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Solving problems using fake Picassos

The European research network POEMA will explore mathematical methods that make it easier to make complex real-world calculations- University of Konstanz mathematicians are partners.

In recent years, maintaining the stability of the German energy grid has become much more difficult due to growing use of wind and solar energy. If all neighbouring countries were to promote renewable energy to the same extent as Germany, the current mathematical methods used to stabilise internationally interlinked energy grids would probably not be up to the challenge. It's about questions such as which cables to use to carry certain amounts of electricity, which power plants should adjust by producing more or less electricity and how much electricity should be imported from and exported to other countries. Working with the French system operator RTE, the young mathematician Cédric Josz, who currently works at the University of California in Berkeley (USA), was recently able to demonstrate that general mathematical tools developed at the University of Konstanz and in other international locations can be modified to stabilise large energy grids.

To that end, engineers developed a range of mathematical models. A new approach to stabilizing energy grids is based on a special type of system of non-linear equations and inequalities, a "polynomial system" with various influential variables that can be added and multiplied using nested parentheses. The older methods, which are geared towards calculating exact solutions, are too slow for such applications, which require that results are available within seconds or minutes. Under certain circumstances, it would take computers many years to calculate solutions for the respective non-linear systems. University of Konstanz mathematicians from the research focus area "Real Geometry and Algebra" led by Professors Salma Kuhlmann, Claus Scheiderer and Markus Schweighofer (the appointment procedure for a fourth professorship is ongoing) are working on new methods capable of solving many instances of such non-linear systems quickly. They are part of the European research network POEMA ("Polynomial Optimization, Efficiency through Moments and Algebra"), which will be launched in early 2019 and run for four years.

The collaborative project involves a total of fourteen partner institutions from science and industry (including, for instance, RTE) and is based on the following principle: The final results provided by solutions of polynomial systems are not exact, but as close to exact solutions as possible. "It's a kind of universal tool kit that can be used anywhere and, when adjusted to the situation at hand, helps make complex problems feasible", explains Markus Schweighofer, who leads the University

of Konstanz branch of the network. Among the virtually limitless areas of application are signal processing, machine learning, energy supply, traffic management and, above all, control theory.

The scientists, who will work with the research divisions of international companies such as IBM, will be funded with approximately € 4m from the Marie Skłodowska-Curie actions programme of the European Union for a period of four years starting in 2019 and ending in 2023. The University of Konstanz is to receive approximately € 500,000. During the funding period, the researchers will not only further optimize their methods, but also customize them for specialist applications. “This tool kit is relatively new, which means that, during the project, we will also try to circulate it more widely”, says Schweighofer.

What is truly innovative about their approach is not merely that the final results of the computer calculations are approximate, but that the interim solutions are “less than approximate”. Since, most of the time, there is not just one interim solution, but a whole set of them, something “like a probability distribution on the set of interim solutions” is calculated. Schweighofer employs an analogy to describe this approach: “Calculating a real probability distribution on the set of interim solutions can be as challenging as painting a Picasso. We therefore work with what could be considered “fake Picassos” that are impossible to tell apart from the original using either the naked eye or a palm-sized magnifying glass – no matter how big the magnification is. You would only be able to prove the forgery if your magnifying glass had an enormously large field of view. That way, the good forgery can go into circulation, i.e. the pseudo interim result can be processed further”.

Concerning the approximative nature of the final results, a method of certifying the approximation quality achieved will also be provided. “In whatever we do, we always also try to prove that the result can only differ from an exact solution to a certain degree and that it is practicable”, he adds.

POEMA is organised around an international network of doctoral researchers working in several European locations. For instance, the two doctoral researcher positions at the University of Konstanz must not be awarded to individuals who have resided in Germany in the past years. The early career researchers’ task will be to develop the “tool kit” further for use in a broader range of applications, especially industrial ones.

Facts:

- European research network POEMA – “Polynomial Optimization, Efficiency through Moments and Algebra”
- University of Konstanz participants include: Professor Markus Schweighofer (on-site project leader), Professor Salma Kuhlmann, Professor Claus Scheiderer, Dr Sabine Burgdorf and Dr Maria Infusino
- A total of 14 partners from industry and science
- A network of 15 doctoral researchers
- Funded in the Marie Skłodowska-Curie actions programme of the European Union
- Funding period: 2019 to 2023
- Overall funding amount: approximately € 4m
- Approximately € 500,000 awarded to the University of Konstanz

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