Yunan Yang wins Leslie Fox Prize for her work on FWI

This year's Leslie Fox Prize Symposium was held at Strathclyde on 24 June. There were five shortlisted contestants Daniel Fortunato (Harvard), Yunan Yang (New York University), Alexander Bastounis (Cambridge), Simone Brugiapaglia (Simon Fraser) and Abdul-Lateef Haji-Ali (Heriot-Watt).

We started the day with an opening by Ben Leimkuhler, *Numerical Analysis: Past, Present, and Future*, which took us on a numerical analysis journey from the Antikythera (a supercomputer dating from 150BC) via Babbage's analytical engine (1838) to today's Archer Supercomputer and how numerical computation became the third leg of scientific research that it is today. He explained that Leslie Fox (Director of Oxford University Computing Laboratory) helped to establish Numerical Analysis as a discipline; and that the future of numerical analysis will be heavily influenced by data science with topics like numerical optimisation, graph Laplacians and computational harmonic analysis coming increasingly to the fore. The focus then turned to the talks of the candidates.

Nick Trefethen congratulating Yunan Yang (first prize), Alex Bastounis, Daniel Fortunato, Abdul-Lateef Haji-Ali, Simone Brugiapaglia (l to r).

In his talk *Fast Poisson Solvers* Daniel Fortunato investigated the question 'Can we make a spectrally-accurate and computationally optimal Poisson solver for the square?' The answer: combine diagonalising (sparsifying) polynomials (ultra-spherical) with Peaceman-Rachford splitting with a strategy to compute optimal shifts (maximally separating spectra) for the latter. Also discussed was the alternating direction implicit (ADI) method as a rank-revealing algorithm for the matrix of the Poisson equation. The paper he presented is a beautiful piece of numerical analysis that combines ideas of spectral solvers, operator splitting techniques and numerical partial differential equations. The hierarchical Poincaré-Steklov method can be used to lift this fast Poisson solver from squared domains towards complex geometries.

Next, Yunan Yang presented her work on full waveform inversion (FWI) with PDE-constrained optimisation and optimal transport. FWI constitutes the inverse problem of computing the wave velocity on measuring wave response on the boundary. This is a form of PDE-constrained optimisation where the objective compares forward simulation using the sought-for wave velocity with real measurements. Her contribution is the realisation that many drawbacks of the classically used least-squares objective can be mitigated by replacing it with the Wasserstein distance, which more naturally accommodates differences due to shift and dilation in the measurements. In particular, the Wasserstein distance is convex under dilation and translation. Dr Yang's work is an impressive example of the power of numerical analysis to solve a tremendously challenging applied problem such as FWI. Her work on the W2 Wasserstein distance for FWI, which constists of both novel theoretical and computational advances for Wasserstein-FWI, has significantly improved upon the conventional L2 squared objective.

Alex Bastounis gave a talk on compressed sensing and explained how his work brought the theory closer to application. The main application of interest is magnetic resonance imaging (MRI). After taking us through the compressed sensing basics such as sparsity, uniform recovery and the null-space property, Alex emphasised the gap between theory and practice of compressed sensing, explaining this with a newly introduced flip test. The latter endorsed his notion of (s,M) sparsity – structured sparsity, the reduced isometry property (RIP) in levels, for which he and his co-authors prove recovery and stability guarantees. The result gives a new framework for compressed sensing, that is doing everything mentioned above (sparsity etc.), but in levels.

Simone Brugiapaglia then gave a talk on correcting for unknown errors in sparse high-dimensional function approximation. For sparse approximation Simone uses orthogonal polynomials which for smooth functions should constitute a sparse approximation of the high-dimensional function; as sparsity-promoting regularisation a weighted L1 norm is used. In their work they derive recovery guarantees without the usual need for an upper bound on the error (noise-blind robust recovery guarantees). Moreover, their derivation is constructive, as it comes with optimal tuning parameter strategies. The derived theory was confirmed by numerical examples. Errors of interest include truncation (discretisation) error and node failure in cluster computations. He finished the talk with an outlook towards using these techniques to prove optimality of sampling in sparse recovery (e.g. in MRI) and deriving adaptive sampling strategies.

Abdul-Lateef Haji-Ali gave the final talk, about Multilevel Monte Carlo (MLMC) for risk estimation. Risk analysis is a very challenging problem: extreme events are viewed as rare, dramatic changes (the thing that makes risk risky!); thus risk measures are not smooth and underlying stochastic models are expensive to evaluate. Abdul-Lateef focused on tackling the last two issues, which boils down to the difficulty of computing nested expectations. For this, multilevel Monte Carlo has been employed. The non-smoothness is tackled by adaptive inner sampling (more sampling when close to discontinuity and less when far away) with each of these added components reducing the computational complexity for risk analysis.

All of the talks were excellent and it was certainly very difficult for the panel (Ben Leimkuhler, Des Higham and Carola-Bibiane Schönlieb) to sort out a unique winner. Eventually, though, the decision went to Yunan Yang who received first prize. Second prizes were awarded to all the remaining participants. Nick Trefethen kindly agreed to announce the results and present the prizes. The chair duties now fall to Des Higham for the 20th Leslie Fox Prize competition.

The judges are extremely grateful to the organisers of the Biennial Numerical Analysis Conference, who made the local arrangements for the prize meeting at the University of Strathclyde, provided catering for all attendees and offered accommodation expenses to the candidates.

Ben Leimkuhler FIMA, Des Higham, Carola-Bibiane Schönlieb FIMA and Alastair Spence