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ONERA
THE FRENCH AEROSPACE LAB

PROPOSITION DE POST-DOCTORAT

Intitulé : Measurement optimization for flow reconstruction

Référence : **PDOC-DAAA-2021-03** *(à rappeler dans toute correspondance)*	
Début du contrat : January 2022	**Date limite de candidature :** December 2021
Duration : 12 months, can be renewed once – Net salary : 25 k€ per year	

Mots clés

Data assimilation, optimization, adjoint method, sensor placement, aerodynamics

Profil et compétences recherchées

PhD in fluid dynamics or applied mathematics, skills in numerical simulation for fluid mechanics applications and/or in optimization techniques

Présentation du projet post-doctoral, contexte et objectif

Experimental fluid dynamics is by essence the most appropriate way of investigating real-world flows for both academic and industrial purposes, and allows to study the behavior of fluids in complex geometries and can provide useful information for aeronautic design. However, measurements from experiments are usually sparse in space and/or time and do not provide a full description of the flow. In order to overcome this limitation, data assimilation techniques are more and more employed to merge experimental measurements with numerical simulation, allowing to extrapolate the measurements, denoise them and improve their resolution [1,2]. A popular data assimilation technique is the so-called variational, or adjoint-based, approach where data assimilation is formulated as an optimal control problem in which one wants to minimize the discrepancies between experimental measurements and the results of a numerical simulation by adjusting its input parameters, such as initial/boundary condition or model parameters [3,4]. The thus optimized simulation can provide an augmented prediction of the considered flow with respect to the available measurements.

Transonic wind tunnel experiment at ONERA, pressure taps are visible on the wing, from Molton et al., 2013, AIAA Journal 51, 761-772

If measurements are very limited, as in the case where only the friction and/or pressure distribution on wall boundaries is available, the data assimilation procedure might fail in accurately extrapolating the considered flow, so that the results of the optimized simulation differ significantly from the true flow state outside measurement locations. In this case, it may be helpful to quantify the errors/uncertainties in the reconstructed flow, without having access to the whole true state. This may be done through the examination of the eigenmodes of the Hessian matrix that is associated to the cost function to be minimized in the data assimilation procedure. The dominant modes will correspond to states that are certain/easily reconstructible, while the other ones will be more difficult to identify. For large scale problems, the estimation of this Hessian matrix can be performed through the use of second-order adjoint models [5]. Once the limitations of the data assimilation procedure have been delineated, one may want to overcome the latter and optimize the measurement process in order to get the most pertinent information about the flow and improve the reconstruction capacities of data assimilation. Such a meta-optimization problem can also be tackled with second-order adjoint models [6].

The first main objective of this postdoctoral project is to rigorously assess the possibilities of mean flow reconstruction through data assimilation from pressure and/or friction distribution measurements over wall boundaries, which is representative of many wind tunnel experiments. Various scenarios will be investigated by varying the type of input parameters that are adjusted through data assimilation. In a second step, locations of pressure/friction sensors will be optimized in order to enhance the performances of the data assimilation procedure. The developed methodologies should help the design of future wind tunnel experiments to better take advantage of the reconstruction and extrapolation capacities of data assimilation. Both the diagnostic and optimization of the measurement process steps will be tackled through the development of the second-order adjoint model for an in-house ONERA code. Flows over airfoils will be considered as flow configurations, first in 2D then 3D setups.

[1] Lewis, Lakshmivarahan and Dall, Dynamic Data Assimilation: A Least Square Approach, Cambridge University Press, 2006

[2] Kato, Yoshizawa, Ueno and Obayashi, A data assimilation methodology for reconstructing turbulent flows around an aircraft, J. Comput. Phys., 2015

[3] Gronskis, Heitz and Mémin, Inflow and initial conditions for direct numerical simulation based on adjoint data assimilation, J. Comput. Phys., 2013

[4] Foures, Dovetta, Sipp and Schmid, A data assimilation for Reynolds-averaged Navier-Stokes-driven mean flow reconstruction, J. Fluid Mech., 2014

[5] Le Dimet, Navon and Daescu, Second-Order Information in Data Assimilation, Mon. Weather Rev., 2002

[6] Cioaca and Sandu, An optimization framework to improve 4D-Var data assimilation system performance, J. Comput. Phys., 2014

Collaborations extérieures

Non

Laboratoire d'accueil à l'ONERA

Département : Aérodynamique, Aéroélasticité, Acoustique

Lieu (centre ONERA) : Meudon

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