Abstract

Sujet : Identification of principal streamlines of a fluid flow by Data Assimilation.
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Key Words : Data Assimilation, Optimization, Shape Optimization, Inverse Problems.

The reconstruction of a fluid's flow geometry is an important element in the work of aircraft and automotive constructors. It allows to get more informations about the flow over the structure wich is essential for the conception, the comfort and the security.
The constructors use the experimentation and numerical simulations. The experimentation requests the instrumentation of the structure and many tests in a wind-tunnel. The cost can be very high. Numerical simulations require accurate and fast numerical methods to reproduce physical phenomena. By using a Navier-Stokes code we can obtain very good results but it could take several days of calculation. The cost can be very high too. The using of Data Assimilation combined with a simple numerical model can reduce this cost.

In my Ph.D. work, we are looking to identify principal streamlines of a fluid's flow over a structure, particularly, the streamlines border between two differents flows areas. For example, an irrotationnal incompressible flow area and the wake (rotationnal flow). For that, we have got observations and a simple numerical model. The modelization we have chosen is simplified (irrotationnal incompressible flow).

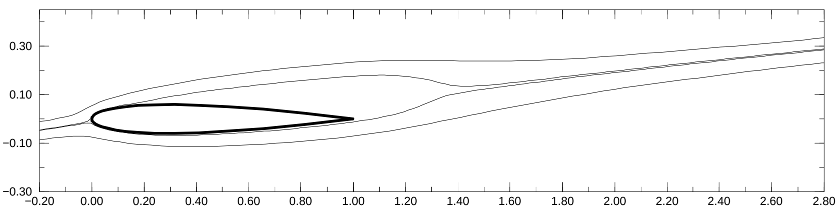

Figure1 : Streamlines over a naca0012 profile.

I started my work by an important bibliographical search on inverse problems. We noticed that our problem is close to a problem treated by Andrieux (EDF Electricité de France), Ben Abda and Jaoua (Ecole d'Ingenieurs de Tunis). In their work, they identified interior cracks in a domain by using overdetermined data on the edge of this domain. They use the reciprocity gap concept. In our case, the streamline we try to identify is equivalent to a crack. We have got overdetermined data in the domain of the fluid flow, so we were interested, in a first time, in the identification of the angle and the position of a streamline in a fluid flow.
Pratically, I developped a fortran code wich allows us to resolve numerically this problem. We used a finite element method for the resolution of the model's equations. The theorem of Betti-Maxwell allows us to identify the angle and the position of the streamline even if we use perturbated data. That shows that the method we developped is strong.

In the second part of my work, we were interested in the identificaton of the length of a streamline. We have formulated our inverse problem as an optimization shape problem. We minimize a quadratic gap between the observation field and the numerical values obtained by the numerical model. The parameter of this minimization is the length of the streamline. In order to define a shape derivative, we have followed the approach of Murat-Simon (derivation with respect to the domain, technicals based on the transport method developped by F. Murat and J. Simon).

An important bibliographical search on shape optimization and the derivation with respect to the domain technicals was necessary.

We used an optimal step gradient method. In order to get the gradient, we used integral equations to resolve the equations of the model and those of the adjoint. The advantage of the integral formulations is to bring the resolution of some problems posed in an non borned domain to the resolution of integral equations posed on the border of this domain. This allows us to save time. Also the using of the integral method, helps us to avoid the remeshing problem that we have when we use a finite element method.
With the numerical results, we verified that we identify the length of the streamline with accuracy even if we use perturbated data.

Afterwards, we have applied this method to identify a wake's area behind a structure. Nevertheless, we must underlined that the identification of an non null surface of a wake area is a problem more complicated than the precedent problems. This area can cover an important space of the fluid's domain.
To be more efficient, we developped an original method. This method consists in cutting the exterior domain in two independant parts (Figures 2 and 3) and resolve in each part the interior Neumann's problem. The advantage is the using of a smallest number of unknowns (the nodles of the streamline) and the parallelization of the two interior problems wich will allows us to save time.

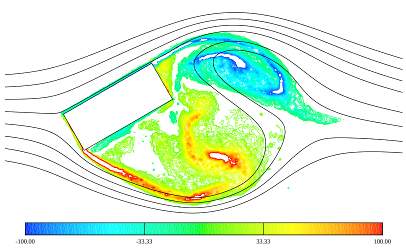

Figure 2

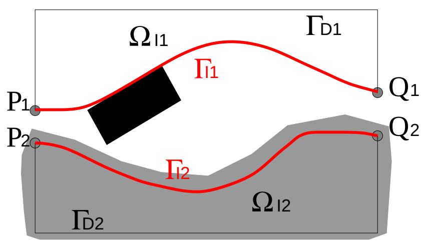

Figure 3

The numerical results show problems with the gradient and the curvature of the identified streamline as appearance of nodles during the iterative process. The introduction of the C^2 $cubic\ uniform\ B-splines$ and a penalization method (control of the curvature) allow to avoid these nodles. In the numerical results, we show that we can identify the streamlines and we minimize the objective-function until 10^{-7} even when we use pertubated data.