Demonstration of Improved Acoustic Simulation

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Figure 1 shows a typical simulation of sound generated by a turbulent jet. In general, Computational AeroAcoustics (CAA) simulations are an important tool for aircraft manufacturers such as Boeing and Airbus to produce aircraft that are quiet enough to be allowed to fly. CAA simulations solve one of a number of PDEs, such as the Linearized Euler equations or the Linearized Navier Stokes equations. State-of-the-art CAA simulations are based either on Discontinuous Galerkin methods or Finite Difference methods, and this project concerns finite differences. Specifically, finite differences (and the related Runge–Kutta time integration) have been optimized to perform well for acoustics simulations with rather few points per wavelength [e.g. 1–6].

A few years ago, Ed showed that these optimized finite difference schemes don't perform anywhere near as well as they were predicted to under realistic conditions [7]. This is because they assume that waves are of constant amplitude, while in fact real waves are decaying or growing. This work has been followed up by student undergraduate summer projects to try to reoptimize the finite differences for non-constant-amplitude waves [8, 9], but to date this work has not been published. There remains a lot of scepticism in the research community about this work, as it has not been demonstrated in large-scale simulations. This is because no-one has tried, not because it doesn't work.

The aim of this project is to write a finite differenece simulation of the 2D Linearized Euler equations, in order to demonstrate the work above in two specific cases. The first case is a standard test case, which unfortunately only involves constant-amplitude waves. The second test case is for sound between two acoustic linings on top of a mean flow (modelling sound reducing linings used in aircraft engines), which would involve waves with widely varying amplitude. It is hoped these will be added to previous work and submitted as a journal publication (perhaps more than one).

The following skills might be useful, though not essential, for this project:

- Some understanding of finite difference differentiation.
- Some understanding of Runge–Kutta time integration.
- Familiarity with fluid dynamics.
- Familiarity with acoustics, or alternatively familiarity with linearization and stability analysis.
- Ability to programme medium-sized projects, ideally in a compiled programming language (e.g. C, C++, Fortran, etc).
- Ability to process data and produce informative plots (using, e.g. gnuplot, matlab, python, etc).

This project has the potential to continue into a PhD, working on the mathematical theory of aeroacoustics simulations and their practical demonstration. Potential project partners include Airbus, DLR (the German NASA), and collaborative research with the University of Le Mans, France. A 2-year postdoctoral researcher will also be employed to work on a similar (though distinct) problem in computational aeroacoustics, and so there is the potential for a small collaborative group within Warwick in the near future.

If there are any questions, or for further details, please feel free to contact Ed. In particular, it would probably be easier to chat with Ed rather than trying to read through any of the cited papers.

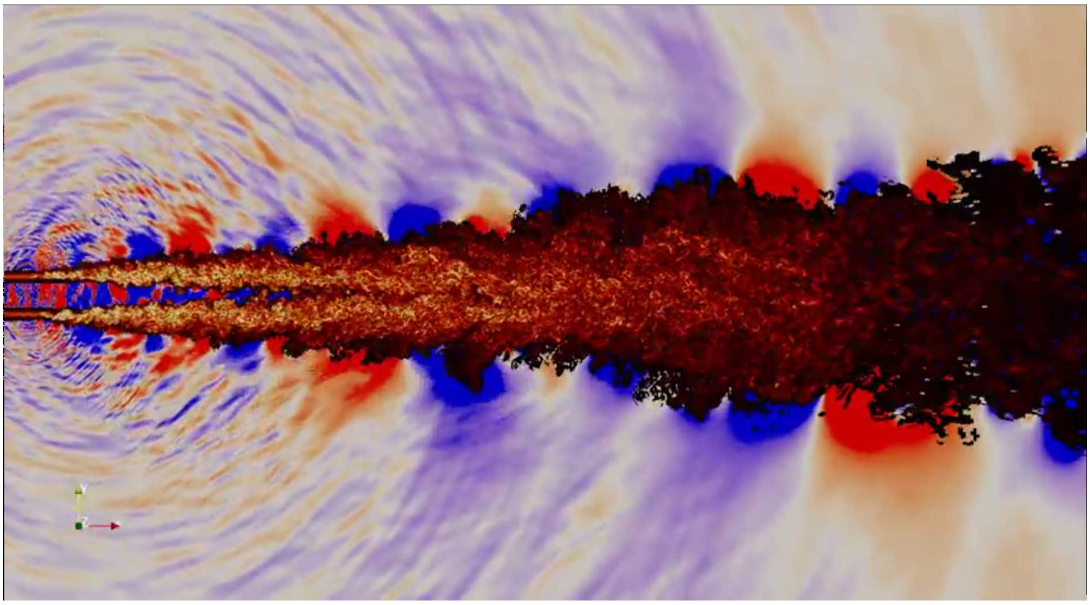

Figure 1: A simulation of jet noise, taken from `https://www.youtube.com/watch?v=CCdZ8wJYTG8`. The turbulence (vorticity field, shown in hot colour scheme) is superimposed on the pressure field (red/blue colour scheme). The simulation took 11 days using 1200 CPUs.

References

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