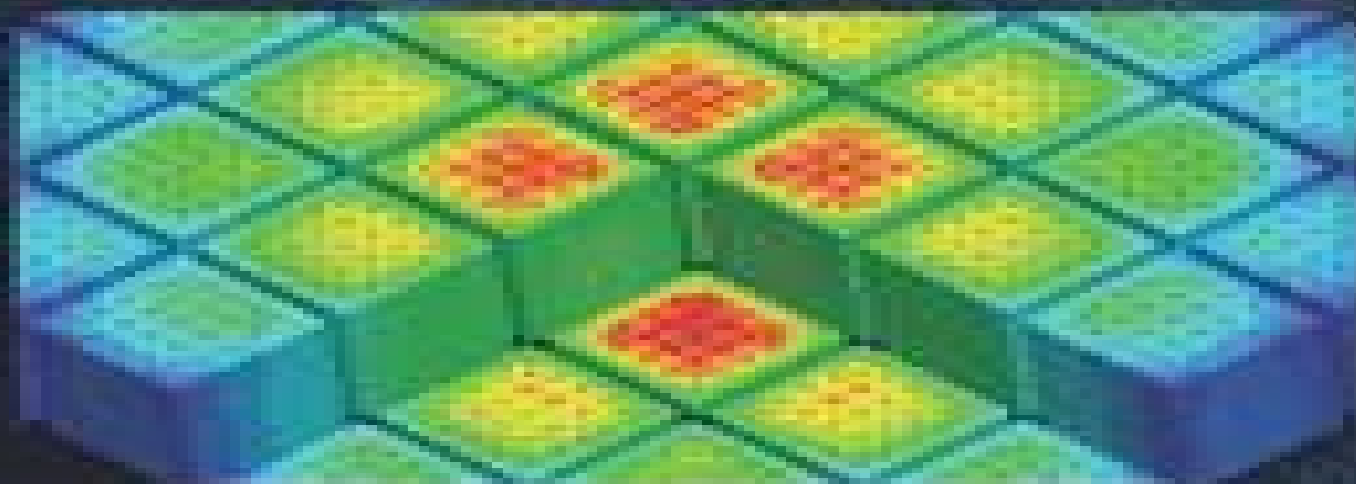
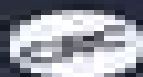


# Monte Carlo Methods for Particle Transport

SECOND EDITION



Alireza Haghighat



CRC Press  
Taylor & Francis Group

# Monte Carlo Particle Transport Methods

**Lulu Li (Ph. D.)**



## **Monte Carlo Particle Transport Methods:**

*Monte Carlo Particle Transport Methods* I. Lux, 2018-05-04 With this book we try to reach several more or less unattainable goals namely To compromise in a single book all the most important achievements of Monte Carlo calculations for solving neutron and photon transport problems To present a book which discusses the same topics in the three levels known from the literature and gives us useful information for both beginners and experienced readers It lists both well established old techniques and also newest findings

**Monte Carlo Methods for Particle Transport** Alireza Haghighat, 2015 The Monte Carlo method has become the de facto standard in radiation transport Although powerful if not understood and used appropriately the method can give misleading results Monte Carlo Methods for Particle Transport teaches appropriate use of the Monte Carlo method explaining the method s fundamental concepts as well as its limitations Concise yet comprehensive this well organized text introduces the particle importance equation and its use for variance reduction describes general and particle transport specific variance reduction techniques presents particle transport eigenvalue issues and methodologies to address these issues explores advanced formulations based on the author s research activities discusses parallel processing concepts and factors affecting parallel performance

Acceleration Methods for Monte Carlo Particle Transport Simulations Lulu Li (Ph. D.), 2017 Performing nuclear reactor core physics analysis is a crucial step in the process of both designing and understanding nuclear power reactors Advancements in the nuclear industry demand more accurate and detailed results from reactor analysis Monte Carlo MC eigenvalue neutron transport methods are uniquely qualified to provide these results due to their accurate treatment of space angle and energy dependencies of neutron distributions Monte Carlo eigenvalue simulations are however challenging because they must resolve the fission source distribution and accumulate sufficient tally statistics resulting in prohibitive run times This thesis proposes the Low Order Operator LOO acceleration method to reduce the run time challenge and provides analyses to support its use for full scale reactor simulations LOO is implemented in the continuous energy Monte Carlo code OpenMC and tested in 2D PWR benchmarks The Low Order Operator LOO acceleration method is a deterministic transport method based on the Method of Characteristics Similar to Coarse Mesh Finite Difference CMFD the other acceleration method evaluated in this thesis LOO parameters are constructed from Monte Carlo tallies The solutions to the LOO equations are then used to update Monte Carlo fission sources This thesis deploys independent simulations to rigorously assess LOO CMFD and unaccelerated Monte Carlo simulating up to a quarter of a trillion neutron histories for each simulation Analysis and performance models are developed to address two aspects of the Monte Carlo run time challenge First this thesis demonstrates that acceleration methods can reduce the vast number of neutron histories required to converge the fission source distribution before tallies can be accumulated Second the slow convergence of tally statistics is improved with the acceleration methods for the earlier active cycles A theoretical model is developed to explain the observed behaviors and

predict convergence rates Finally numerical results and theoretical models shed light on the selection of optimal simulation parameters such that a desired statistical uncertainty can be achieved with minimum neutron histories This thesis demonstrates that the conventional wisdom e g maximizing the number of cycles rather than the number of neutrons per cycle in performing unaccelerated MC simulations can be improved simply by using more optimal parameters LOO acceleration provides reduction of a factor of at least 2 2 in neutron histories compared to the unaccelerated Monte Carlo scheme and the CPU time and memory overhead associated with LOO are small

Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications Andreas Kling,Fernando J.C. Barao,Masayuki Nakagawa,Luis Tavora,Pedro Vaz,2014-02-22 This book focusses on the state of the art of Monte Carlo methods in radiation physics and particle transport simulation and applications the latter involving in particular the use and development of electron gamma neutron gamma and hadronic codes Besides the basic theory and the methods employed special attention is paid to algorithm development for modeling and the analysis of experiments and measurements in a variety of fields ranging from particle to medical physics

**Particle Transport Simulation with the Monte Carlo Method** Leland Lavele Carter,E. D. Cashwell,1975

**Monte Carlo Particle Transport** H. Scott,N. Gentile,R. Procassini,2005 Monte Carlo methods are frequently used for neutron and radiation transport These methods have several advantages such as relative ease of programming and dealing with complex meshes Disadvantages include long run times and statistical noise Monte Carlo photon transport calculations also often suffer from inaccuracies in matter temperature due to the lack of implicitness In this paper we discuss the Monte Carlo algorithm as it is applied to neutron and photon transport detail the differences between neutron and photon Monte Carlo and give an overview of the ways the numerical method has been modified to deal with issues that arise in photon Monte Carlo simulations

**Reactor Physics: Methods and Applications** Tengfei Zhang,Ding She,Shripad T. Revankar,Jun Wang,Qian Zhang,2022-06-29

**Heat Conduction** Vyacheslav Vikhrenko,2011-11-30 The content of this book covers several up to date approaches in the heat conduction theory such as inverse heat conduction problems non linear and non classic heat conduction equations coupled thermal and electromagnetic or mechanical effects and numerical methods for solving heat conduction equations as well The book is comprised of 14 chapters divided into four sections In the first section inverse heat conduction problems are discuss The first two chapters of the second section are devoted to construction of analytical solutions of nonlinear heat conduction problems In the last two chapters of this section wavelike solutions are attained The third section is devoted to combined effects of heat conduction and electromagnetic interactions in plasmas or in pyroelectric material elastic deformations and hydrodynamics Two chapters in the last section are dedicated to numerical methods for solving heat conduction problems

*Development of a Multiple Perturbation Monte Carlo Method for Eigenvalue Problems and Implementation on Parallel Processors* Amitava Majumdar,1996

*A Variationally-based Variance Reduction Method for Monte Carlo Particle Transport Problems* Carla Lynn Barrett,1999

**Variance Reduction Techniques for the Monte Carlo Calculations of Electron Dose Distributions** Mark Albert Holmes, 1995 **Nuclear Science Abstracts**, 1976 Accelerating Monte Carlo Particle Transport with Adaptively Generated Importance Maps Michel Nowak, 2018 Monte Carlo methods are a reference asset for the study of radiation transport in shielding problems. Their use naturally implies the sampling of rare events and needs to be tackled with variance reduction methods. These methods require the definition of an importance function map. The aim of this study is to propose an adaptive strategy for the generation of such importance maps during the Monte Carlo simulation. The work was performed within TRIPOLI 4, a Monte Carlo transport code developed at the nuclear energy division of CEA in Saclay, France. The core of this PhD thesis is the implementation of a forward weighted adjoint score that relies on the trajectories sampled with Adaptive Multilevel Splitting, a robust variance reduction method. It was validated with the integration of a deterministic module in TRIPOLI 4. Three strategies were proposed for the reintegration of this score as an importance map and accelerations were observed. Two of these strategies assess the convergence of the adjoint score during exploitation phases by evaluating the figure of merit yielded by the use of the current adjoint score. Finally, the smoothing of the importance map with machine learning algorithms concludes this work with a special focus on Kernel Density Estimators. *Parallel Algorithms for Monte Carlo Particle Transport Simulation on Exascale Computing Architectures* Paul Kollath Romano, Massachusetts Institute of Technology. Department of Nuclear Science and Engineering, 2013 Monte Carlo particle transport methods are being considered as a viable option for high fidelity simulation of nuclear reactors. While Monte Carlo methods offer several potential advantages over deterministic methods, there are a number of algorithmic shortcomings that would prevent their immediate adoption for full core analyses. In this thesis, algorithms are proposed both to ameliorate the degradation in parallel efficiency typically observed for large numbers of processors and to offer a means of decomposing large tally data that will be needed for reactor analysis. A nearest neighbor fission bank algorithm was proposed and subsequently implemented in the OpenMC Monte Carlo code. A theoretical analysis of the communication pattern shows that the expected cost is  $O(\sqrt{N})$  whereas traditional fission bank algorithms are  $O(N)$  at best. The algorithm was tested on two supercomputers, the Intrepid Blue Gene/P and the Titan Cray XK7, and demonstrated nearly linear parallel scaling up to 163,840 processor cores on a full core benchmark problem. An algorithm for reducing network communication arising from tally reduction was analyzed and implemented in OpenMC. The proposed algorithm groups only particle histories on a single processor into batches for tally purposes; in doing so, it prevents all network communication for tallies until the very end of the simulation. The algorithm was tested again on a full core benchmark and shown to reduce network communication substantially. A model was developed to predict the impact of load imbalances on the performance of domain decomposed simulations. The analysis demonstrated that load imbalances in domain decomposed simulations arise from two distinct phenomena: non-uniform particle densities and non-uniform spatial leakage. The dominant performance penalty for domain

decomposition was shown to come from these physical effects rather than insufficient network bandwidth or high latency The model predictions were verified with measured data from simulations in OpenMC on a full core benchmark problem Finally a novel algorithm for decomposing large tally data was proposed analyzed and implemented tested in OpenMC The algorithm relies on disjoint sets of compute processes and tally servers The analysis showed that for a range of parameters relevant to LWR analysis the tally server algorithm should perform with minimal overhead Tests were performed on Intrepid and Titan and demonstrated that the algorithm did indeed perform well over a wide range of parameters

*Domain Decomposition for Monte Carlo Particle Transport Simulations of Nuclear Reactors* Nicholas Edward Horelik, 2015 Monte Carlo MC neutral particle transport methods have long been considered the gold standard for nuclear simulations but high computational cost has limited their use significantly However as we move towards higher fidelity nuclear reactor analyses the method has become competitive with traditional deterministic transport algorithms for the same level of accuracy especially considering the inherent parallelism of the method and the ever increasing concurrency of modern high performance computers Yet before such analysis can be practical several algorithmic challenges must be addressed particularly in regards to the memory requirements of the method In this thesis a robust domain decomposition algorithm is proposed to alleviate this along with models and analysis to support its use for full scale reactor analysis Algorithms were implemented in the full physics Monte Carlo code OpenMC and tested for a highly detailed PWR benchmark BEAVRS The proposed domain decomposition implementation incorporates efficient algorithms for scalable inter domain particle communication in a manner that is reproducible with any pseudo random number seed Algorithms are also proposed to scalably manage material and tally data with on the fly allocation during simulation along with numerous optimizations required for scalability as the domain mesh is refined and divided among thousands of compute processes The algorithms were tested on two supercomputers namely the Mira Blue Gene Q and the Titan XK7 demonstrating good performance with realistic tallies and materials requiring over a terabyte of aggregate memory Performance models were also developed to more accurately predict the network and load imbalance penalties that arise from communicating particles between distributed compute nodes tracking different spatial domains These were evaluated using machine properties and tallied particle movement characteristics and empirically validated with observed timing results from the new implementation Network penalties were shown to be almost negligible with per process particle counts as low as 1000 and load imbalance penalties higher than a factor of four were not observed or predicted for finer domain meshes relevant to reactor analysis Load balancing strategies were also explored and intra domain replication was shown to be very effective at improving parallel efficiencies without adding significant complexity to the algorithm or burden to the user Performance of the strategy was quantified with a performance model and shown to agree well with observed timings Imbalances were shown to be almost completely removed for the finest domain meshes Finally full core studies were carried out to demonstrate the efficacy of domain decomposed Monte Carlo in tackling the full

scope of the problem A detailed mesh required for a robust depletion treatment was used and good performance was demonstrated for depletion tallies with 206 nuclides The largest runs scored six reaction rates for each nuclide in 51M regions for a total aggregate memory requirement of 1 4TB and particle tracking rates were consistent with those observed for smaller non domain decomposed runs with equivalent tally complexity These types of runs were previously not achievable with traditional Monte Carlo methods and can be accomplished with domain decomposition with between 1 4x and 1 75x overhead with simple load balancing

*PARTICLE-TRANSPORT SIMULATION WITH THE MONTE CARLO METHOD* Leland L. Carter, Edmond Darrell Cashwell, 1975

**Particle-transport simulation with the Monte Carlo method** Leland L. Carter, 1975

*An Automated Variance Reduction Method for Global Monte Carlo Neutral Particle Transport Problems* Marc. A. Cooper, 1999

Mathematics and Computations, Reactor Physics, and Environmental Analyses , 1995

**Particle-transport Simulation with the Monte Carlo Method** , 1975 Attention is focused on the application of the Monte Carlo method to particle transport problems with emphasis on neutron and photon transport Topics covered include sampling methods mathematical prescriptions for simulating particle transport mechanics of simulating particle transport neutron transport and photon transport A literature survey of 204 references is included GMT

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