Domain Decomposition for Next-Generation Monte-Carlo Neutron Transport Code TRIPOLI-5.

Start in : As soon as possible
Workplace : Fontenay-aux-roses, France
Duration : 18 months

Context

IRSN has started, in collaboration with CEA, a new project for the development of a new particles transport code TRIPOLI-5, based on the Monte-Carlo simulation method, for the French nuclear industry. Monte Carlo simulations are the "golden standard" for neutron transport simulations, due to its "exact" treatment of the energy variable in the Boltzmann equation. Contrary to the deterministic codes, the collisions are treated with continuous energy kinematics using the full information at our disposal included in the Evaluated Nuclear Data Files, without any multi-group approximations.

The goal of this new generation code is to achieve multi-physics calculations at the core level, but with a detailed description of the geometry at a pin level. These multi-physics calculations imply a coupling between the transport equation solver for the neutron population density, thermal and thermohydraulic solvers for the heat transfer, as well as a Bateman solver for computing the isotopic evolution of the nuclear fuel during a reactor cycle at full or partial power. These calculations, still unfeasible a few years ago, can nowadays be in our reach thanks to the dramatic increase in computing power of present-day and tomorrow's super-computers. They are feasible, but still a steep challenge from many points of view.

In order to perform burnup calculations with realistic temperature and density distributions throughout the full core, a large number of temperatures must be considered and a very large number of tallies need to be computed and stored. We are talking of thousands of reaction rates for 60000 pins with 100 axial zones and several (~10) radial rings: this add up to some terabyte of RAM memory, which is still not available today on a single node of a supercomputer, but it can be attained by distributing a single Monte-Carlo simulation over several nodes.

Work

From the above discussion, we conclude that Monte Carlo burnup calculations are actually memory-bound, and the solution to this limitation lies in some sort of Domain Decomposition in order to distribute the memory requirements of a single simulation over several compute nodes. The problem of domain decomposition does not present the same challenges nor does it use the same approaches for deterministic methods and for Monte-Carlo simulations. A number of domain-decomposition methods adapted to neutron transport criticality calculations have been suggested in

the literature, and a few codes, both production and research type, have tested some implementations.

A first bibliographic step of the work will allow to collect the ensemble of the already proposed methods and to perform a first analysis of advantages and disadvantages. Out of this analysis two competing methods will be proposed for actual implementation in the TRIPOLI-5 code.

These implementations will need to work smoothly with the multi-level parallelism already defined in TRIPOLI-5: shared-memory, distributed-memory and independent simulations. Another important point is that TRIPOLI-5 is supposed to work with both CPU and GPU architectures, and consequently with history-based and event-based algorithms. The point in choosing two algorithms is to ensure that the architecture of the implementations respects the founding principle of T5, that the code must be able to support multiple algorithms for similar functionalities.

Performances will be tested for several problems of varying scale and assessed for the two hardware targets: CPU and GPU.

Qualifications

A PhD in Nuclear Engineering or related field is required. Skills in C++ and python are also indispensable.

Contacts

Candidates should send their CV and a motivation letter to Julien Taforeau (julien.taforeau@irsn.fr) and/or Fausto Malvagi (fausto.malvagi@irsn.fr).