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JetStick: Using Air Jet Tactile Feedback to Prevent Aircraft Stalls

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Abstract. Haptic enhanced flight sticks have been used to guide pilots for avoiding aircraft stalls. However, they do not inform the pilot about the aircraft flying status during critical flying phases. We present JetStick, a flight stick that provides air jet feedback to help pilots avoiding dangerous situations in critical flight phases. Our preliminary results show that our device can provide tactile information about aerodynamic phenomenon outside the cockpit. This could be useful in context such aerobatics or training flights.

Keywords: Air jet feedback · Aeronautics · Pilots · Cockpit.

1 Introduction

Haptic enhanced flight sticks have been used in aeronautics to warn pilots about aircraft stalls, a state where aircraft wings can no longer generate enough lift to maintain flight level [1]. More recently, research has looked into guiding pilots to maintain aircraft within flight envelopes (i.e. within parameters ranges where the manoeuvrability of the aircraft is optimal) [5, 4]. *Zikmund et al.* have proposed vibrotactile and sliding surface actuation feedback on flight sticks to guide pilots' hand movement for avoiding stalls [5]. *Van Baelen et al.* have shown that force feedback can physically guide pilots away from the envelop limits [4]. However, such systems do not provide tactile information that may help pilots to understand the aircraft flying status.

To raise pilots' awareness about the aircraft flying status in critical flight phases, we introduce JetStick (JS). This flight stick is equipped with 4 proportional valves that can blow air to the pilot's hand to simulate airflow [3]. With JS, pilots are able to feel the invisible airflow around the aircraft and build a better awareness of the aerodynamics taking place outside the cockpit.

2 JetStick

JetStick (JS) provides air jets on the four sides of the joystick (Fig. 1). We have designed 3D-printed nozzles which we have integrated to a Speedlink Dark Tornado joystick. To provide airflow to the nozzles, a Stanley Fatmax DST compressor provides continuous

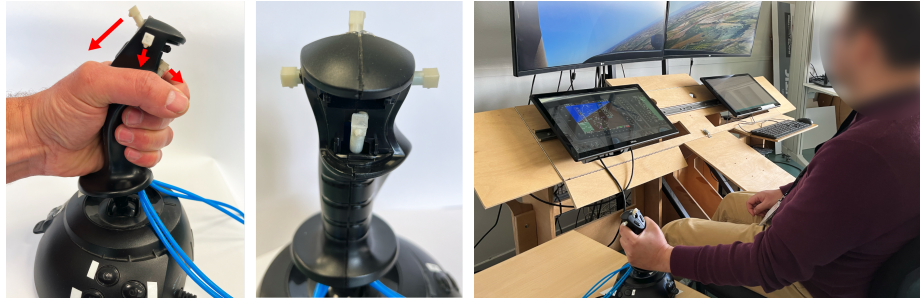


Fig. 1. On the left, the joystick gripped with the 4 nozzles (front, rear, left, right) on the upper part; center, the nozzles printed in white PLA are attached to the joystick by thermobonding and the pipes are integrated into the body of the device; right, the simulation platform.

pressure of 4 bars throughout the air distribution system. The airflow is controlled by 4 SMC PVQ30 proportional solenoid valves connected to HW-039 motor controllers. The valves behaviour is driven by an Arduino Uno board.

The locations, the force and the continuity of air jets can be controlled at the same time by using an application programming interface. In addition, flight parameters such as angle-of-attack or stall information available in flight simulation applications like XPlane can also drive the air jets.

3 Preliminary Results and Future Work

To identify use cases where JS could support pilots, we have carried out a workshop where a flight instructor could experience the air jet tactile feedback from the device. Critical situations that can lead to stalls such as takeoffs, landings, turns or flying with high angles-of-attack were also discussed. We then explored how air jet tactile feedback could prevent stalls in these situations and how to improve the JS design.

We then designed air jet tactile feedback techniques for these situations. For example, when the pilot increases the aircraft altitude, continuous air jet is blown at the front of the joystick to the pilot's fingers. As the angle-of-attack to maintain aircraft lift increases, the force of the air jet decreases. When the critical angle, the angle where the greatest amount of lift is produced, is about to be overshoot, the device sends air jet bursts at the front of the joystick. The air jet bursts indicate that the aircraft is about to stall if the angle-of-attack keeps increasing. As soon as the bursts are felt, the pilot can push the flight stick to reduce the angle-of-attack and avoid stalling. Other feedback techniques were proposed for taking off at the right speed or maintaining the flight symmetry during turns.

We conducted a study with two flight instructors to collect qualitative feedback about their experience with JS. The instructors were asked to perform a takeoff, a turn and to increase the angle-of-attack in a flight simulation using JS. Overall, JS was thought as a good addition to existing support systems such as the stall audio warning or the force feedback flight stick systems. They also thought that JS could be used to feel

aerodynamic phenomena that are difficult to perceive inside the cockpit, in specific flying contexts such as in aerobatic or training flights. In particular, one participant reported that he felt that his "*hand was like the wing of the aircraft*" and he could "*feel what was happening around the wing*". They also liked that air jet could provide both progressive and "*cahotic*" feedback to mimic what happens under the wing when the aircraft stalls.

These preliminary results show that JS could be useful to help understand the aerodynamic phenomena happening outside the cockpit and avoid dangerous flying situations which can lead to stalls. Our future research will explore how to simulate aerodynamic phenomena inside the cockpit with air jet tactile feedback. For example, it is unclear what level of airflow representation fidelity is needed to inform pilots about aircraft aerodynamics [2]. User studies will then be carried out to assess the pilots' understanding of the simulated phenomena and response to the air jet feedback techniques.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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