A Fuzzy Supervisory Model for Analysis of Manual Landing Control

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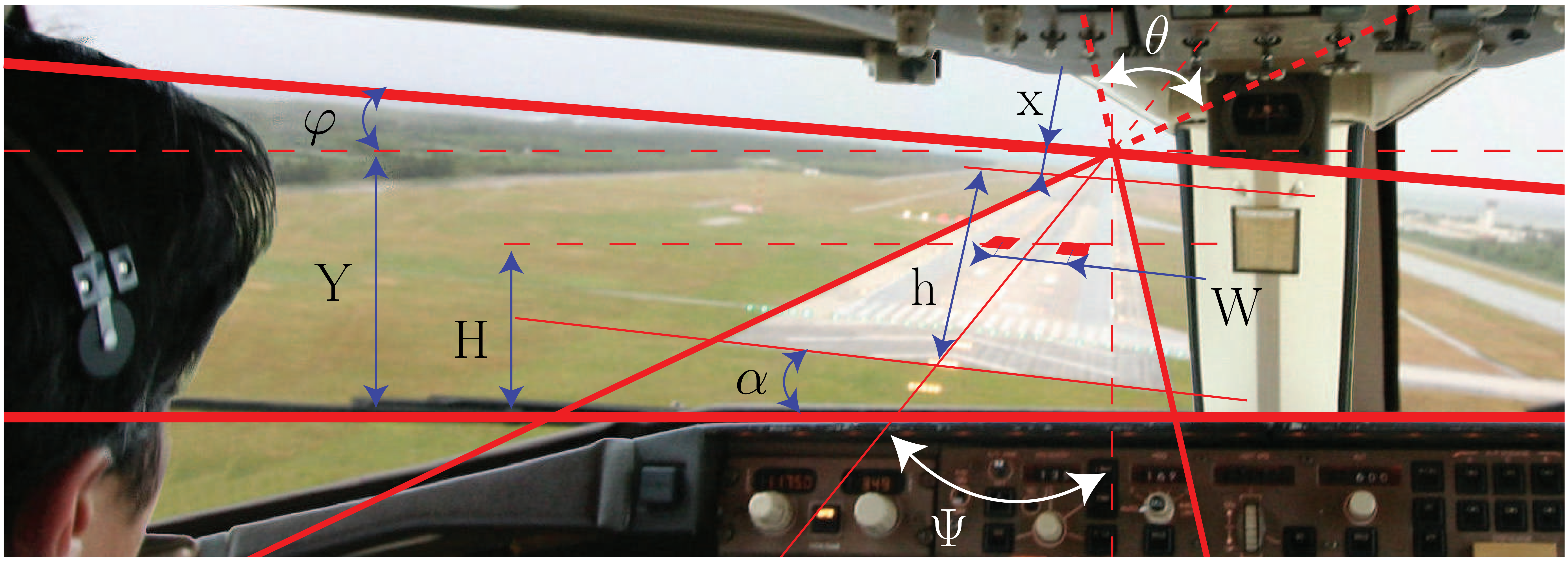

Abstract

Visual and control input data from real or simulated flights are used to construct a pilot model. The model consists of neural networks (NNs) and supervisory fuzzy logic control and can be used in pilot training or assessment.

Data Acquisition

Several real and simulated landings were performed by experienced pilots. For the real landings, Visual and control input data were obtained using 2 video cameras (see Fig. 1) and off line image processing. For the simulator experiments the cues were back-calculated from the aircraft states and scene definition.

Fig. 1: The control command is recorded using a white cross marker on the column (left), the visual cues are recorded with the camera on the right.

Perception

The selection of visual inputs for the pilot model is a difficult task. From literature and pilot interviews a rough selection has been made. The horizon (Y), runway perspective (θ), distance between the markers (W), time to contact τ and the absolute H-distance (Y-H) were chosen for the control of longitudinal motion (lateral motion is not considered yet). The temporal derivatives of these cues are considered as well.

As the usage of cues may depend on a pilot's preference or aircraft type, and varies through the phases of the landing, the selection of appropriate visual cues is part of the modeling process.

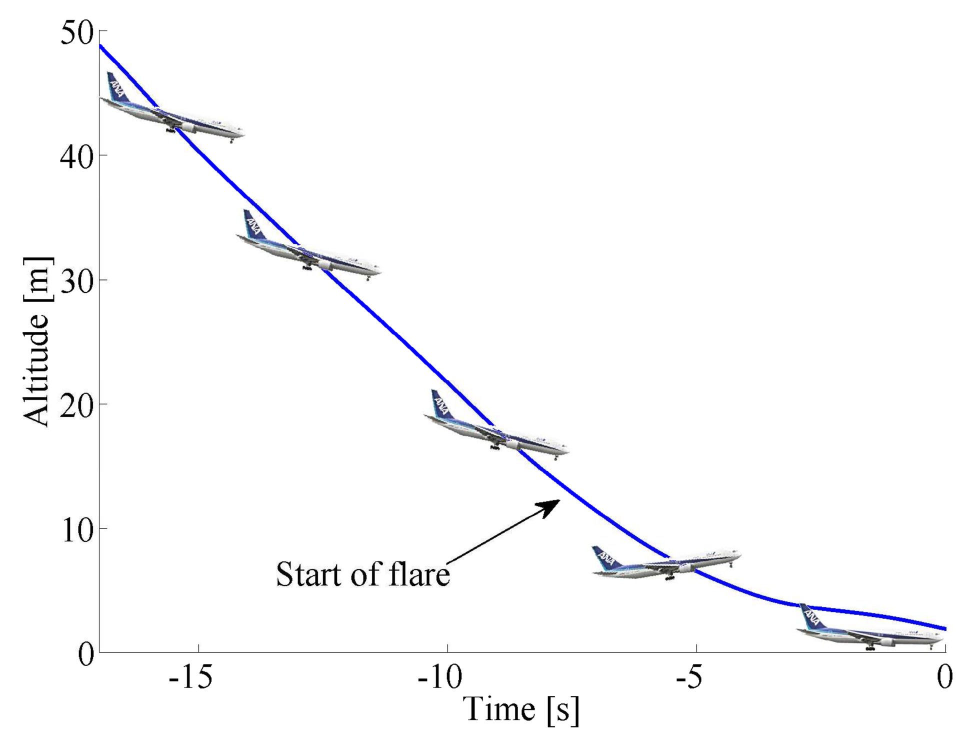

Fig. 2: In the final approach to landing, the pilot pitches up to arrest sink rate and land softly on the main gear. This maneuver is called the flare.

Modeling

There are two distinct phases in the final approach to landing: glide and flare (see figure 2). As it is suspected that different cues will be used for the control in these phases, they are modeled separately. The transition is modeled using fuzzy supervisory control. Figure 3 shows the process of model generation.

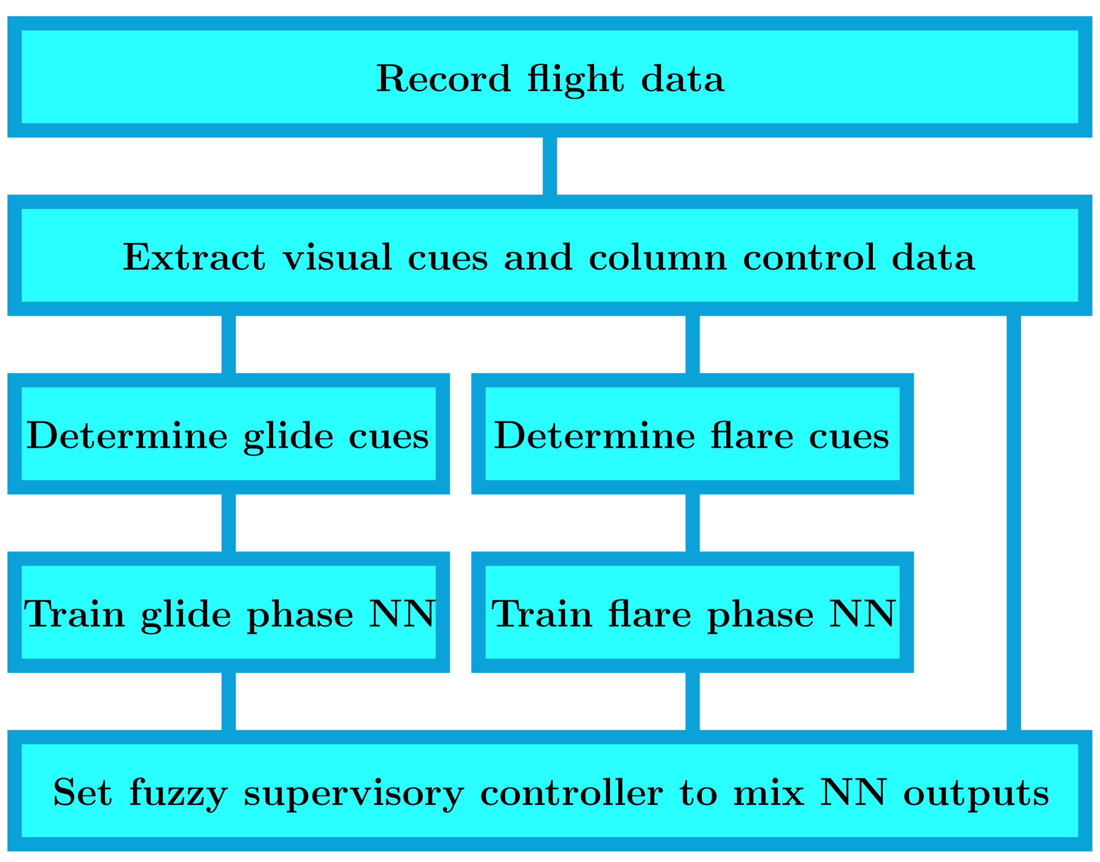

Fig. 3: Flowchart of the modeling process.

Results

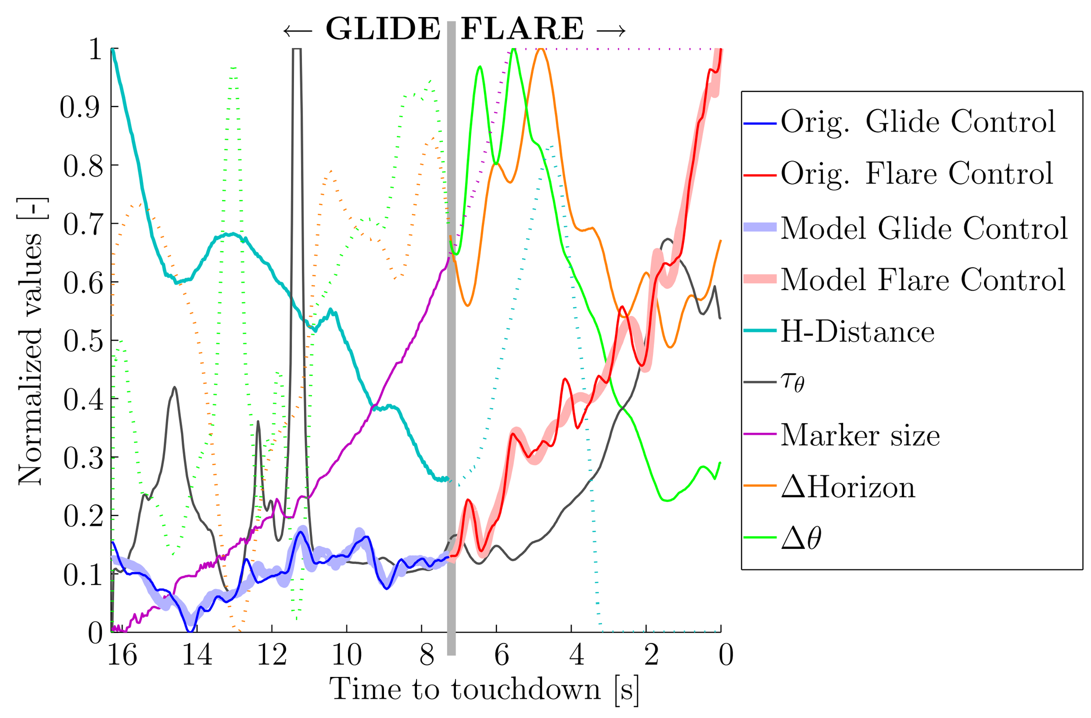

Fig. 4: Column deflection and selected visual cues in real flight. It can be seen that the pilot initiates the flare 7s before touchdown. If cues are not used in a phase, lines are dotted.

The current, preliminary results were obtained using simulator and real flight data available from previous research. Fuzzy c-means clustering was applied to separate the glide and flare phase data. Manual selection would have had the same result.

Analysis of the data revealed that the horizon and τ_θ ($\theta/\dot{\theta}$) are mostly applied in the flare phase. In the glide phase τ_θ also seems to be used, but also the H-distance and marker size are identified to be important. Using these cues, very simple (3 neuron) neural networks were trained which proved to be able to cover the pilot's control characteristics. Figure 4 illustrates these results.

A threshold value of the (absolute) H-distance seems to play a role in flare timing. A combination of τ_θ and $\dot{\theta}$ was also identified as a possible trigger for the flare. Interesting to note is that, when the same analysis method is applied to the aircraft states recorded from the simulator landings, a combination of altitude and sink rate is found, confirming the findings of Grosz et al [1].

1. **J. Grosz, R.Th. Rysdyk, R.J. Bootsma, J.A. Mulder, J.C. van der Vaart, and P.C.W. van Wieringen.** "perceptual support for timing of the flare in the landing of an aircraft". In J.M Flach, P.A Hancock, J.K Caird, and K.J. Vicente (eds), "Local applications of the ecological approach to human-machine systems", vol.2, ch.4, pp 104–121, 1995.

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