Centre de Mathématiques et de Leurs Applications
ENS Cachan et CNRS

GazTransport et Technigaz
Saint-Rémy-Lèz-Chevreuse

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Demande de soutien à l'Institut FARMAN

Couplage de modèles pour la simulation d'impacts de vagues

Durée du projet : 12 mois

Responsable scientifique : Ghidaglia Jean-Michel

Membres de l'équipe-projet avec la proportion de temps consacré au projet

Nom	Qualité	Temps
Brosset Laurent	Ingénieur Sénior R&D, GTT	20%
Mrabet Amine	Doctorant CMLA	50%
Ghidaglia Jean-Michel	PR CMLA	20%
X	Stagiaire	80%

Description de la problématique scientifique

This is a high performance computing project based on a finite volume code with interface capture called FluxIC. The method has been developed in [5-[6]] and belongs to the family of the CmFD (Computational multi-Fluid Dynamics) codes.

FluxIC has proved its efficiency on various physical test cases, more particularly for impacts calculations, this type of results have been presented during several ISOPE conferences (http://www.isope.org/) and are the subject of scientific publications [1] and [4].

The goal of the project is to compute the free fall of a liquid block or waves propagation in an enclosed rectangular space filled with gas and describe the impact on a rigid wall as precisely as possible. The sloshing problem during the transport of a liquid in a ship, which is a major issue in naval hydrodynamics, is the main driver for this type of computations.

Numerical methods and algorithms description

FluxIC is a pure Eulerian conservative scheme that allows to compute sharp interfaces between non miscible fluids. The underlying flux scheme in single material cells is the so called FVCF scheme [7], whereas interface reconstruction and directional splitting is used in multi-material cells. A sliding boundary condition is enforced at the interface between two materials. In the project, we use FluxIC ENIP, Enhanced Natural Interface Positioning [6], this method takes advantage of a consistent description of the interface in the numerical scheme. FluxIC is a Fortran 90 code which uses the MPI library and the OpenMP API [2] and [3].

One interesting feature for parallel computing is that each phase of the directional splitting in a generic direction x does not use information from other directions, except the 2D interface normal vector to impose the sliding condition at interfaces. That makes the computation of each cell line of the mesh independent from the others, so an interesting property for parallel computing. During the computation of the horizontal step of the directional splitting, the 2D domain is decomposed in horizontal slices. Each slice is computed by a processor on a distributed memory system. In the same way, we use vertical slices to decompose the domain during the vertical step. Thus, each slice contains the same number of cells (equal to the total number of cells divided by the number of processors) which allows to ensure a good load balancing between processors. However, with this kind of parallel algorithm, a processor has to compute a different subset of cells (vertical or horizontal slice) at each step (vertical or horizontal) of the directional splitting. Thus, to allow a given processor to compute the appropriate subset of cells following the direction change, we propose a ''transposition algorithm''. This transposition allows to transfer the necessary data using the Message Passing Interface (MPI).

We will take advantage of the project to improve parallelism in FluxIC, which is relatively new regarding the FVCF and interface positioning schemes.

[1] J. Costes, F. Dias, J.-M. Ghidaglia, A. Mrabet, Simulation of breaking wave impacts on a flat rigid wall by a 2D parallel Finite Volume solver with two compressible fluids and an advanced free surface reconstruction, ISOPE conference, submitted April 2013

[2] J.P. Braeunig, J. Costes, J.-M. Ghidaglia, M. Peybernes, Hybrid parallelization of a pure Eulerian finite volume solver for multi-material fluid flows, Parallel Computing, submitted September 2012

[3] M. Peybernes, J.-P. Braeunig, Parallélisation MPI par transposition d'un solveur volumes finis multimatériaux, Rapport CEA, 2011

[4] J.-P. Braeunig, L. Brosset, F. Dias, J.-M. Ghidaglia, On the effect of phase transition on impact pressure due to sloshing, ISOPE conference, 2010

[5] J.-P. Braeunig, B. Desjardins, J.-M. Ghidaglia, A pure Eulerian scheme for multi-material fluid flows, European journal of mechanics, B-/fluids, 2009

[6] R. Loubère, J.P. Braeunig, J.-M Ghidaglia, A totally Eulerian finite volume solver for multimaterial fluid flows: Enhanced Natural Interface Positioning (ENIP), European journal of mechanics, B-/fluids, 2012

[7] J.-M. Ghidaglia, A. Kumbaro, G. Le Coq, On the numerical solution to two fluid models via a cell centered finite volume method, European journal of mechanics, B-/fluids, 2001

Originalité du projet

La CFD n'est pas capable aujourd'hui (et pour très longtemps encore) de simuler les impacts de vagues à l'échelle 1 car s'agissant d'évènements rares, il faudrait simuler une heure de temps physique au moins un grand nombre de fois en variant les conditions initiales (convergence statistique). La taille des mailles devant être de l'ordre de quelques millimètres pour des longueurs caractéristiques de l'ordre de 10 m, on se heurte à un mur (sic) ! Notre projet utilise le HPC pour comprendre finement la phénoménologie des impacts tant à l'échelle 1 qu'à l'échelle 1/40, sachant que GTT mène de très nombreuses campagnes expérimentales à l'échelle réduite. Afin de réduire le temps calcul avec le code compressible, nous étudierons la possibilité de réaliser une grande partie de la simulation avec un code incompressible opensource : Gerris http://gfs.sourceforge.net/wiki/index.php/Main_Page

Le résultat de ce modèle incompressible à deux fluides servira comme initialisation pour le code compressible FluxIC.

Apport scientifique des différents partenaires à la réalisation du projet

Partenaire	Apports scientifiques
GTT	Phénoménologie par le retour d'expérience à l'échelle 1 et par les expériences de laboratoire
CMLA	Modèles mathématiques Méthode numérique ad hoc (VF hybrides Euler - Lagrange) Algorithmique parallèle (HPC)

Demande financière, destination des fonds clairement explicitée avec une répartition :

fonctionnement (dont gratifications de stage) et équipement.

Nous demandons une participation financière de 5 k€ à l'Institut FARMAN.

Equipement : 2 k€

Financement stage : 3 k€