# Uncertainty Quantification Framework for Large-Scale Unsteady Problems (ESR4)

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## 1 Context

This PhD position is funded through the UTOPIAE project, which is a training and research network funded by the European Commission through the H2020 funding stream.

The main objectives of this research program are to train, by research and by example, 15 Early Stage Researchers (ESR) in the field of Uncertainty Quantification (UQ) and Optimization and to become leading independent researchers and entrepreneurs that will increase the innovation capacity of the EU, and to equip them with the skills needed for successful careers in academia and industry, to develop, through the ESR individual projects, fundamental mathematical methods and algorithms to bridge the gap between Uncertainty Quantification and Optimization and between Probability Theory and Imprecise Probability Theory for Uncertainty Quantification, and to efficiently solve high-dimensional, expensive and complex engineering problems.

## 2 Objectives

Computational Science aims at developing reliable and predictive numerical tools, relying on and mixing experiment, computation and theory. The objective is not only to numerically reproduce with high-fidelity an observed phenomenon, but also to predict the reality in situations for which the numerical tool has not been specifically validated nor tested. To this end, reliable numerical predictions require sophisticated physical models as well as a systematic and comprehensive treatment of calibration and validation procedure, including the quantification of inherent uncertainties.

Complex physical models call for simplifications that usually introduce parameters. For instance, using turbulence models instead of direct Navier-Stokes (DNS) simulations introduces some modeling constants to be calibrated or estimated. Consequently, these model parameters remains uncertain, as they can not be known exactly, and it is crucial to assess the impact of these uncertainties on future predictions. Unfortunately, increasing the number of uncertain parameters immediately translates in an increased computational cost for the uncertainty quantification (UQ), due to the so-called curse of dimensionality. The design of UQ methods should then be robust to the number of uncertain parameters, in order to remain feasible for engineering problems of interest.

Moreover, UQ methods have to be applied on top of the deterministic solvers to enable large scale applications (i.e. non-intrusively). In particular, they should take advantage of the modern computational infrastructures with massive parallelism. For instance, the possibility to solve *in parallel* a numerical model for different values of the uncertain parameters is routinely exploited in black-box methods. However, designing computational strategies that closely associate deterministic solution methods (for PDEs) and UQ methods appears as a promising way to reduce the computational cost of UQ problems. Indeed, although the computations for different parameter values are independent, one may found advantages in reusing information of one solve to accelerate another (*e.g.* recycling adapted meshes). Other possibilities include revisiting deterministic approaches, such as Domain

Decomposition methods, to adapt and extend them for the UQ task. From the computational performance perspective, it is also critical to exploit structures in the uncertain parameters effects to design efficient UQ strategies. However, since these effects are usually unknown a priori, one needs to rely on dedicated procedures to adapt and revise the UQ strategy as the knowledge of the parameters impact is progressing.

The aim of the ESR is to develop original UQ algorithms and solvers to deal with complex model dependencies in high parametric dimension. As the project targets large scale simulations, High Performance Computing aspects will be a major concern in the design of UQ algorithms taking advantage of modern computational infrastructures. The ESR will work with Stanford University on the HPC framework for treating large-dimension unsteady problems, during a three-months secondment. The ESR will apply the developed framework to the design of morphing airfoil for helicopter application, during a three-months secondment at Politecnico di Milano.

## 3 Supervision

The ESR will be supervised by P.M. Congedo (INRIA) and Olivier Le Maître (CNRS), experts in uncertainty quantification methods (see `http://www.pietrocongedo.altervista.org/` and `http://perso.limsi.fr/olm/`).

This thesis will be held at INRIA, Center of Saclay (`http://www.inria.fr/en/centre/saclay`).

Established in 1967, Inria is the only French public research body fully dedicated to computational sciences. It is a national operator in research in digital sciences and is a primary contact point for the French Government on digital matters. Under its founding decree as a public science and technology institution, jointly supervised by the French ministries for research and industry, Inria's missions are to produce outstanding research in the computing and mathematical fields of digital sciences and to ensure the impact of this research on the economy and society in particular. Inria covers the entire spectrum of research at the heart of these activity fields and works on digitally-related issues raised by other sciences and by actors in the economy and society at large. Beyond its structures, Inria's identity and strength are forged by its ability to develop a culture of scientific innovation, to stimulate creativity in digital research. Throughout its 8 research centres and its 180 project teams, Inria has a workforce of 3 400 scientists with an annual budget of 265 million euros, 29% of which coming from its own resources.

## 4 Eligibility Criteria

- Early-Stage Researchers (ESRs) shall, at the time of recruitment by the host organisation, be in the first four years (full-time equivalent research experience) of their research careers and have not been awarded a doctoral degree.
- All researchers recruited in an ITN must be Early-Stage Researchers (ESRs) and undertake transnational mobility (including, but not limited to secondments with other UTOPIAE partner institutions, conference attendance, outreach and engagement work and any other appropriate work requiring travel as deemed necessary by their supervisor).
- Mobility Rule: at the time of recruitment by the host organisation, researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organisation for more than 12 months in the 3 years immediately prior to the reference date. Compulsory national service and/or short stays such as holidays are not taken into account.

For all recruitment, the eligibility of the researcher will be determined at the time of their first recruitment in the project. The status of the researcher will not evolve over the life-time of the project.

## 5 Duration of the Project and of the Recruitment

The recruitment of each individual ESR will be 36 months.

**Starting date:** September-November 2017.

## 6 Type of contract

The successful ESR applicant will be offered a three year full-time funded contract by INRIA. Duration: 36 months, Gross salary: 39,820.00 per year. Work location: mainly INRIA (Center of Saclay), and also Stanford, USA (during 3-6 months), and Milano, Italy (Politecnico di Milano, during 3-6 months).

## 7 Requirements and Application Procedure

Candidates are required to have a Master's degree in engineering, applied mathematics or a related discipline, and a specialization in computational fluid dynamics, uncertainty quantification, optimization or related fields. Preferable qualifications for candidates include proven research talent, an excellent command of English, and good academic writing and presentation skills.

Applicants should submit a Curriculum Vitae, a covering letter as a single document detailing the knowledge, skills and experience you think make you the right candidate for the job, two letters of reference, a list of your MSc courses and grades, copy of your Master's thesis and preferably a list of publications.

Applicants should confirm within their covering letter the length of time they have resided in the host country in the last 3 years before the 1st of October 2017.

Note that each applicant can apply for a maximum of 2 posts within the network, and must indicate their order of preference.

For further details and applications, please contact Pietro Marco Congedo (`pietro.congedo@inria.fr`). All applications should be emailed to `apply@utopiae.eu` and to `pietro.congedo@inria.fr` by Sunday, 30 April 2017.