Adaptive Flight Control

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INTRODUCTION The general control method used to overcome the nonlinear dynamic behaviour of aircraft is gain scheduling. Scheduling is limited by the number of design points, and that it cannot correct for the deviations of the model from the real plant. The feasibility of **indirect adaptive control** approach was investigated in this thesis to resolve the above limitations. This method identifies the system online and redesigns the controller based on the estimated predictor. The applicability of the framework has been tested seeking MIMO control assuming trim condition is unknown.

RESEARCH OBJECTIVES
– control design without deep understanding of the particular system dynamics
– linear design without knowledge of the trim conditions
– MIMO identification and control for better performance
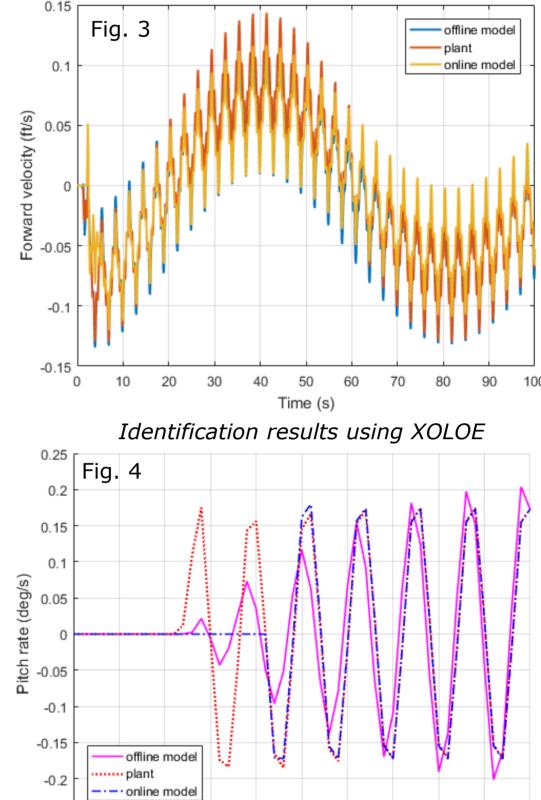– evaluation based on a full, 6-DOF, nonlinear, fixed-wing F-16 model [2]

IDENTIFICATION
For the broadest perspective **MIMO identification** algorithms were applied assuming no knowledge of the trim condition.
Identification methods tested:
– Grey-box identification
– **R**ecursive **L**east **S**quares for State Space estimation
– **R**ecursive **P**rediction **E**rror **M**ethod (Figs. 1-2)
– **E**xtended **O**pen-**L**oop **O**utput **E**rror (Figs. 3-4)
No MIMO state-space or transfer function estimations were able to estimate the model with appropriate accuracy

SISO DECOUPLING
Based on direct I/O dominance the following **input-output pairs** were selected to be used for separated SISO control:
thrust — forward velocity   elevator — pitch rate
aileron — roll rate   rudder — yaw rate
Transfer function estimation - applying XOLOE - for **SISO pairs** was satisfactory even in a few seconds if off-trim values were used when utilising PRBS excitation. Results showed great sensitivity to PRBS initial value. To relax the excitation condition **directional forgetting** was implemented [3] and the stability combined with XOLOE method was analysed based on passivity of an equivalent feedback loop. [1]
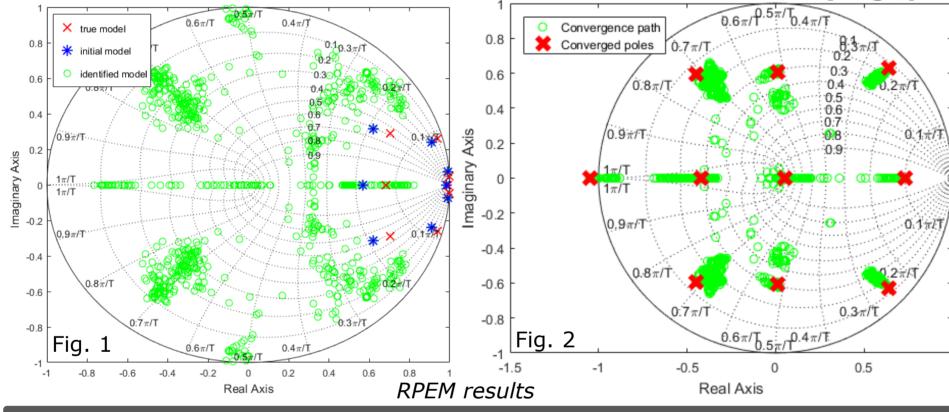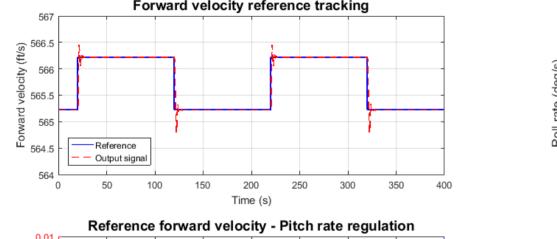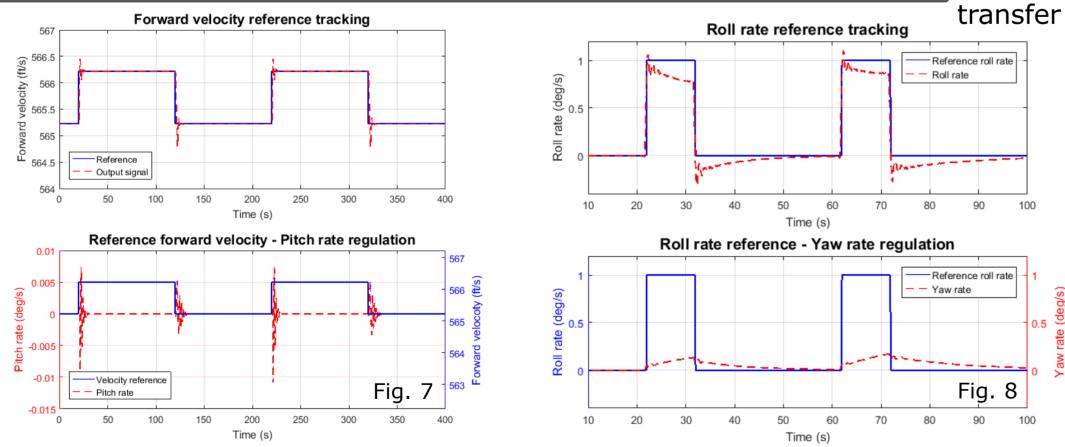
CONTROL DESIGN
The traditional method of aircraft control is **pole-placement**, because it is directly related to the **flying qualities**. To account for the estimation uncertainties and utilise the identified noise model an **R-S-T** controller was used to achieve the tracking and the regulation objectives separately but simultaneously (Fig. 5). As an alternative **Generalised Predictive Control** (Fig. 6) was realised [4] and compared.

Identification results using XOLOE

RPEM results

[1] I. D. Landau, R. Lozano, M. M'Saad, and A. Karimi, *Adaptive Control, Algorithms, Analysis and Applications*, 2 ed. London: Springer-Verlag, 2011.
[2] R. S. Russel, "Non-linear F-16 Simulation using Simulink and Matlab," University of Minnesota, 2003.
[3] L. Cao and H. Schwartz, "A directional forgetting algorithm based on the decomposition of the information matrix," Automatica, vol. 36, pp. 1725-1731, 2000.
[4] J. A. Rossiter, Model-based Predictive Control: A Practical Approach. London: CRC Press, 2003.
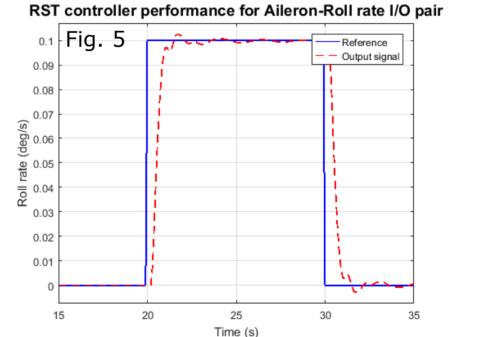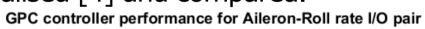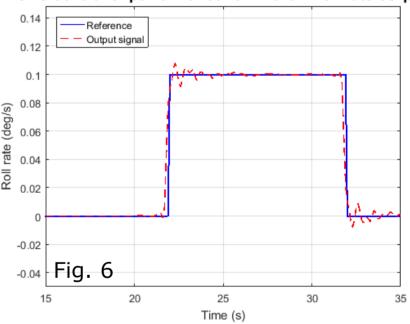
The control performance of applied automatic design on the identified SISO transfer functions between the selected I/O pairs was satisfactory (Figs. 7-8)

CONCLUSION
The research showed that it is possible to design a suitable flight control system using the indirect adaptive framework even for **high manoeuvrability aircraft.** Investigations also explored the limitations of the framework in respect of the necessary knowledge of trim condition, the requirement for appropriate excitation regardless of directional forgetting and the sensitivity to the applied PRBS excitation. In case of appropriate identification the controller created by automatic design methods could even guarantee the prescribed performance levels of the Defence Standards.

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Research sponsored by:
BAE SYSTEMS
I N S P I R E D   W O R K