Approximated models for aerodynamics coefficients estimation in a multidisciplinary design environment

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It is known how the aerospace engineering is characterized by great complexity. This is related to the fact that it deals with large-scale systems and that the involved issues are numerous, different in nature and often not independent. Also for aircraft industries, some design requirements are more and more demanding.

On the one hand the need to maintain competitiveness in terms of design quality and reduction of time to market (which can be translated into a physiological reduction in design time). On the other hand the need to reduce development and production costs is reflected in the will to develop an optimal design since the early (preliminary) stages in order to reduce the entity and amount of changes (typically cumbersome and expensive) done in further design phases.

A good response to these demands is the use of tools and methodologies that go under the name of Concurrent Engineering (CE) and Multidisciplinary Analysis (MDA)[1]. The need to reduce the time for design process is also strictly related to a containment of computational burden. It is therefore necessary to find methods of analysis that allow a significant reduction of both running time and computing resources used. In engineering literature there are several methods to address this problems. They are multi-fidelity modeling approaches and approximations of analysis process.

The multi-fidelity approach involves the use of analysis models characterized by different levels of fidelity [2, 3]. In this framework typical high fidelity models are implementations of methods that allow a very accurate analysis (i.e. for aerodynamic analysis, 3D finite volume Computational Fluid Dynamics (CFD) model with very refined discretization and physics description). On the other hand low fidelity models families are various: implementation of the same high fidelity approach, but with a rougher description or discretization of the problem, implementation of simplified physics models and approximations by the use of surrogate modeling approaches.

The first two options go under the name of hierarchical surrogate modeling [4]. Alexandrov and Lewis widely deals with this kind of methodologies and their performances [5].

Speaking about surrogate modeling, different kind of methodologies can be found. In particular it is possible to distinguish between two families of surrogates. The first is the group of data fit models [6, 7]; they are generated via interpolation of data related to simulations at given sets of design points; the most known data fit techniques are response surface models [8] and Kriging models [9]. The second family gathers reduced order models that are typically based on the reduction of the state dimension [10]; Proper Orthogonal Decomposition (POD) techniques are widely used examples of these methods [11, 12].

In this paper variable fidelity analyses are investigated. Moreover we will build different kind of approximations to be used in a wide multidisciplinary design environment for aircraft design. Speaking about the matter in hand, in order to obtain the surrogate models to be used in the main design process, a proper framework is built using the I-sight environment for process and variables management. Approximated models for the estimation of aerodynamic coefficients are evaluated on design spaces of different dimensions and considering different set of variables (i.e. geometric parameters and flight conditions). They are mainly based on the hybrid combination of Vortex Lattice Method (VLM) models (representing basic low fidelity analysis) and 3D finite volume Computational Fluid Dynamics models (representing basic high fidelity analysis tool). Different strategies for the evaluation of the surrogate model are considered and compared.

References

[1] Alexandrov, N., Lewis, R. M. 2002. Analytical and computational aspects of collaborative optimization for multidisciplinary design. *AIAA Journal*. 40(2):301-309.
[2] Alexandrov, N., Lewis, R., Lewis, M., Gumbert, C., Green, L., Newman, P., 1999. Optimization with variable-fidelity models applied to wing design. Technical Report CR 209826, NASA.
[3] Alexandrov, N., Lewis, R., Lewis, M., Gumbert, C., Green, L., and Newman, P. 2001. Approximation and model management in aerodynamic optimization with variable-fidelity models. *AIAA Journal.* 38(6):1093-1101.
[4] Robinson, T., Eldred, M., Willcox, K., and Haimes, R. 2006. Strategies for multi-fidelity optimization with variable dimensional hierarchical models., In: *47th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference.* AIAA-2006-1819.
[5] Alexandrov, N., Lewis, R. M. 2000. First-order frameworks for managing models in engineering optimization. In: *1st Int. Workshop on Surrogate Modelling and Space Mapping for Eng Opt*.
[6] Venter, G., Haftka, R., and Starnes, J. 1998. Construction of response surface approximations for design optimization. *AIAA Journal.* 36(12):2242-2249.
[7] Eldred, M., Giunta, A., and Collis, S. 2004. Second-order corrections for surrogate based optimization with model hierarchies. In: *10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference*. AIAA 2004-4457.
[8] Simpson, T., Peplinski, J., Koch, P., and Allen, J. 2001. Metamodels for computer based engineering design: Survey and recommendations. *Engineering with Computers*. 17:129-150.
[9] Sacks, J., Welch, W., Mitchell, T., and Wynn, H. 1989. Design and analysis of computer experiments. *Statistical Scienc.* 4(4):409-435.
[10] Antoulas, A.C. 2005. Approximation of Large-Scale Dynamical Systems. Book Series: Advances in Design and Control, DC 06, 479 pages, SIAM, Philadelphia.
[11] Willcox, K., Peraire, J. 2002. Balanced model reduction via the proper orthogonal decomposition. *AIAA Journal*. 40(11):2323-2330.
[12] Bui-Thanh, T., Damodaran, M., Willcox, K. 2003. Proper orthogonal decomposition extensions for parametricapplications in transonic aerodynamics. In: *21th AIAA Applied Aerodynamics Conference*. AIAA 2003-4213.