2018 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:
Eigenvalue optimization

Helmholtz Centre and institute:
Forschungszentrum Jülich, Institute for Advanced Simulation (IAS), Jülich Supercomputing Centre (JSC)

Project leader: Dr. rer. nat. habil. Andreas Kleefeld

Web-address:
http://www.fz-juelich.de/SharedDocs/Personen/IAS/JSC/EN/staff/kleefeld_a.html

Description of the project:
The aim in non-destructive testing is to visualize the interior of a given three-dimensional object in order to uncover location, size, and geometry of inhomogeneities. Interior transmission eigenvalues can be used for this purpose. However, the efficient numerical calculation of interior transmission eigenvalues is a challenging task due to the fact that the corresponding interior transmission problem is nonlinear, non-elliptic, and non-self-adjoint.

Since the shape of the objects determines (for example) the first acoustic interior Dirichlet eigenvalues, there are still open theoretical questions in two-dimensions like: How does the shape of a convex obstacle with a fixed area has to look like to minimize the first interior Dirichlet eigenvalue. Even the numerical calculation is a challenging task due to the fact that the admissible shapes are not easy to describe in general and the object might have corners. The conjecture is that a regular polygon is the minimizer. So far it has only been shown to be true for the regular triangle and the regular square (G. Polya and G. Szegö, Isoperimetric inequalities in mathematical physics, Ann. of Math. Stud., 27 , Princeton Univ. Press (1951)).

Of course one might investigate if similar results seem to be true in three dimensions or what happens if one uses the first interior transmission eigenvalue. Additionally, it is worthwhile investigating whether similar conjectures can be established for electromagnetic or elastic scattering and then verify them by numerical results.

The nine goals (G) of this project are: (G1) to establish a method to numerically solve nonlinear eigenvalue problems arising in acoustic, electromagnetic, and elastic scattering for smooth and piecewise-smooth obstacles in two and three dimensions. (G2) to implement this method in Matlab (for testing), then in C/C++ (for performance gain) and use MPI/OpenMP for the parallelization of the code (for ultimate performance). (G3) to work out the analysis (stability, convergence, and convergence rate). (G4) to establish a method to numerically optimize an eigenvalue with respect to the shape of an object both in two and three dimensions. Here the eigenvalue can be an interior Dirichlet or an interior transmission eigenvalue. The scattering problem under consideration can be acoustic, electromagnetic, and elastic. (G5) to implement this method in Matlab (for testing), then in C/C++ (for performance gain) and use MPI/OpenMP for the parallelization of the code (for ultimate performance). (G6) to work out the numerical analysis for this algorithm. (G7) to verify or disprove numerically the conjecture of Polya and Szegö and to establish new conjectures fundamented by numerical results in three dimensions complemented by new results for interior transmission eigenvalues arising in acoustic, electromagnetic, or elastic scattering problems. (G8) to show why it is so difficult to prove the conjectures (or even prove them, if possible). (G9) to publish all the result with the project leader Dr. Andreas Kleefeld.

Description of existing or sought Chinese collaboration partner institute:

Dr. Andreas Kleefeld has been the first who numerically calculated interior transmission eigenvalues to high accuracy for a variety of three-dimensional objects via a combination of a system of boundary integral equations and complex-valued contour integrals. He is a well-known expert within this research field and additionally has a high reputation in his research community which is shown by his numerous collaborations and publications. Also, he has published over 30 peer-reviewed articles in various fields such as Numerical Analysis, Inverse Problems, Image Processing, and Statistics which also shows a large diversity of topics.

However, Mr. Kleefeld currently has no existing collaboration with China, although he knows many Chinese researchers from his community in person (such as Xiaodong Liu & Xia Ji, Chinese Academy of Sciences, Beijing; Jijun Liu & Tiexiang Li, Southeast University, Nanjing; Guanghui Hu, Beijing Computational Science Research Center; Yidu Yang, Guizhou Normal University; Fang Zeng, Chongqing University). He also visited Zhejiang University, Hangzhou for the conference Applied Inverse Problems in May 2017 and got to know many researchers. A collaboration with one of these universities might be an option, but applications from other institutions that fulfill the research focus are also welcome.

Required qualification of the post-doc:

- PhD in mathematics and/or scientific computing
- Experience with numerical analysis (partial differential equations, boundary integral equations, boundary element collocation method, numerical integration and differentiation) and numerical linear algebra (eigenvalues, singular value decomposition)
- Additional skills in programming Matlab and C/C++ and basic knowledge of MPI and OpenMP

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team