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Title: Bad Estimates as a Function of Exceeding the MCNP Random Number Stride

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Report
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Bad Estimates as a Function of Exceeding the MCNP Random Number Stride

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Abstract

Examples of bad MCNP estimates resulting from exceeding the MCNP random number stride are given for a simple infinite medium problem.

1 Introduction

There have been a number of informal assertions that exceeding the MCNP random number stride does not result in bad estimates. There apparently are no theoretical justifications ever presented for these assertions. Often, it is simply asserted, as apparently obvious, that no bad estimates will result because the random numbers reused when exceeding the stride will be "used for different purposes" in "real problems." The recent discussion concerning this random number stride issue was on the MCNP forum on January 9, 2014. Typical assertions over the years have been similar to Brian Kiedrowski's [1].

> "Like the choice of the random number seed, the choice of the stride is entirely arbitrary. The stride does need to be large enough such that the random numbers will not be used for the same thing."

Note several things:

1. Though this quote is out of context, the main assertion here is typically what people remember and repeat; the context is often insufficiently emphasized or even not mentioned at all.

2. The context is sometimes implicitly *assumed* rather than explicitly stated.

3. The authors of the statements may intend that their statements be interpreted for the typical cases that the *authors* have in mind. The proper interpretation of the statements is often inadequately conveyed.

4. There is a lot of leeway in the terms “large enough” and “for the same thing.” A number of people have asserted that exceeding the stride did not matter using similarly vague terminology.

The purpose of this work is to give a simple infinite medium transport example for which MCNP flux tallies depend on the stride. Note that the example cannot be said to prove or disprove the imprecise lore about random number strides. It is not the purpose of this note to debate whether the examples given meet the “large enough” and “for the same thing” criteria. It is not unlikely that the lore may be valid in most cases. On the other hand, perhaps the examples show that *caveat emptor* is a reasonable approach to the lore in some circumstances.

2 The Test Problem

The test problem is an infinite medium fission system as shown below.

```
infinite medium fission system
    1  1 -1.0    -1
    2  0 1

    1 so 1.e11

mode   n
imp:n  1 0
m1     92239.70c   4.45  1001.70c 2  8016.70c  1
sdef    erg=2.0
f4:n    1
t4     1e4 1e5 1e6 1e7 1e8 1e9 1e10 1e11 1e12
vol    1 0
nps    1000000
cut:n   2.e9 j 0 0
rand     gen=2   stride= 1111152917
print
```

There were two sets of runs; one set of million particle runs and one set of ten million particle runs. Within a set, the only difference was the random number stride that was used.

3 One million particle runs

Tables 1 and 2 show early time and late time MCNP results for the 1 million particle runs. The reference case is with a stride of 111152917; this reference stride was never exceeded. Note that a stride of 1000 shows a large difference from the reference case. In particular there is almost a factor of two difference in the 2×10^9 time bin. That is 2.91570E+04 (reference) versus

1.58374E+04. Even at strides of 5000 and 10000 in the 2×10^9 time bin, the results look suspicious. Note that the one million particle run with a stride of 2000 did not pass MCNP's statistical tests. The rest of the one million particle runs passed the statistical tests. Here is MCNP output detail for the run with stride of 2000.

```
1tally        4        nps =     1000000
           tally type 4    track length estimate of particle flux.      units   1/cm**2
           particle(s): neutrons

           volumes
                   cell:       1
                         1.00000E+00

 cell  1
        time:       1.0000E+04          1.0000E+05          1.0000E+06          1.0000E+07          1.0000E+08
                8.33418E+03 0.0049   1.66519E+04 0.0115   3.89681E+03 0.0505   1.38708E+03 0.0520   7.66249E+03 0.0238

        time:       1.0000E+09          2.0000E+09           total
                3.53743E+04 0.0218   1.88448E+04 0.0307   9.21515E+04 0.0170


 ===================================================================================================================================

          results of 10 statistical checks for the estimated answer for the tally fluctuation chart (tfc) bin of tally       4

 tfc bin     --mean--      ---------relative error---------      ----variance of the variance----      --figure of merit--     -pdf-
 behavior    behavior      value   decrease   decrease rate      value   decrease   decrease rate       value    behavior     slope

 desired      random       <0.10      yes      1/sqrt(nps)       <0.10      yes         1/nps          constant    random     >3.00
 observed     random        0.02       no          no             0.00      yes          no            decrease    random      3.11
 passed?       yes          yes        no          no              yes      yes          no               no        yes         yes

 ===================================================================================================================================


 warning.  the tally in the tally fluctuation chart bin did not pass  4 of the 10 statistical checks.
```

```
      nps      mean     error   vov  slope    fom
    64000   6.9068E+04 0.0566 0.0181  3.4      24
   128000   7.7291E+04 0.0372 0.0068 10.0      25
   192000   7.8675E+04 0.0305 0.0050 10.0      25
   256000   8.0300E+04 0.0280 0.0063  4.7      21
   320000   7.8963E+04 0.0249 0.0048  2.7      22
   384000   7.8227E+04 0.0228 0.0038  5.6      22
   448000   8.1384E+04 0.0213 0.0030 10.0      21
   512000   8.1112E+04 0.0200 0.0025 10.0      21
   576000   8.3744E+04 0.0196 0.0029 10.0      19
   640000   8.8009E+04 0.0198 0.0036  5.9      16
   704000   8.7093E+04 0.0187 0.0033  5.4      16
   768000   9.2101E+04 0.0199 0.0048  6.1      12
   832000   9.2108E+04 0.0189 0.0043  5.2      13
   896000   9.2216E+04 0.0182 0.0039  6.1      13
   960000   9.2512E+04 0.0174 0.0035  3.1      13
  1000000   9.2152E+04 0.0170 0.0034  3.1      13
```

Table 1: Early times on 1 million particle runs

stride	time 1.0000E+04	time 1.0000E+05	time 1.0000E+06	time 1.0000E+07	times stride exceeded
1000	8.29471E+03 0.0049	1.58804E+04 0.0111	2.52317E+03 0.0387	1.21254E+03 0.0446	283984
2000	8.33418E+03 0.0049	1.66519E+04 0.0115	3.89681E+03 0.0505	1.38708E+03 0.0520	199366
5000	8.42154E+03 0.0050	1.75335E+04 0.0115	3.64764E+03 0.0462	1.53010E+03 0.0577	124568
10000	8.37007E+03 0.0050	1.71213E+04 0.0115	3.45582E+03 0.0463	1.45445E+03 0.0508	87643
20000	8.38088E+03 0.0050	1.77812E+04 0.0114	3.77033E+03 0.0446	1.55431E+03 0.0500	61521
50000	8.34281E+03 0.0050	1.75441E+04 0.0116	3.59448E+03 0.0429	1.53030E+03 0.0491	38164
111152917	8.42560E+03 0.0050	1.76903E+04 0.0116	3.64263E+03 0.0401	1.52114E+03 0.0505	0

Table 2: Late times on 1 million particle runs

stride	time 1.0000E+08	time 1.0000E+09	time 2.0000E+09	time total	times stride exceeded
1000	6.90403E+03 0.0243	3.22593E+04 0.0197	1.58374E+04 0.0308	8.29116E+04 0.0144	283984
2000	7.66249E+03 0.0238	3.53743E+04 0.0218	1.88448E+04 0.0307	9.21515E+04 0.0170	199366
5000	8.43538E+03 0.0262	3.94349E+04 0.0222	2.59983E+04 0.0322	1.05001E+05 0.0177	124568
10000	8.68752E+03 0.0269	4.04040E+04 0.0236	2.72949E+04 0.0324	1.06788E+05 0.0182	87643
20000	8.76767E+03 0.0264	4.31024E+04 0.0227	2.84519E+04 0.0312	1.11809E+05 0.0179	61521
50000	8.94740E+03 0.0266	4.31878E+04 0.0233	2.89412E+04 0.0319	1.12088E+05 0.0184	38164
111152917	9.03989E+03 0.0275	4.35742E+04 0.0226	2.91570E+04 0.0299	1.13051E+05 0.0177	0

4 Ten million particle runs

Tables 3 and 4 show early time and late time MCNP results for the 10 million particle runs. The reference case is with a stride of 111152917; this reference stride was never exceeded. Note that runs below a stride of 2000 show significant differences from the reference case. Note that all the ten million particle runs with a strides 256 and smaller did not pass MCNP's statistical tests. The rest of the ten million particle runs passed the statistical tests. Here is MCNP output detail for the run with stride of 256:

```
1tally        4        nps =    10000000
           tally type 4    track length estimate of particle flux.      units   1/cm**2
           particle(s): neutrons


           volumes
                   cell:       1
                         1.00000E+00


 cell  1
       time:       1.0000E+04           1.0000E+05           1.0000E+06           1.0000E+07           1.0000E+08
               8.34059E+03 0.0016   1.69408E+04 0.0036   3.82760E+03 0.0149   1.28630E+03 0.0148   7.78633E+03 0.0076
```

time:	1.0000E+09	2.0000E+09	total
	3.92528E+04 0.0069	2.43567E+04 0.0106	1.01791E+05 0.0057

===

results of 10 statistical checks for the estimated answer for the tally fluctuation chart (tfc) bin of tally 4

tfc bin	--mean--	---------relative error---------			----variance of the variance----			--figure of merit--		-pdf-
behavior	behavior	value	decrease	decrease rate	value	decrease	decrease rate	value	behavior	slope
desired	random	<0.10	yes	1/sqrt(nps)	<0.10	yes	1/nps	constant	random	>3.00
observed	random	0.01	no	no	0.00	yes	no	decrease	random	2.60
passed?	yes	yes	no	no	yes	yes	no	no	yes	no

===

warning. the tally in the tally fluctuation chart bin did not pass 5 of the 10 statistical checks.

nps	mean	error	vov	slope	fom
512000	6.7548E+04	0.0191	0.0026	10.0	15
1024000	7.7226E+04	0.0132	0.0009	10.0	13
1536000	7.8037E+04	0.0110	0.0007	10.0	13
2048000	7.9415E+04	0.0101	0.0008	10.0	11
2560000	7.9253E+04	0.0089	0.0006	10.0	11
3072000	8.0405E+04	0.0082	0.0005	10.0	11
3584000	8.2885E+04	0.0077	0.0004	10.0	10
4096000	8.2978E+04	0.0072	0.0003	10.0	10
4608000	8.4691E+04	0.0070	0.0003	10.0	9.7E+00
5120000	8.8871E+04	0.0070	0.0004	10.0	8.3E+00
5632000	8.7596E+04	0.0066	0.0004	10.0	8.6E+00
6144000	9.1585E+04	0.0070	0.0006	10.0	6.7E+00
6656000	9.2033E+04	0.0066	0.0005	10.0	6.8E+00
7168000	9.2145E+04	0.0064	0.0005	10.0	6.8E+00
7680000	9.2184E+04	0.0061	0.0004	10.0	7.0E+00
8192000	9.3000E+04	0.0059	0.0004	10.0	6.9E+00
8704000	9.3956E+04	0.0057	0.0003	10.0	7.1E+00
9216000	9.4758E+04	0.0055	0.0003	10.0	7.2E+00
9728000	1.0208E+05	0.0058	0.0004	2.6	6.1E+00
10000000	1.0179E+05	0.0057	0.0004	2.6	6.2E+00

Table 3: Early times on 10 million particle runs

stride	time 1.0000E+04	time 1.0000E+05	time 1.0000E+06	time 1.0000E+07	times stride exceeded
4	8.62890E+03 0.0016	1.71437E+04 0.0033	7.03076E+02 0.0136	6.06901E+02 0.0091	10000000
8	8.40593E+03 0.0016	1.55996E+04 0.0034	6.36511E+02 0.0132	8.52108E+02 0.0085	9948877
16	8.15656E+03 0.0015	1.38057E+04 0.0034	5.72039E+02 0.0126	1.45242E+03 0.0087	9897673
32	8.26089E+03 0.0016	1.58542E+04 0.0035	2.46423E+03 0.0139	1.17818E+03 0.0116	9756833
64	8.27895E+03 0.0016	1.55018E+04 0.0034	2.19086E+03 0.0133	1.11183E+03 0.0119	9359642
128	8.32731E+03 0.0016	1.64748E+04 0.0037	2.90336E+03 0.0120	1.27521E+03 0.0148	8246198
256	8.34059E+03 0.0016	1.69408E+04 0.0036	3.82760E+03 0.0149	1.28630E+03 0.0148	5845470
512	8.35765E+03 0.0016	1.72044E+04 0.0037	3.49359E+03 0.0140	1.61628E+03 0.0180	3941714
1000	8.37908E+03 0.0016	1.72065E+04 0.0037	3.35588E+03 0.0131	1.54230E+03 0.0164	2840818
2000	8.38672E+03 0.0016	1.75688E+04 0.0037	3.59777E+03 0.0130	1.51652E+03 0.0153	1994426
5000	8.35596E+03 0.0016	1.74548E+04 0.0037	3.44686E+03 0.0131	1.52471E+03 0.0160	1248496
10000	8.37296E+03 0.0016	1.74667E+04 0.0037	3.53901E+03 0.0129	1.50401E+03 0.0157	877926
20000	8.37713E+03 0.0016	1.73799E+04 0.0036	3.53436E+03 0.0128	1.51571E+03 0.0154	615692
50000	8.34761E+03 0.0016	1.74597E+04 0.0036	3.59823E+03 0.0126	1.51480E+03 0.0153	383460
111152917	8.37297E+03 0.0016	1.73927E+04 0.0037	3.56358E+03 0.0128	1.54175E+03 0.0153	0

Table 4: Late times on 10 million particle runs

stride	time 1.0000E+08	time 1.0000E+09	time 2.0000E+09	time total	times stride exceeded
4	8.94582E+03 0.0069	3.65851E+04 0.0062	3.75593E+04 0.0062	1.10173E+05 0.0043	10000000
8	6.15031E+03 0.0075	2.94001E+04 0.0060	2.28253E+04 0.0075	8.38698E+04 0.0043	9948877
16	4.71375E+03 0.0079	2.27866E+04 0.0061	1.36935E+04 0.0090	6.51806E+04 0.0043	9897673
32	6.90231E+03 0.0079	3.02711E+04 0.0061	1.55182E+04 0.0082	8.04492E+04 0.0044	9756833
64	6.50453E+03 0.0078	3.15383E+04 0.0062	1.49857E+04 0.0091	8.01119E+04 0.0045	9359642
128	7.63931E+03 0.0078	3.48216E+04 0.0068	1.71896E+04 0.0101	8.86312E+04 0.0050	8246198
256	7.78633E+03 0.0076	3.92528E+04 0.0069	2.43567E+04 0.0106	1.01791E+05 0.0057	5845470
512	8.15965E+03 0.0083	3.96555E+04 0.0070	2.62217E+04 0.0099	1.04709E+05 0.0055	3941714
1000	8.48283E+03 0.0083	4.13028E+04 0.0073	2.68425E+04 0.0098	1.07112E+05 0.0056	2840818
2000	8.57010E+03 0.0084	4.30759E+04 0.0072	2.82495E+04 0.0097	1.10965E+05 0.0056	1994426
5000	8.73097E+03 0.0084	4.29361E+04 0.0074	2.89770E+04 0.0102	1.11426E+05 0.0058	1248496
10000	8.76775E+03 0.0084	4.38078E+04 0.0074	2.91971E+04 0.0100	1.12655E+05 0.0058	877926
20000	8.67877E+03 0.0082	4.36380E+04 0.0072	2.93541E+04 0.0099	1.12478E+05 0.0057	615692
50000	8.67245E+03 0.0083	4.30747E+04 0.0072	2.92431E+04 0.0100	1.11911E+05 0.0057	383460
111152917	8.77685E+03 0.0083	4.28879E+04 0.0072	2.92135E+04 0.0099	1.11749E+05 0.0057	0

5 Summary

This note has shown that bad MCNP estimates are sometimes obtained when the random number stride is exceeded. Five things are worth noting

1. Erroneous results were obtained for strides smaller than a few thousand.
2. Very early versions of MCNP had a default stride in the range of 4000.
3. The bad estimates were apparent only in runs for which the stride was exceeded on a significant fraction of the particles. Preumably an MCNP user would increase the stride if the stride were being so routinely exceeded. In this sense, the tests reported here would hopefully be unrealistic in practice.
4. Although not the main point of this study, note the second and higher score moments estimates are even more problematic than the mean score estimates, as often indicated by the failure to pass MCNP's statistical tests. A look at the two FOM tables presented herein shows erratic behavior.
5. The author believes that is probably possible to construct examples of bad mean estimates when the random number stride is exceeded relatively rarely, say only 1% of the time.

References

[1] Communication from Brian Kiedrowski to the MCNP forum on January 9, 2014.