Asynchronous parallel in time algorithms for data assimilation.

MSIAM (MSCI) research Internship proposal

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Keywords

Data assimilation, optimal control, multigrid, minimisation precondtionning, high performance computing, parallel in time, asynchronous methods.

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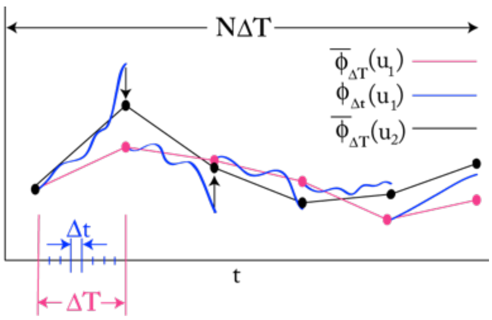
Description

Variational data assimilation[1] is a very common method for the initialisation of numerical models. It is widely used for instance in Numerical Weather Prediction systems (Météo-France, UK MetOffice, ...). It aims at finding an optimal initial solution that will bring the model trajectory closer to observations of the system over a given time window. This is done using optimal control techniques where a cost function depending on the sought initial condition is minimised using an iterative method.

Recent trend in computing resources leads to a spectacular increase in the number of numerical cores while the efficiency of said cores remain stable. This implies that new sources of parallelism have to be found in demanding applications. Even though the model can be fully parallel, variational data assimilation algorithms are by essence sequential (minimisation). A possible way out is to increase parallelism through the time dimension using Parareal[3]- or Pita[2]-type approaches. Here a coarser (cheaper) problem is solved on the entire time window, then the time dimension is split into separate sub-windows where the full problem is solved in parallel starting from initial conditions given by the coarser solution. This process is iterated several times until convergence. Another consequence of this ever rising number of computing units is the increase of the probability of a hardware failure. This led to the development of asynchronous methods that could cope with such failure as well as heterogeneity in the computing nodes [3].



Schematic representation of the parareal algorithm

The topic of this internship is to perform a theoretical study of the interactions between iterations of the data assimilation minimisation and these of the parallel in time algorithm. Specific focuses will be on their convergence properties and on proper and efficient ways of preconditioning. This will then be illustrated on a simple idealized test case. If time permits, this study can be extended to asynchronous parallel in time algorithms. This is primarily an applied mathematics internship, with applications to high performance computing.

This internship may lead to a PhD, where a possible application to ocean regional circulation modelling is foreseen.

Prerequisites

— strong interest in applied mathematics and a taste for computer sciences.
— Basic knowledge in numerical analysis and optimisation.
— Programming skills in python and/or Fortran.

Bibliography

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[4] F. Magoulès, C. Venet. (2018). Asynchronous iterative substructuring methods. In Mathematics and Computers in Simulation 145 :34-49.