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Report on the "Habilitation à Diriger des Recherches" of Monsieur Eric Dumonteil, titled "Marches aléatoires branchantes et Simulation Monte-Carlo du Transport des Neutrons", to be defended on the 22nd of May at INSTN (CEA Centre Saclay)

Dear colleagues,

thank you very much for the nomination as examiner of the work performed and the habilitation submitted by **Monsieur Eric Dumonteil**, which I gladly accept. As per your request, please find on the following pages my written report and assessment of Monsieur Dumonteil's academic and professional performance in general, as well as on his "Habilitation à Diriger des Recherches" in particular.

I am looking forward to my participation as examiner in the defense of the habilitation on May 22nd, 2014.

With my best regards,

(Andreas Pautz)
École Polytechnique Fédérale de Lausanne (EPFL)

Report on the *Habilitation à Diriger des Recherches* of

Monsieur Eric Dumonteil

Submitted to Université Paris Sud, and titled

“ Marches aléatoires branchantes et Simulation Monte-Carlo du Transport des Neutrons ”

On the following pages I will provide my brief assessment of the academic and professional achievements of Monsieur Eric Dumonteil, as they have been documented in his habilitation thesis, recently submitted to Université Paris Sud. Let me briefly introduce my background: I am a full professor (Professeur Ordinaire) for Nuclear Engineering in the school of basic sciences at the École Polytechnique Fédérale de Lausanne (EPFL), one of the two Swiss Federal Institutes of Technology. I also serve as the Director of the Laboratory for Reactor Physics and Systems Behavior (LRS) of the Paul Scherrer Institute (PSI) in Villigen, Switzerland. PSI is the largest research center for natural and engineering sciences within Switzerland; in particular it is the primary laboratory for developing technologies related to nuclear energy and safety. My research focuses on computational reactor physics, especially the application of advanced neutron transport methods for light water reactors and innovative reactor concepts. I have served and serve on a variety of national and international committees, for example, as the chairman of the governing board of the European Severe Accident Research Network of Excellence, the OECD Program Review Group of the Committee for the Safety of Nuclear Installations (CSNI), and as member of the Nuclear Science Committee of the OECD/NEA. My expertise and knowledge, in particular in the area of neutron transport, computational reactor physics, and uncertainty and sensitivity analysis put me in a good position to judge the importance and quality of Monsieur Dumonteil’s work.

The work of Monsieur Dumonteil evolve around the theory of random walk and branching Brownian motion; this description of the physical motion of particles in systems in non-equilibrium is e.g. inherent in the Monte Carlo modelling of neutron transport, but can be also found in many other areas of statistical physics, like gas dynamics, radiative transfer etc. A central part of Monsieur Dumonteil’s work is his contribution to a Feynman Path Integral-like formulation (“Feynman-Kac Approach”) of neutron transport which, unlike the standard formulation in terms of the Boltzmann equation (that only provides mean field information) can provide information on higher moments of the probability distributions of physical observables.

Monsieur Dumonteil has also successfully endeavored into other areas and applied the theory of Branching Brownian Motion in epidemiology (viz. in the characterization of the spatial extend of epidemics in the outbreak phase) and game theory.

Monsieur Dumonteil has contributed significantly to the development of the Monte Carlo Code TRIPOLI-4®, one of the most powerful tools for the 3D simulation of neutral particle transport in complex systems, and the European "Capitalization Platform" for stochastic transport methods. Besides the implementation of ROOT (a CERN pre- and postprocessing tool for large data) functionality into TRIPOLI-4®, especially his implementation of an advanced variance reduction technique based on neural networks is worthwhile mentioning. The integration of particle-tracking in Monte Carlo (i.e. saving the whole history of particle motion from collision to collision on hard disk) is a unique capability of TRIPOLI-4®, which provides the code user with numerous new options for post-processing, e.g. for the search for rare events that can be subsequently used as bias information for variance reduction and thus acceleration of the simulation. The necessity for such advanced technique arises in particular in problems related to shielding and deep penetration of particles.

Monsieur Dumonteil's work has recently focused on some practical and highly relevant aspects of Monte Carlo simulation of large nuclear systems, viz. the so-called effect of "Particle Clustering" in criticality simulations, and the development of an unbiased scheme for the solution of the coupled Boltzmann/Bateman equations for nuclear depletion calculations. These two areas are at the heart of currently ongoing research activities worldwide, hence Monsieur Dumonteil's contribution is extremely timely and relevant to the field. The particle clustering effect has been a major impediment in simulating large Pressurized Water Reactor cores with Monte Carlo methods, since it provoked unphysical oscillations of the neutron population from neutron generation to neutron generation and cycle-to-cycle, even after sufficient eigenvalue convergence. The derivation of an empirical correlation function for the detection of such spatial heterogeneities is an important step towards controlling and minimizing local fluctuations by means of reliable estimators.
Coupled Monte-Carlo/depletion calculations have only recently become feasible due to the enormous advances in computing power available; it has therefore in principle become possible to perform Monte-Carlo-based transport calculations on a whole fuel assembly and at the same time track the time-dependent development of the nuclide inventory therein. However, due to the non-linearity of the coupled problem, this approach leads a priori to systematic biases in the nuclide concentrations, that do not only yield false results but also hinder efficient parallelization of the

problem. Monsieur Dumonteil has proposed an unbiased minimum variance estimator (based on the matrix exponential governing the fuel depletion equations) to tackle this problem, and the benchmark results being published lately seem extremely promising, and will be a substantial contribution to making Monte-Carlo-based depletion calculations fit for application in an highly demanding application context.

In what follows I will make the attempt to rate the work and performance of Monsieur Dumonteil according to some standardized criteria, and based on the information that was made available to me in his “Habilitation” script:

Academic and Professional Standing: As outlined above, Monsieur Dumonteil’s work covers a broad range of activities, ranging from very fundamental theoretical research work on Random Walk and Branching Brownian Motion to strongly applied research in the field of neutronics design calculations, that are of high relevance for the reactor physics community. He has also shown pronounced skills in the development of large-scale simulation software packages (viz. TRIPOLI-4®), and employing large data pre- and postprocessing techniques that are indispensable in modern advanced neutron transport methods. The capability of bridging the gap between fundamental research and practical application, i.e. having an overall broad view on the topic is what makes an excellent scholar in the field, and it is without hesitation that I attest Monsieur Dumonteil these skills.

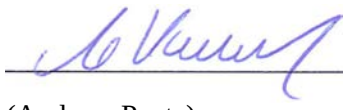
Abilities and Qualities in Respect of Research Work: the information provided to me was sufficient to judge the relevance of Monsieur Dumonteil’s work for the nuclear community. I have pointed out only two of his major achievements above (on Monte Carlo criticality calculation and Particle Clustering, as well as coupled Monte Carlo depletion calculations) that are by themselves very timely contributions to some of the most pressing problems in the field of stochastic transport. It is therefore fair to say that Monsieur Dumonteil is in excellent control of this field, and I presume that this statement also holds for his contributions to the theory of Branching Brownian Motion. From reading a selected subset of his publications, I gain the overall impression that they are all extremely well written, carefully and meticulously researched, and systematically structured. Hence, I have no doubts that he fulfils the high quality standards required in academic research. I also appreciate that Monsieur Dumonteil made significant efforts to endeavour into other areas of application of random walk theory, which shows a high amount of flexibility.

Teaching Capabilities and Capacity to Stimulate Study: the wealth of publications in different areas testifies the fruitful cooperation that Monsieur Dumonteil fostered over the years. Especially the collaboration with Andrea Zoia and his collaborators at CEA seems to have been particularly fruitful in the past. I understand that Monsieur Dumonteil has actively engaged in teaching activities and "Administration de la recherché" at numerous occasions, and has instructed/co-supervised doctoral and post-doctoral research projects. Given his strong background in the field, I have no doubts that he will excel in teaching and will have large potential to stimulate research in highly relevant areas. His particular strength lies also in the fact that he is well acquainted with the nitty-gritty parts of code development and the complications that come with large-scale development projects. This will make him also an excellent instructor in software development projects and practical/applied research in an industrial context.

Relationship with Colleagues and Ability to share the work within a research group: in line with my comments above, I am convinced that Monsieur Dumonteil is capable of fostering a good working relationship with his research fellows, and to efficiently distribute tasks amongst a research group.

Overall speaking, I conclude from my assessment of Monsieur Dumenteil's work that he will be well capable of directing and leading research activities in his broad field of expertise, and fulfil the high standards that are required to supervise/direct doctoral and post-doctoral research. I believe that he will be a strong asset to the faculty he will be affiliated with and therefore strongly recommend his "Habilitation à Diriger des Recherches" to be accepted by the Université Paris Sud.

With my best regards



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