ONERA

THE FRENCH AEROSPACE LAB

www.onera.fr

PROPOSITION DE SUJET DE THESE

Intitulé : Improvement of large sparse system inversion for computational fluid dynamics (CFD)

Référence : **SNA-DAAA- 2018-005**
(à rappeler dans toute correspondance)

Laboratoire d'accueil à l'ONERA :

Branche : SNA

Lieu (centre ONERA) : Chatillon

Département : DAAA

Unité : CLEF

Tél. : 01 46 73 42 56

Responsable ONERA : Maugars B. et Content C.

Email : cedric.content@onera.fr

Directeur de thèse envisagé :

Nom : Grigori Laura

Adresse : 2 Rue Simone IFF, 75012 Paris

Tél. : 01 80 49 42 60 Email : laura.grigori@inria.fr

Sujet : **Improvement of large sparse system inversion for computational fluid dynamics (CFD)**

keywords : Computational Fluid Dynamics (CFD), High Performance Computing (HPC), Generalized Minimal RESidual (GMRES), Jacobian-Free Newton-Krylov (JFNK), Automatic Differentiation (AD)

context: elsA (1) is a large CFD simulation software developed in the framework of a cooperation between ONERA, Airbus and Safran. ElsA deals with internal and external aerodynamics from the low subsonic to the high supersonic flow regime. In addition, elsA interoperates with multidisciplinary simulation platforms in order to integrate CFD simulation capabilities into industrial workflows.

During the past decades, in order to achieve Moore's law (2), computer architecture has moved from higher processor frequency to the increase of the number of cores with lower frequency and lower amount of memory. In the context of CFD in general and more specifically for the ONERA's elsA software, this leads to a need to reimplement algorithms in order to make the most of new architectural features and achieve the speedup that they enable. In particular many studies (such as stability analysis, computation of steady states) are based on the computation of fixed points of the Navier-Stokes (or RANS) equations which requires an efficient and robust inversion of the extremely large sparse systems. As the system is large we focus on algorithm that does not require the storage of the entire Jacobian matrix. Due to the possible stiffness of the system to solve, GMRES (3) appears to be the best candidate.

Then two main questions have to be solved that constitute the two objectives of the present thesis. The first consists in find the best way to evaluate the jacobian-vector product. On the one hand, JFNK method (4),in which the jacobian-vector product is obtained by means of a first order Taylor series expansion, ensures the inheritance of the good HPC behavior (cache-blocking) and extensions to several numerical schemes are straightfoward. On the other hand, to sill satisfy the HPC implementation and also have an easy access to the discrete adjoint, the product could be obtained by means of automatic differenciation (5). In that case, the strategy must be validate for each spatial scheme. The second objective is to construct a well suited precoditionner that does not require the formation of the entire Jacobian matrix. Such a precoditionner depends on physical system to solve (Euler, Navier-Stokes, RANS) and on numerical strategy (spatial scheme, structured or unstructured grids).

The developped method will be validated on several well documented test cases before being used to perform 3D turbomachinery simulations.

The results will be the subject of publications in journals and scientific conferences.

(1) L. Cambier, S. Heib, S. Plot, The ONERA elsA CFD software: input from research and feedback from industry ,Mech.Ind (2013)

(2) G. E. Moore, *Cramming more components onto integrated circuits. Electronics (1965).*

(3) Y. Saad and M. H. Schultz. *GMRES: A generalized minimal residual algorithm for solving nonsymmetric linear systems*. SIAM J. Sci. Stat. Comput.,(1986)

(4)D. A. Knoll and D. E. Keyes. *Jacobian-free newton-krylov methods: a survey of approches and applications*. Journal of Computational Physics (2004)

(5) L. Hascoët, and V. Pascual.*The Tapenade automatic differentiation tool: Principles, model, and specification* ACM Trans. Math. Softw. 39 (3): 20 (*2013*)

Collaborations extérieures : INRIA (Laura Grigori & L. Hascoet)

PROFIL DU CANDIDAT

Formation : M.Sc. degree in Applied Mathematics, Mechanics or a related discipline, with excellent academic record

Spécificités souhaitées : A solid background in Computational Mechanics (numerical analysis of PDEs), programming skills and motivation to learn are required**.**