PhD thesis subject proposal

Numerical computations of Green's functions using an adjoint based method for acoustic propagation through complex flows

ED162 MEGA / Ecole Centrale de Lyon / LMFA

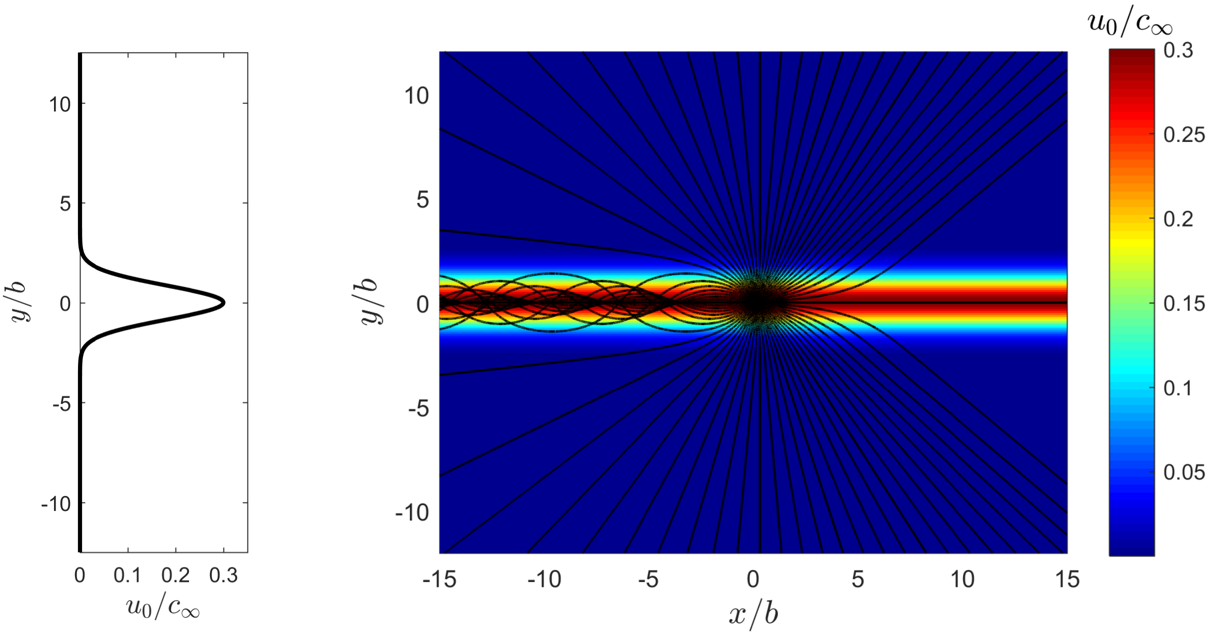

FIGURE 1 – Ray paths through a jet with a Gaussian velocity profile, for a point acoustic source located at $(x_s, y_s) = (0, 0)$. We can observe refraction effects bending the rays when they travel through the jet. We can also notice that some rays propagating towards $x < 0$ are trapped within the jet, acting as a waveguide.

Context

Transportation noise is a major nuisance for populations located in the vicinity of large infrastructures and particularly airports. For the air transportation domain, the traffic is expected to grow by about 4.6% per year between 2012 and 2032. In order to limit noise exposure around airports, the International Civil Aviation Organisation (ICAO) defines restrictive regulations that plane and engine manufacturers have to satisfy.

Aeroacoustic noise sources are related to the generation of turbulent flows (for example, landing gear wakes or high velocity exhaust of combustion gases) and to the interaction of turbulence with solid surfaces (such as the fan blades and the outlet guide vanes in the turbofan). In order to locate and characterise these sources, experimental methods making use of microphones antennas have been developed. They consist in detecting an acoustical event, then go back in time to extract a signature within the aerodynamic field that could be the origin of the sound emission and identify the associated physical mechanism. These methods can also be used on numerical simulation results, with the advantage of having access to aerodynamic quantities that are difficult to measure experimentally.

The presence of an inhomogeneous mean flow or of reflecting and diffracting surfaces affects the propagation of sound between the source and the microphone antenna. In such conditions, the Green's function describing the acoustic propagation can generally not be expressed analytically and it is necessary to resort to numerical simulation. Given that aeroacoustic sources are usually distributed over a large volume, the direct calculation of the Green's function between each point of the source region and the microphones can be extremely costly in terms of computational resources.

An alternative method consists in solving an adjoint problem by inverting sources and receivers [1, 2, 3] in order to estimate the Green's function. This method has the advantage of only requiring a number of estimations for the Green's function corresponding to the number of microphones, which is much lower than the number of source points. The computational cost is thus greatly reduced.

Objectives

The main objective of this project is to develop a method to solve the adjoint problem in order to estimate Green's functions in complex configurations, which will then be used in aeroacoustic sources localisation and identification techniques. The provisional schedule of the project can be briefly described by the following items :

- Bibliographic study on the adjoint problem and its use in acoustics.
- Formalisation of the adjoint problem for the equations under considerations and the configurations of interest (flows, boundaries).
- Computation of Green's function from the adjoint problem solution on simple configurations for which analytical or numerical solutions are available.
- Implementation of the method developed on complex configurations (to be defined) to characterise aeroacoustic sources.

This PhD thesis will be carried out within the acoustic group of the Fluid Mechanics and Acoustics Laboratory (LMFA) on the Ecole Centrale de Lyon campus. Moreover, this work are related to a research project on the identification and characterisation of aeroacoustic sources with a consortium of academic and industrial partners. This project aims at the development of a software solution allowing to process data coming from numerical simulations or experimental campaigns (microphones antenna) in order to localise and study the mechanisms responsible for noise generation. During this project, the PhD student will interact with the partners and may present his work during progress meetings.

Profile

The candidate must hold a master's degree or equivalent and have knowledge and skills in acoustics and/or fluid mechanics. A marked interest for applied mathematics would be a appreciated. The knowledge of one or more scientific programming languages (Matlab, Python, Fortran, C++) is expected and notions in numerical simulation methods would be a plus.

Contacts

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Références

[1] Giles, M. B. and Pierce, N. A., 1997, Adjoint equations in CFD : duality, boundary conditions and solution behaviour, *13th Computational Fluid Dynamics Conference*, Paper nº AIAA-97-1850.

[2] Tam, C. K. W. and Auriault, L., 1998, Mean flow refraction effects on sound radiated from localized source in a jet, *Journal of Fluid Mechanics*, **370**, pp. 149-174.

[3] Spieser, É. and Bailly, C., 2018, Adjoint solution to the linearized Euler equations computed from the direct problem, *14ème Congrès Français d'Acoustique*, pp. 73-79.