundspeed of a body and the air velocity of the environment. It means that in that case the referential is the wind. Therefore the groundspeed will always be greater than 0 for a moving body, while its airspeed could be equal to 0.

3 Mechanism

There are several modes of dynamic soaring that can be performed by albatrosses with a series of 90° or 180° turns over the surface of the ocean[1]. However, for UAVs, dynamic soaring is usually achieved flying a loop. We will focus on this simple pattern in order to investigate what happen during one loop (figure 2) and see how an aircraft can gain energy with this technique.

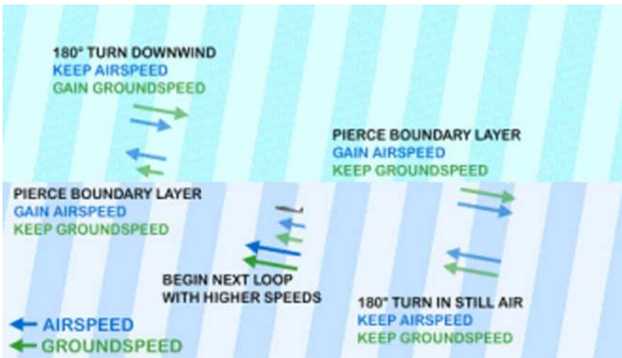

Fig. 2 . Dynamic soaring simplified mechanism.

The aircraft needs to pierce the boundary layer at a sharp angle. The airspeed will thus increase when going from the stationary airmass to the moving one. Then, a 180° turn in the moving airmass, changing the glider from flying upwind to flying downwind, will make the ground speed increase while the airspeed remains constant. Its airspeed will be almost (as the boundary is not perfect in reality) instantly increased again when crossing the thin wind shear area in the other direction, since the airspeed will go from a high forward value to zero, and the groundspeed will again remain constant thanks to inertia. Finally, the glider returns to the starting point with an increased groundspeed and airspeed. The process can be repeated in order to increase the speed once more, until a maximum value is attained.

In fact, some simplifications have been made in the previous explanation since drag forces would continually act opposite to the aircraft motion, thus decreasing its speed. Therefore, the maximum speed will be reached when, with increasing speed, the drag forces will offset the energy gained with dynamic soaring. This can be seen on data from a dynamic soaring simulation over 10 loops (figure 3)[2]. The fluctuation that we can see, which was also not considered in the simplified explanation, is simply due to the kinetic energy converted into potential energy when climbing, and vice versa.

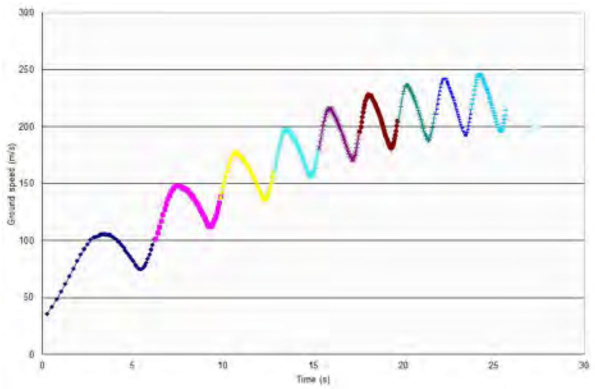

Fig. 3 . Ground speed of a RC glider over time in a dynamic soaring simulation.

4 Applications and perspective

The first pilot to use the dynamic soaring in order to fly successfully was Ingo Renner in 1974 with a single-seat sailplane [3].

In 90's the first Remote Control gliders appeared. These mini aircrafts are mainly use to fly as fast as possible without traveling distance, only by making loop. According to some calculations and observations, the acceleration during a loop can reach 100 g [1]. That is why the gliders are built with composite materials capable of resisting to hard conditions. The unofficial world record is today hold by Spencer Lisenby who reach the speed of 835 km/h (0.68 M) with his RC glider in april 2017 [4]. The theoretical maximum speed by using the dynamic soaring is about 9,5 the wind speed velocity of the upper zone [1]. Some characteristics, mainly inspired by the albatross shape, are required to performed successfully a dynamic soaring. A high Lift-to-drag ratio (approximately 30 for albatrosses or RC gliders) allows to reduce the drag as much as possible in order not to lose the energy gained thanks to dynamic soaring. That is why dynamic soaring can only be observed with particular vehicles that have such properties.

The NASA VISTA office investigated the feasibility of dynamic soaring through a UAV able to cross the ocean by using the dynamic soaring to fishery surveillance and monitoring [5]. Inspired by the albatross shape, this glider concept would be able to fly indefinitely as long as there is wind. Two turbines on the tip wing are able to extract the power due to the vortex in order to recharge a battery. This battery is exclusively used in order to take off after a period of no-wind or if the UAV needs to maneuver away from an obstacle.

However this project has limits because of the flight complexities. It is very difficult to imitate an albatross flight as they are indeed able to feel where is the best region to fly. Also they can easily fly close to, and sometimes scrape, the water, which is difficult and dangerous for a UAV. Therefore, as UAVs could hardly take full advantage of the shear wind effects over the ocean, dynamic soaring is, at the present time, mainly used in areas where the dead air behind a massive obstacle like a mountain creates an substantial wind gradient.

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