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Neural Network Modeling of Lateral Pilot Landing Control

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Human pilot landing control has been analyzed by the authors using neural network modeling. Although the previous research considered only longitudinal control, analysis of the lateral control is the focus of this paper. The lateral control can be quite difficult under crosswind conditions, because the combination of two lateral control methodologies (crab method and wing-low method) is needed for a successful landing. To analyze lateral control, this paper makes a first step: a lateral pilot control model is established. The necessary visual cues for lateral control are defined, and neural network models for aileron and rudder controls are constructed. The adequacy of the proposed neural network model is checked by Monte Carlo simulations.

I. Introduction

RECENT commercial aircraft not only have an autopilot system, but they also have an automatic landing system, so that the aircraft can land at the airport automatically and safely. While cruising, the autopilot system is widely used, and the main task of the human pilot is monitoring instrument panels and checking the aircraft states for any abnormality. On the other hand, during approach and landing, the automatic landing system is rarely used. Compared with the cruising autopilot, the automatic landing system has many requirements. For example, the airport needs to be equipped with an advanced instrument landing system (such as CAT III), and the captain pilot and the aircraft have to be specially certified. The weather condition can also form restrictions for autolanding. In addition, if the pilots rely on autolanding excessively, it might result in a decline of their control skills. Manual pilot control will always be required as backup in case of failure of the automated system. Taking all these points into consideration, it is not surprising that the landing maneuvers are performed manually in most cases.

The landing is more difficult than other operations for airline pilots. The pilot has to perceive the continuous change of the situation and control the aircraft accordingly. During the final landing, he cannot afford to watch instrument panels and gets the necessary information mainly from the out-the-window view. The characteristics contained in this view will be referred to as *visual cues*. The authors have examined the relationships between visual cues and pilot control (e.g., how he times his control and what cue the pilot focuses on as time goes by). We have developed a method for the mathematical modeling of pilot control using a neural network (NN), and we have applied the obtained model to analyze a pilot's control, using contribution and sensitivity analyses [1,2] to quantitatively examine the pilot's points of attention and his subsequent reactions during flight. The difference in control strategy between veteran and freshman pilots can pinpoint any shortcomings of the freshman pilot, which makes the pilot training more effective. The ultimate goal is to develop a pilot training tool that can be used by airlines.

The authors' team considered only longitudinal motion in the past research [1,2]. In other words, only the elevator and throttle deflection were analyzed. The effectiveness of the applied analysis method was verified through simulator tests [1,2] and real flight experiments [3]. To follow up, this paper considers the lateral control. The lateral control requires two additional control devices (aileron and rudder), and there is a characteristic difficult control called *decrab* under crosswind condition. The pilot workload increases under critical flight conditions, and it is considered that the differences between pilots can be found more clearly with the analysis of lateral control. In this paper, longitudinal modeling method of the previous study is adapted to include lateral motion. In Sec. II, landing control in a visual approach is explained in detail, and the characteristic controls (flare and decrab) are introduced. In Sec. III, NN structure for longitudinal control modeling is explained first. Although the basic modeling methods were established in the previous works [1,2], there were several modeling problems. For example, the learning was time-consuming, because several NN parameters such as initial weights and biases were optimized by a genetic algorithm to assure convergence of the training error. Thus, an enhanced modeling method is detailed in this paper. In particular, the NN inputs are strictly selected, and the objective function for NN learning is refined. Next, NN models of a pilot's lateral landing control are constructed using training data obtained with a B747 simulator owned by the authors' laboratory. In Sec. IV, the adequacy of the constructed network is verified. In other words, it is confirmed that the network can obtain the characteristic of the pilot control through Monte Carlo simulations. The obtained NN models control the simulator instead of the pilot, and the flight trajectories and the time histories of aircraft states are compared. In Sec. V, this paper is concluded.

II. Visual Landing Control

A. Characteristics of Landing Control

This paper considers manual landing control of a simulated B747. For longitudinal control, a flare maneuver is difficult to control. The flare maneuver is a lifting-the-nose control just before the landing. Its purpose is twofold: to decrease the sink rate at the landing and to land at the main gear first. The timing of the flare maneuver is not fixed and depends on the situation. During the landing, numerous tasks have to be completed in a short time, which leads to a high workload. That is why the longitudinal control has been analyzed first in previous research. The lateral control at landing should also be considered. The lateral control is more difficult than the longitudinal control, because the lateral motion comprises two attitudes (roll and yaw), whereas longitudinal motion comprises only one attitude (pitch). The number of parameters that should be adjusted at the landing also increases. For lateral control, the additional parameters at landing are lateral position and roll and yaw angles. Although keeping the roll angle low is important to prevent touching the runway with the wingtip, the yaw angle is also an important factor. If the aircraft lands with a high yaw angle, the lateral loads on the undercarriage will be high, which might lead to damage.

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