Accepted Manuscript

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PII: S1270-9638(17)31824-2
DOI: https://doi.org/10.1016/j.ast.2018.02.026
Reference: AESCTE 4439

To appear in: *Aerospace Science and Technology*

Received date: 7 October 2017
Revised date: 7 February 2018
Accepted date: 13 February 2018

Please cite this article in press as: Y. Dong, An application of deep neural networks to the in-flight parameter identification for detection and characterization of aircraft icing, *Aerosp. Sci. Technol.* (2018), https://doi.org/10.1016/j.ast.2018.02.026

An Application of Deep Neural Networks to the In-flight Parameter Identification for Detection and Characterization of Aircraft Icing

Yiqun Dong*

Abstract: This paper applies the Deep Neural Networks to the in-flight parameter identification for detection and characterization of the aircraft icing. General dynamics of the aircraft are firstly presented, ice effects on the dynamics are characterized. Deep Neural Networks (DNNs) including Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) are briefly introduced. We propose a "state-image" approach for the pre-processing of the input flight state, then we design a DNN structure which models both local connectivity (using CNN) and temporal characteristics (using RNN) of the flight state. The identified parameters are exported from the DNN output layer directly. To fully evaluate the performance of the DNN-based approach, we conduct simulation tests for different cases which correspond to clean and aircraft icing at different locations (wing, tail, wing and tail) with different severities (moderate, severe). A comparison of the DNN-based approach with a baseline H∞-based identification algorithm (state-of-the-art for aircraft icing) is also delivered. Based on the test and comparison results, the DNN-based approach yields more accurate identification performance for more parameters, which shows promising applicability to the in-flight parameter identification problem.

Keywords: In-flight Parameter Identification; Aircraft Icing; Deep Learning; Deep Neural Networks; Convolutional Neural Network; Recurrent Neural Network.

Nomenclature

$C_{(*)clean}$, $C_{(*)iced}$	Flight dynamics parameters, clean and iced cases
η_{ice}	Icing severity parameter
k_{C*}	Weights of ice effects on the aircraft flight dynamics parameters
C_η	Conduciveness coefficient of the atmosphere to icing
N_1, N_2	Coefficients used to define the time-varying ice effects on aircraft flight dynamics parameters
T_{cld}	Aircraft icing duration time
d_η	Difference between the assumed and actual icing conduciveness
d_p	Atmospheric disturbance to the aircraft flight
V, α, β	Aircraft velocity, angle of attack, and angle of sideslip defined in wind axis
u, v, w	Aircraft velocity components in body axis
ψ, θ, ϕ	Aircraft yaw, pitch, and roll Euler angles
g_y, g_z	Load factors in aircraft body y and z axis
$\dot{V}_w$, $\dot{\alpha}_w$, $\dot{\beta}_w$	Atmospheric disturbance effects on aircraft velocity, angle of attack, and angle of sideslip
$\dot{u}_w$, $\dot{v}_w$, $\dot{w}_w$	Atmospheric disturbance effects on aircraft velocity components in the body-axis
$I(t)$, $I(i, j)$	Input to the convolution operation, continuous and discrete forms
$K(t)$, $K(i, j)$	Kernel function (filter) for the convolution operation, continuous and discrete forms

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