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RICERCA DI SISTEMA ELETTRICO

## Development of Monte Carlo Algorithms for Eigenvalue Calculations

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DEVELOPMENT OF MONTE CARLO ALGORITHMS FOR EIGENVALUE CALCULATIONS

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**Development of Monte Carlo Algorithms for Eigenvalue Calculations**

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**Sommario**


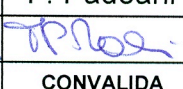
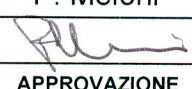
As a first stage in the development of new algorithms to reduce the variance in eigenvalue calculations with the source-iteration approach, a “superhistory” approach has been introduced into MCNP5. An adjustment of the v-value to ensure a supply of children at each normalization in the case that keff differs appreciably from unity has not yet been inserted.


Following this, the development will be articulated in two steps – firstly a search for the trade-off between an optimum population within each cycle (or superhistory) and at the next normalization point (i.e. end of superhistory); secondly a search for the trade-off between cycle size and number of normalization points.

**Note**

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## 1. Introduction

For many years optimization of fixed source Monte Carlo radiation transport calculations has been under development at ENEA [1]. Recently the focus has been redirected from fixed source to eigenvalue calculations employing the source iteration approach.

At first sight the developments at ENEA, named the “DSA” (Direct Statistical Approach to Variance Reduction Optimization), look to be well suited to deal with the source iteration approach as:

- a) they explicitly take into account correlations between progeny coming from the same progenitor, be the event an artificial bifurcation (*viz.* splitting) or a natural bifurcation [e.g. (n,xn), fission].
- b) They search for the optimum trade-off between greater splitting that decreases the second moment and increases the time (and thereby allows less source particle histories to be run in a given time) and greater Russian roulette that increases the second moment and decreases the time (and thereby allows more source particle histories to be run in a given time).

In the source iteration method, correlations between fission daughters contribute to underestimating the standard error, which is calculated under the assumption that fission generations are independent. Furthermore the balance between the number of fission neutrons per generation and the total number of generations is decided empirically. Both these issues look susceptible to an approach such as the DSA.

Furthermore the question of calculating a neutronic/photonic response in a spatially limited domain in a source-iteration calculation remains an unsolved problem.

## 2. Discussion of Approach

Initially an attempt was made to treat the source-iteration problem as a fixed source problem by firstly assuming that the fundamental mode of fission sites has been reached and secondly sampling fission chains starting from this source, normalizing the result from each source history by both the length of the fission chain. Unfortunately calculating responses in this way gives a first moment that tends to decrease dramatically as the number of cycles increases. This is because more successful fission neutrons tend to make longer fission chains, and because of the normalization by the length of each fission chain, tend to count less than less successful fission neutrons with shorter fission chains (due to absorption, leakage, etc.).


An approach nearer the source-iteration algorithm looked to be indicated. As a first step the number of fission site renormalizations was reduced from “at every fission generation” to “at every L fission generations”, i.e. the “superhistory” approach.

## 3. Superhistories

Reducing the number of fission site renormalizations was first proposed in [2] to reduce the bias in the estimated variance. Here it is employed instead as a first step in an approach to improve variance reduction.

The DSA is not a stand-alone code but employs the well-known general-purpose radiation transport code, MCNP [3], as a vehicle. Thus any code is distributed as a “patch” to MCNP that could also be modified to patch another code.

As a first step, a superhistory patch has been inserted into MCNP5 (ver. 1.4). This patch is shown in the Appendix. An adjustment of the  $\nu$ -value to ensure a supply of children at each

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normalization in the case that  $k_{\text{eff}}$  differs appreciably from unity, as made in [2], has not yet been inserted.

#### 4. Current State of Project

The superhistory patch runs and has been tested. The current version of the DSA patch for fixed source problems was updated between 2010 and 2011 to be compatible with MCNP5 (ver. 1.3) and in particular to run with MPI. Currently the DSA patch is being updated to MCNP5 (ver. 1.4). (An important advantage of ver. 1.4 over ver. 1.3 is the presence of the Shannon entropy diagnostics.) It will then be combined with the superhistory patch and further developed to calculate spatially limited neutronic responses in reactor cores (e.g. in-core neutron detectors) and neutron detector responses near fissile storage arrays. The development will be articulated in two steps – firstly a search for the trade-off between an optimum population within each cycle (or superhistory) and at the next normalization point (i.e. end of superhistory); secondly a search for the trade-off between cycle size and number of normalization points.

#### References

- [1] K.W. Burn “Optimizing Monte Carlo to Multiple Responses: the Direct Statistical Approach, 10 Years On”, *Nucl. Technol.* **175**, 138 (2011).
- [2] R.J. Brissenden, A.R. Garlick “Biases in the Estimation of  $K_{\text{eff}}$  and Its Error by Monte Carlo Methods”, *Ann. Nucl. Energy* **13-2**, 63 (1986).
- [3] X-5 Monte Carlo Team “MCNP – A General Monte Carlo N-Particle Transport Code, Version 5”, LA-UR-03-1987 (2003)





```

*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ dyn_deallocate $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*/
*/
*/
*d,setdas.1363,setdas.1370
  if( allocated(ara) ) then
    deallocate( &
      & ara, den, rkpl, tfc, vol, xlk, yla, &
      & jfq, lfcl, lfclsv, nbal, npsw, nsl, ntbb, &
      & ddm, ddn, dec, dxc, dxd, febl, flx, fme, fso, pac, &
      & pan, pcc, pwb, rho, shsd, stt, sump, swwfa,wns, wwfa, &
      & isef, laj, lcaj, lse, maze, ndpf, ndr, nhsd &
    &)
*/
*/
*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ mcrun
*/
*/
*/
*open,mcrun.F90
*/
*i,mcrun.72

  do 50 i=1,mtx
50 lfclsv(i) = lfcl(i)
*/
*/
*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ isourc
*/
*/
*/
*open,isourc.F90
*/
*i,isourc.32

  nsz = nsa

*/
*/
*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ crit1_mod
*/
*open,crit1_mod.F90
*/
*/
*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ kcalc $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*/
*/
*/
*d,crit1_.75

!   zz(i) = sumk(i)/nsrck
   zz(i) = sumk(i)/wt0/nsz
   if(idum(5).eq.100)write(jtty,*)'kcalc; calculating 3 keffs; nps,nsz,wt0: ',nps,nsz,wt0

*/
*i,crit1_.222

  nsz = nsa

*/
*i,crit1_.232

  if(idum(5).eq.100)write(jtty,*)'kcalc; checking source overrun; kcy,nps,kcsf: ',kcy,nps,kcsf

*/
*i,crit1_.240

  nsz = nsa

*/
*/
*/
*/ $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$ msgcon
*/
*/
*/
*open,msgcon.F90
*/
*i,msgcon.462

  call msg_get( n )
                                nsz = nsz+n

```









