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RTRA—A New National Research Initiative in France

By Iain Duff

Readers familiar with the organization and funding of research in applied mathematics in France will recognize the names of three important agencies: CNRS, INRIA, and the French Ministry of National Education, Higher Education and Research (MESR). Beginning in 2007, many grants have been awarded by the ANR (Agence Nationale de la Recherche) Programme of MESR; ANR can be thought of as the French counterpart of the U.S. National Science Foundation.

The focus of this article is a new nationwide initiative, le Réseau Thématique de Recherche Avancée (RTRA), established by the French government and launched with a call for proposals in May 2006. The idea behind RTRA is to use government money (some 200 million euros) to stimulate research in France, favouring the development of research projects at the highest international level. The initial solicitation drew 37 proposals, 13 of which were selected.

The disciplines covered by the 13 accepted proposals, which are distributed throughout France, include economics, neuroscience, physics, chemistry, epidemiology, nanoscience, and agriculture. The mathematical sciences are the focus of two of the successful proposals, one from Paris and the other from Toulouse. In Toulouse, the foundation "Sciences et Technologies pour l'Aéronautique et l'Espace," or STAE, as discussed in the remainder of this article, has already had a significant impact on the student and research community—the largest in France outside Paris.

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STAE was created to stimulate advances in the aeronautic and space sector in the Midi–Pyrénées region (in which Toulouse is located). Its objectives are to promote excellence in multidisciplinary (aeronautic, space, and environmental) research; to enhance training and basic research programs; and to develop new avenues leading to innovative research and technology. STAE is a private foundation, with seven founding and associate members: CNRS, CNES, ONERA, IRD, Météo France, the University of Toulouse, and TOMPASSE (an association of 18 industrial partners). Calls for proposals in 2007 and 2008 resulted in five projects starting in 2008, another nine in 2009, and two so far in 2010. A total of more than €13 million has been divided among those 16 projects, in which 25 laboratories in Toulouse are involved.

Of the 16 projects, two are in embedded systems, three are in observation and functioning of earth systems, four in aeronautics, four in sensors and instrumentation, and three in modelling and simulation. In the planning stage are two additional projects, one in high-performance computing and the other in materials micro-analysis.

Participating laboratories range from large public research laboratories to laboratories like CERFACS (European Centre for Research and Advanced Training in Scientific Computation). The very ambitious intention is that projects will eventually give rise to centres of excellence on a world scale that will attract top people from outside France. At present, the RTRA–STAE employs 45 scientists from 22 countries.

A glimpse of two of the projects illustrates both the interests of STAE and the extensive network of labs in Toulouse. ADTAO (Assimilation de Données pour le Système Couplé Terre–Atmosphère–Océan) is a joint project of CERFACS, ENSEEIHT–IRIT, CNRM–Game (Météo France), and LDTP (Laboratoire de Dynamique Terrestre et Planétaire). The objective is to design the next generation of operational data assimilation systems by improving the representation of model errors in large, multiscale, highly nonlinear dynamical systems. The resulting improved descriptions of the components of the coupled Earth–atmosphere–ocean system would provide far-reaching benefits to society in the form of enhanced reliability and accuracy of operational forecasts of important weather and climate phenomena, such as extreme events, El Niño, climate change.

At the STAE workshop on nonlinear optimization, Jean-Claude Andre makes an introduction; Serge Gratton is at the computer. Photo copyright Clément Moussière, élève ENSIACET.

The main mathematical challenge is to solve a nonlinear least-squares problem with millions of unknowns. Versions of the most effective solver, a Gauss–Newton algorithm, are already in use in many weather and climate centres. One approach taken by project researchers is to build quasi-Newton preconditioners, using only information generated in the solution of linear subproblems by Krylov methods, The new preconditioners serve as a "warm-start" technique when a sequence of linear least-squares problems is considered in the Gauss–Newton process.

Another approach has been to solve the problems in a model space two orders of magnitude smaller than the observation space (10^7 rather than 10^9). The storage and computational costs of this reduced preconditioned conjugate gradient algorithm are much lower than those of its full-space counterpart. A next step will be the introduction of range-space variants of standard Krylov iterative solvers for both unsymmetric and symmetric linear systems. There are possible extensions of this work to the so-called dual approach PSAS (Physical Space Assimilation System) that is used in some operational centres.

Further cost-reduction efforts will involve inexact matrix–vector products: We can compute formal error bounds based on the size of the residuals obtained under two accuracy models, and it has been shown that a model controlling the forward error on the product is often preferable to one controlling the backward error on the operator. We are now considering the particular case in which the quadratic regularization term is approximated by an inexact solution of the heat equation obtained with an implicit discretization scheme.

Data assimilation problems arise in many other areas, including signal processing, geophysics, space dynamics, and meteorology. Much of the mathematics done within the ADTAO project is applicable to these more general problems. Common to most of these applications is a strong structure that has to be exploited to obtain efficient algorithms.

The goal of OSYCAF, the second STAE project briefly described here, is to develop a collaborative and distributed multidisciplinary optimization methodology in an aeronautics setting. Four of the major players from Toulouse (CERFACS, ONERA, ISAE, UPS) share many scientific objectives in areas that include computational fluid dynamics, mathematical algorithms, optimization, and structural mechanics. A current research focus is the multidisciplinary optimization of a coupled fluid–structure system involving a flexible wing in a transonic flow. The aerodynamics and structural mechanics subproblems are optimized with respect to their internal parameters.

The use of surrogate models is one approach to aerodynamic optimization being investigated. For the optimization engineering community, surrogate models and heuristics are a convenient way to deal with functions characterized by expensive evaluation, noise, or lack of convexity; typically, convergence of any kind is not guaranteed under reasonable assumptions, and local convergence is frequently slow. This work will incorporate surrogate models, heuristics, or any other process for obtaining a function value decrease with trust-region algorithms for unconstrained derivative-free optimization, while maintaining global convergence of the algorithms to stationary points. The approach follows the lines of direct-search poll methods and corresponding surrogate management frameworks, both in algorithmic design and in the convergence theory.

Descriptions of all existing projects can be found at http://www.fondation-stae.net/fr/actions/projets-cours.html. The page is in French, but the pop-up windows for each project are written in English.

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Another of STAE's activities is to fund advanced workshops on topics of interest to STAE projects and research in the Toulouse region. An example is a CERFACS/ENSEEIHT–IRIT workshop on advanced methods and perspectives in nonlinear optimization, held in Toulouse in February 2010 with STAE support of more than €30,000. Unlike some funding agencies, STAE encourages the involvement of top people from outside France; accordingly, much of the funding was used to support attendees from overseas.

The very successful workshop drew 110 attendees. Readers may recognize the names of several speakers, including editors of *SIAM Journal on Optimization* and three recipients of the Lagrange Prize in Continuous Optimization. Sven Leyffer, SIAM's vice president for programs (and one of the optimization prize recipients), gave a talk titled "Software for Integer and Nonlinear Optimization," and Stephen Wright, a member of the SIAM Board of Trustees, discussed sparse optimization methods. Given the lively discussions of derivative-free optimization and genetic algorithms, follow-up workshops are a possibility.

The programme, abstracts, and pdf files for the presentations can be found at http://www.fondation-stae.net/fr/actions/seminaires-archives.html.

Iain Duff, the current chair of the SIAM Board of Trustees and a SIAM Fellow, is an STFC Senior Fellow at Rutherford Appleton Laboratory and project leader of the Numerical Algorithms Group at CERFACS. He is currently working for the RTRA ADTAO Project. He thanks several of his colleagues in Toulouse for help in writing this article.