

StatSoft®
Business White Paper

Random Number Generation in *STATISTICA*

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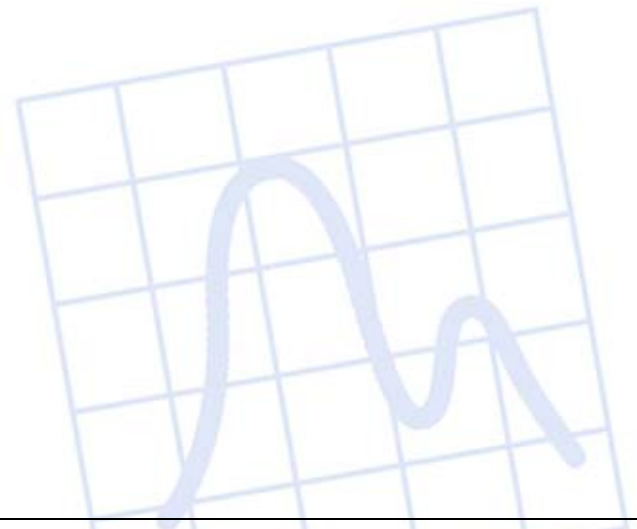
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Table of Contents

Overview3

References.....4

Diehard Test Results.....5



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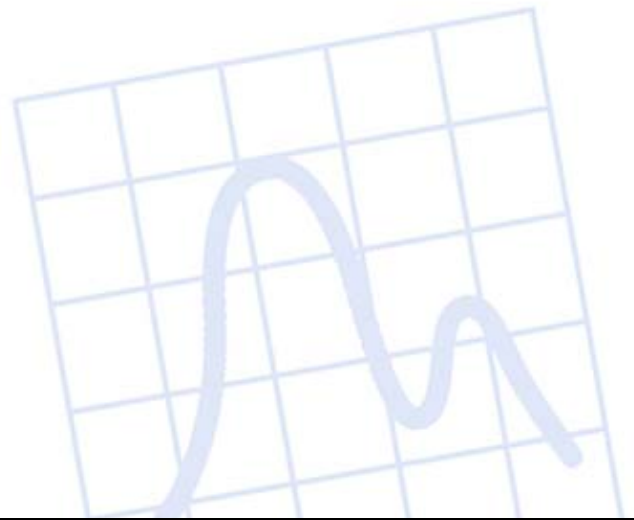
Overview

Many areas of statistical analysis, research, and simulation rely on high quality random number generators. Most programs for statistical data analysis contain a function for generating uniform random numbers. A two-part article (McCullough, 1998, 1999) which appeared in *The American Statistician* tested the random number generators of several programs using the so-called DIEHART suite of tests (Marsaglia, 1998). DIEHARD applies various methods of assembling and combining uniform random numbers, and then performs statistical tests that are expected to be non-significant; this suite of tests has become a standard method of evaluating the quality of uniform random number generator routines. Our Statistical Development department recently applied the DIEHARD suite of tests to the random number generator available in *STATISTICA* (Version 5.5 BASIC, and Version 6 *STATISTICA* Visual Basic), and we are happy to report that- as expected - our program passed all tests.

It should be pointed out that the DIEHARD suite of tests applies various approaches in order to detect non-randomness in the stream of (supposedly) uniform random numbers, and success (passing all tests) is by no means guaranteed. For example, in the review by McCullough (1999) SAS and SPSS failed one of the tests ("Count the Ones Test"), and S-Plus failed multiple tests (see Table 2, p. 156, of McCullough, 1999). Also, in a recent review (Altman, 2000), the SAS JMP program was found to fail 3 of the DIEHARD tests, and Altman (2000) concluded that "This argues against its [JMP's] use for any serious simulation."

So we believe that this is a very convincing, independent demonstration and documentation of the quality of *STATISTICA*'s random number generator, which makes the *STATISTICA* programming environment suitable, for example, for demanding Monte Carlo simulations or analyses using advanced Bayesian methods.

The actual results of the DIEHARD tests follows.



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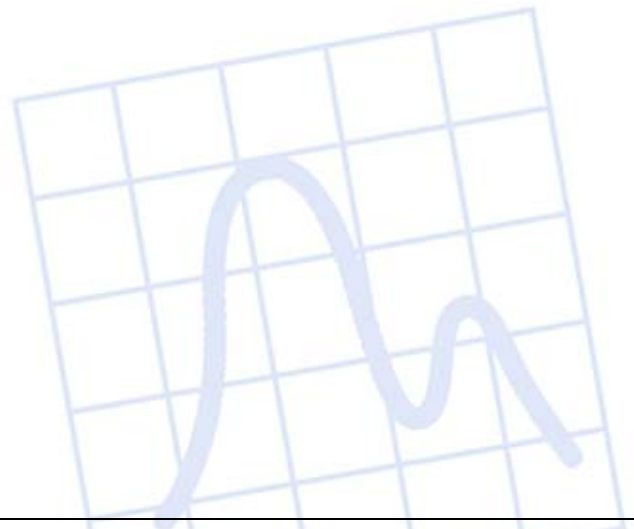
References

Altman, M. Software review: JMP, V. 4.02 At <http://iilt.ilstu.edu/gmklass/ITPnews/fall00/MAltmanf00.htm>

McCullough, B. D., 1998. Assessing the reliability of statistical software: Part I. The American Statistician, 52, 358-366.

McCullough, B. D., 1999. Assessing the reliability of statistical software: Part II. The American Statistician, 53, 149-159.

Marsaglia, G., 1996. DIEHARD: A battery of tests of randomness. At <http://stat.fsu.edu/~geo/diehard.html>.



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Diehard Test Results

NOTE: Most of the tests in DIEHARD return a p-value, which should be uniform on [0,1) if the input file contains truly independent random bits. Those p-values are obtained by $p=F(X)$, where F is the assumed distribution of the sample random variable X---often normal. But that assumed F is just an asymptotic approximation, for which the fit will be worst in the tails. Thus you should not be surprised with occasional p-values near 0 or 1, such as .0012 or .9983. When a bit stream really FAILS BIG, you will get p's of 0 or 1 to six or more places. By all means, do not, as a Statistician might, think that a $p < .025$ or $p > .975$ means that the RNG has "failed the test at the .05 level". Such p's happen among the hundreds that DIEHARD produces, even with good RNG's. So keep in mind that " p happens".

```

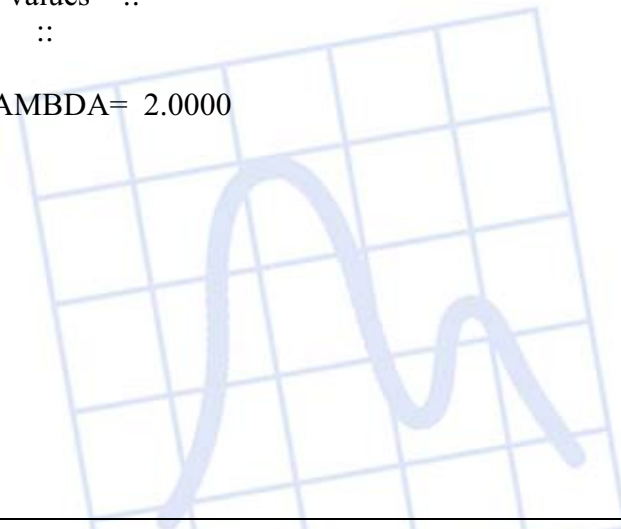
.....
::      This is the BIRTHDAY SPACINGS TEST      ::
:: Choose m birthdays in a year of n days. List the spacings ::
:: between the birthdays. If j is the number of values that ::
:: occur more than once in that list, then j is asymptotically ::
:: Poisson distributed with mean  $m^3/(4n)$ . Experience shows n ::
:: must be quite large, say  $n \geq 2^{18}$ , for comparing the results ::
:: to the Poisson distribution with that mean. This test uses ::
::  $n=2^{24}$  and  $m=2^9$ , so that the underlying distribution for j ::
:: is taken to be Poisson with  $\lambda=2^{27}/(2^{26})=2$ . A sample ::
:: of 500 j's is taken, and a chi-square goodness of fit test ::
:: provides a p value. The first test uses bits 1-24 (counting ::
:: from the left) from integers in the specified file.      ::
:: Then the file is closed and reopened. Next, bits 2-25 are ::
:: used to provide birthdays, then 3-26 and so on to bits 9-32. ::
:: Each set of bits provides a p-value, and the nine p-values ::
:: provide a sample for a KSTEST.                          ::
.....

```

BIRTHDAY SPACINGS TEST, M= 512 N=2**24 LAMBDA= 2.0000

Results for bin2.txt

	For a sample of size 500:	mean
bin2.txt	using bits 1 to 24	1.954
duplicate spacings	number observed	number expected
0	67.	67.668
1	144.	135.335
2	139.	135.335



3 86. 90.224
 4 39. 45.112
 5 15. 18.045
 6 to INF 10. 8.282
 Chisquare with 6 d.o.f. = 2.56 p-value= .137910

.....
 For a sample of size 500: mean
 bin2.txt using bits 2 to 25 1.894

duplicate spacings	number observed	number expected
0	73.	67.668
1	145.	135.335
2	136.	135.335
3	88.	90.224
4	36.	45.112
5	14.	18.045

6 to INF 8. 8.282
 Chisquare with 6 d.o.f. = 3.93 p-value= .313184

.....
 For a sample of size 500: mean
 bin2.txt using bits 3 to 26 1.984

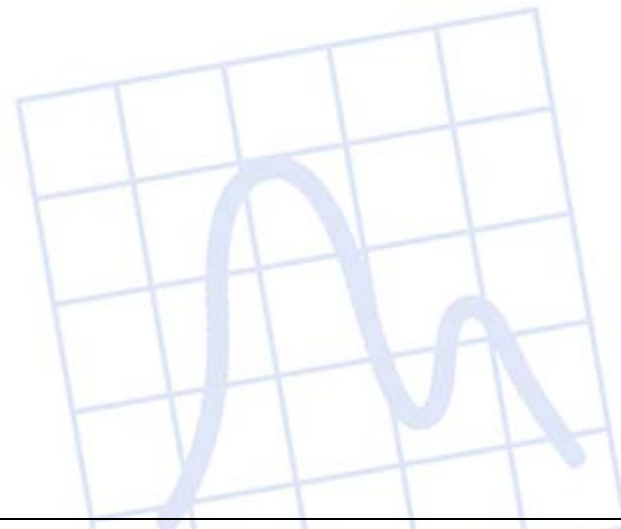
duplicate spacings	number observed	number expected
0	74.	67.668
1	139.	135.335
2	124.	135.335
3	88.	90.224
4	49.	45.112
5	16.	18.045

6 to INF 10. 8.282
 Chisquare with 6 d.o.f. = 2.62 p-value= .145118

.....
 For a sample of size 500: mean
 bin2.txt using bits 4 to 27 2.062

duplicate spacings	number observed	number expected
0	53.	67.668
1	136.	135.335
2	154.	135.335
3	84.	90.224
4	40.	45.112
5	23.	18.045

6 to INF 10. 8.282
 Chisquare with 6 d.o.f. = 8.48 p-value= .795161



```

.....
      For a sample of size 500:  mean
bin2.txt  using bits 5 to 28  2.084
duplicate  number  number
spacings  observed  expected
  0      64.    67.668
  1     117.   135.335
  2     147.   135.335
  3     96.    90.224
  4     47.    45.112
  5     19.    18.045
6 to INF   10.    8.282
Chisquare with 6 d.o.f. = 4.54 p-value= .396545
    
```

```

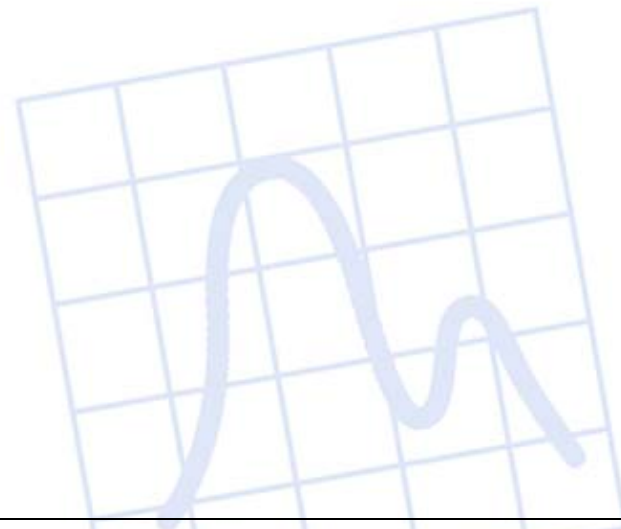
.....
      For a sample of size 500:  mean
bin2.txt  using bits 6 to 29  1.954
duplicate  number  number
spacings  observed  expected
  0      72.    67.668
  1     140.   135.335
  2     133.   135.335
  3     85.    90.224
  4     43.    45.112
  5     19.    18.045
6 to INF   8.    8.282
Chisquare with 6 d.o.f. = .94 p-value= .012211
    
```

```

.....
      For a sample of size 500:  mean
bin2.txt  using bits 7 to 30  1.858
duplicate  number  number
spacings  observed  expected
  0      70.    67.668
  1     150.   135.335
  2     136.   135.335
  3     95.    90.224
  4     29.    45.112
  5     15.    18.045
6 to INF   5.    8.282
Chisquare with 6 d.o.f. = 9.49 p-value= .852364
    
```

```

.....
      For a sample of size 500:  mean
bin2.txt  using bits 8 to 31  1.970
duplicate  number  number
spacings  observed  expected
    
```



OPERM5 test for file bin2.txt

For a sample of 1,000,000 consecutive 5-tuples,
 chisquare for 99 degrees of freedom= 87.771; p-value= .216861

OPERM5 test for file bin2.txt

For a sample of 1,000,000 consecutive 5-tuples,
 chisquare for 99 degrees of freedom=106.111; p-value= .705785

.....
 :: This is the BINARY RANK TEST for 31x31 matrices. The leftmost ::
 :: 31 bits of 31 random integers from the test sequence are used ::
 :: to form a 31x31 binary matrix over the field {0,1}. The rank ::
 :: is determined. That rank can be from 0 to 31, but ranks < 28 ::
 :: are rare, and their counts are pooled with those for rank 28. ::
 :: Ranks are found for 40,000 such random matrices and a chisqua-::
 :: re test is performed on counts for ranks 31,30,29 and <=28. ::

Binary rank test for bin2.txt

Rank test for 31x31 binary matrices:
 rows from leftmost 31 bits of each 32-bit integer

rank	observed	expected	(o-e)^2/e	sum
28	235	211.4	2.630382	2.630
29	5131	5134.0	.001765	2.632
30	23205	23103.0	.449916	3.082
31	11429	11551.5	1.299589	4.382

chisquare= 4.382 for 3 d. of f.; p-value= .795071

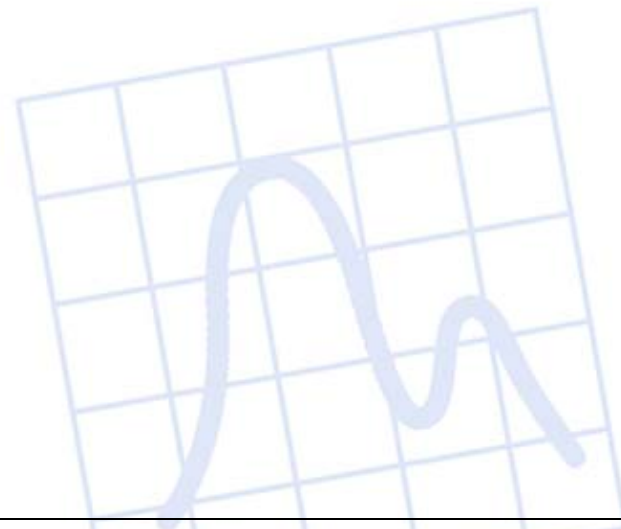
.....
 :: This is the BINARY RANK TEST for 32x32 matrices. A random 32x ::
 :: 32 binary matrix is formed, each row a 32-bit random integer. ::
 :: The rank is determined. That rank can be from 0 to 32, ranks ::
 :: less than 29 are rare, and their counts are pooled with those ::
 :: for rank 29. Ranks are found for 40,000 such random matrices ::
 :: and a chisquare test is performed on counts for ranks 32,31, ::
 :: 30 and <=29. ::

Binary rank test for bin2.txt

Rank test for 32x32 binary matrices:
 rows from leftmost 32 bits of each 32-bit integer

rank	observed	expected	(o-e)^2/e	sum
29	227	211.4	1.148427	1.148
30	5213	5134.0	1.215303	2.364
31	23066	23103.0	.059406	2.423
32	11494	11551.5	.286461	2.710

chisquare= 2.710 for 3 d. of f.; p-value= .611275



r =6 77315 77311.8 .000 .496
 p=1-exp(-SUM/2)= .21953

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 5 to 12

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	980	944.3	1.350	1.350
r =5	21961	21743.9	2.168	3.517
r =6	77059	77311.8	.827	4.344

p=1-exp(-SUM/2)= .88604

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 6 to 13

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	947	944.3	.008	.008
r =5	21808	21743.9	.189	.197
r =6	77245	77311.8	.058	.254

p=1-exp(-SUM/2)= .11944

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 7 to 14

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	869	944.3	6.005	6.005
r =5	21874	21743.9	.778	6.783
r =6	77257	77311.8	.039	6.822

p=1-exp(-SUM/2)= .96699

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 8 to 15

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	937	944.3	.056	.056
r =5	21710	21743.9	.053	.109
r =6	77353	77311.8	.022	.131

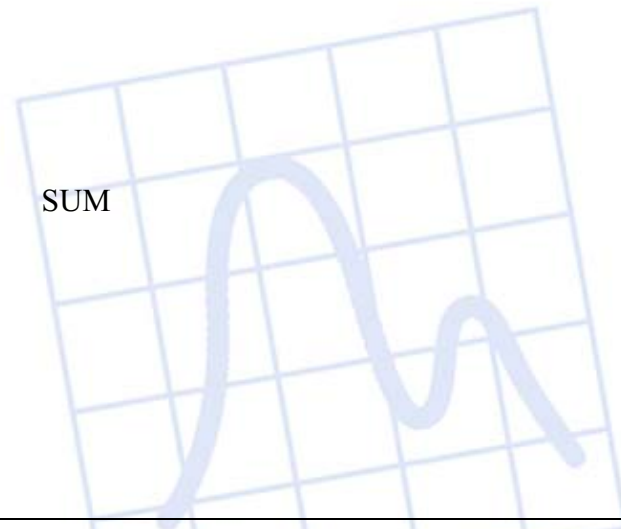
p=1-exp(-SUM/2)= .06352

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 9 to 16

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	975	944.3	.998	.998
r =5	21615	21743.9	.764	1.762
r =6	77410	77311.8	.125	1.887

p=1-exp(-SUM/2)= .61071

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt



b-rank test for bits 10 to 17

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	930	944.3	.217	.217
r =5	21622	21743.9	.683	.900
r =6	77448	77311.8	.240	1.140
p=1-exp(-SUM/2)= .43445				

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 11 to 18

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	975	944.3	.998	.998
r =5	21634	21743.9	.555	1.553
r =6	77391	77311.8	.081	1.635
p=1-exp(-SUM/2)= .55838				

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 12 to 19

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	988	944.3	2.022	2.022
r =5	21534	21743.9	2.026	4.048
r =6	77478	77311.8	.357	4.406
p=1-exp(-SUM/2)= .88951				

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 13 to 20

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	916	944.3	.848	.848
r =5	21884	21743.9	.903	1.751
r =6	77200	77311.8	.162	1.913
p=1-exp(-SUM/2)= .61568				

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

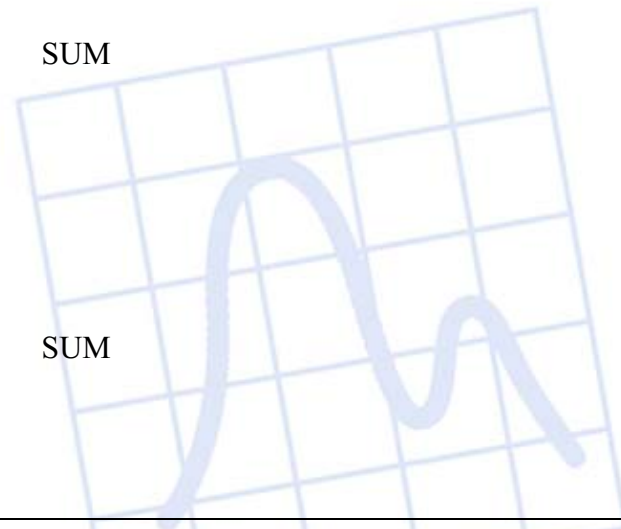
b-rank test for bits 14 to 21

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	1007	944.3	4.163	4.163
r =5	21988	21743.9	2.740	6.903
r =6	77005	77311.8	1.218	8.121
p=1-exp(-SUM/2)= .98276				

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 15 to 22

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	967	944.3	.546	.546
r =5	21962	21743.9	2.188	2.733



r =6 77071 77311.8 .750 3.483
 p=1-exp(-SUM/2)= .82477

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 16 to 23

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	947	944.3	.008	.008
r =5	21852	21743.9	.537	.545
r =6	77201	77311.8	.159	.704

p=1-exp(-SUM/2)= .29670

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 17 to 24

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	968	944.3	.595	.595
r =5	21830	21743.9	.341	.936
r =6	77202	77311.8	.156	1.092

p=1-exp(-SUM/2)= .42063

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 18 to 25

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	935	944.3	.092	.092
r =5	21982	21743.9	2.607	2.699
r =6	77083	77311.8	.677	3.376

p=1-exp(-SUM/2)= .81511

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 19 to 26

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	912	944.3	1.105	1.105
r =5	21668	21743.9	.265	1.370
r =6	77420	77311.8	.151	1.521

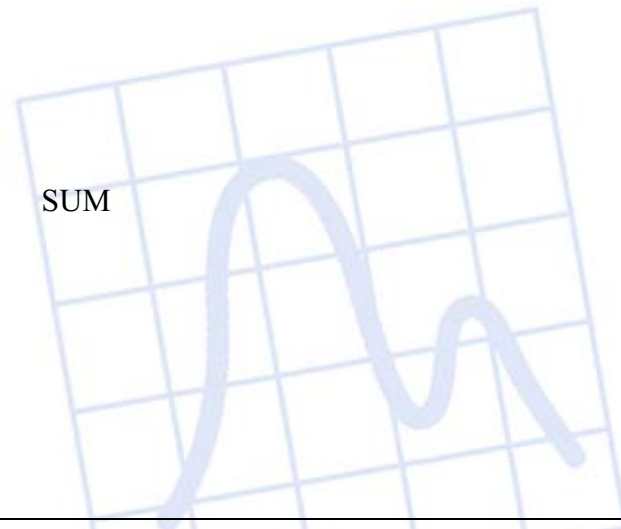
p=1-exp(-SUM/2)= .53263

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt
 b-rank test for bits 20 to 27

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	922	944.3	.527	.527
r =5	21530	21743.9	2.104	2.631
r =6	77548	77311.8	.722	3.352

p=1-exp(-SUM/2)= .81292

Rank of a 6x8 binary matrix,
 rows formed from eight bits of the RNG bin2.txt



b-rank test for bits 21 to 28

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	925	944.3	.395	.395
r =5	21713	21743.9	.044	.438
r =6	77362	77311.8	.033	.471

p=1-exp(-SUM/2)= .20983

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 22 to 29

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	949	944.3	.023	.023
r =5	21611	21743.9	.812	.836
r =6	77440	77311.8	.213	1.048

p=1-exp(-SUM/2)= .40793

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 23 to 30

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	956	944.3	.145	.145
r =5	21665	21743.9	.286	.431
r =6	77379	77311.8	.058	.490

p=1-exp(-SUM/2)= .21715

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 24 to 31

	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	941	944.3	.012	.012
r =5	21738	21743.9	.002	.013
r =6	77321	77311.8	.001	.014

p=1-exp(-SUM/2)= .00709

Rank of a 6x8 binary matrix,
rows formed from eight bits of the RNG bin2.txt

b-rank test for bits 25 to 32

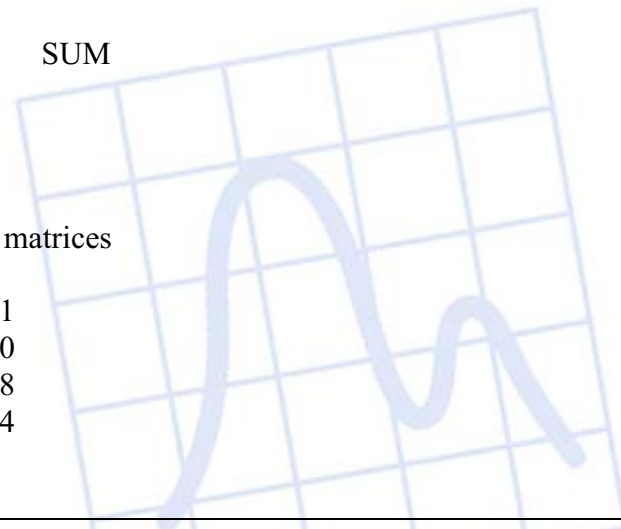
	OBSERVED	EXPECTED	(O-E)^2/E	SUM
r<=4	933	944.3	.135	.135
r =5	21741	21743.9	.000	.136
r =6	77326	77311.8	.003	.138

p=1-exp(-SUM/2)= .06679

TEST SUMMARY, 25 tests on 100,000 random 6x8 matrices

These should be 25 uniform [0,1] random variables:

.625920	.280241	.769795	.219525	.886041
.119442	.966992	.063521	.610709	.434450
.558376	.889513	.615684	.982758	.824768
.296697	.420634	.815111	.532631	.812924



	mw	z	p
OPSO for bin2.txt	using bits 23 to 32	142614	2.430 .9924
OPSO for bin2.txt	using bits 22 to 31	141787	-.422 .3366
OPSO for bin2.txt	using bits 21 to 30	141739	-.587 .2785
OPSO for bin2.txt	using bits 20 to 29	141865	-.153 .4393
OPSO for bin2.txt	using bits 19 to 28	142254	1.189 .8827
OPSO for bin2.txt	using bits 18 to 27	142214	1.051 .8533
OPSO for bin2.txt	using bits 17 to 26	142219	1.068 .8572
OPSO for bin2.txt	using bits 16 to 25	142144	.809 .7908
OPSO for bin2.txt	using bits 15 to 24	141837	-.249 .4015
OPSO for bin2.txt	using bits 14 to 23	142199	.999 .8411
OPSO for bin2.txt	using bits 13 to 22	142124	.740 .7704
OPSO for bin2.txt	using bits 12 to 21	141454	-1.570 .0582
OPSO for bin2.txt	using bits 11 to 20	141940	.106 .5421
OPSO for bin2.txt	using bits 10 to 19	142167	.889 .8129
OPSO for bin2.txt	using bits 9 to 18	142065	.537 .7043
OPSO for bin2.txt	using bits 8 to 17	141922	.044 .5174
OPSO for bin2.txt	using bits 7 to 16	141925	.054 .5215
OPSO for bin2.txt	using bits 6 to 15	141867	-.146 .4420
OPSO for bin2.txt	using bits 5 to 14	141560	-1.205 .1142
OPSO for bin2.txt	using bits 4 to 13	141716	-.667 .2525
OPSO for bin2.txt	using bits 3 to 12	141926	.057 .5229
OPSO for bin2.txt	using bits 2 to 11	142025	.399 .6550
OPSO for bin2.txt	using bits 1 to 10	141464	-1.536 .0623

OQSO test for generator bin2.txt

Output: No. missing words (mw), equiv normal variate (z), p-value (p)

	mw	z	p
OQSO for bin2.txt	using bits 28 to 32	141962	.179 .5709
OQSO for bin2.txt	using bits 27 to 31	141568	-1.157 .1236
OQSO for bin2.txt	using bits 26 to 30	142119	.711 .7614
OQSO for bin2.txt	using bits 25 to 29	142002	.314 .6233
OQSO for bin2.txt	using bits 24 to 28	141941	.107 .5427
OQSO for bin2.txt	using bits 23 to 27	142288	1.284 .9004
OQSO for bin2.txt	using bits 22 to 26	141959	.168 .5669
OQSO for bin2.txt	using bits 21 to 25	141152	-2.567 .0051
OQSO for bin2.txt	using bits 20 to 24	141497	-1.398 .0811
OQSO for bin2.txt	using bits 19 to 23	142223	1.063 .8562
OQSO for bin2.txt	using bits 18 to 22	141870	-.133 .4470
OQSO for bin2.txt	using bits 17 to 21	142104	.660 .7453
OQSO for bin2.txt	using bits 16 to 20	141609	-1.018 .1543
OQSO for bin2.txt	using bits 15 to 19	142298	1.318 .9062
OQSO for bin2.txt	using bits 14 to 18	142314	1.372 .9149
OQSO for bin2.txt	using bits 13 to 17	141808	-.343 .3656
OQSO for bin2.txt	using bits 12 to 16	141656	-.859 .1952

OQSO for bin2.txt	using bits 11 to 15	141981	.243	.5960
OQSO for bin2.txt	using bits 10 to 14	141801	-.367	.3567
OQSO for bin2.txt	using bits 9 to 13	142085	.595	.7242
OQSO for bin2.txt	using bits 8 to 12	142145	.799	.7878
OQSO for bin2.txt	using bits 7 to 11	141509	-1.357	.0874
OQSO for bin2.txt	using bits 6 to 10	142913	3.402	.9997
OQSO for bin2.txt	using bits 5 to 9	142289	1.287	.9010
OQSO for bin2.txt	using bits 4 to 8	142100	.646	.7410
OQSO for bin2.txt	using bits 3 to 7	141711	-.672	.2507
OQSO for bin2.txt	using bits 2 to 6	141819	-.306	.3797
OQSO for bin2.txt	using bits 1 to 5	141351	-1.893	.0292

DNA test for generator bin2.txt

Output: No. missing words (mw), equiv normal variate (z), p-value (p)

		mw	z	p
DNA for bin2.txt	using bits 31 to 32	141695	-.632	.2636
DNA for bin2.txt	using bits 30 to 31	141603	-.904	.1831
DNA for bin2.txt	using bits 29 to 30	141940	.090	.5360
DNA for bin2.txt	using bits 28 to 29	141583	-.963	.1679
DNA for bin2.txt	using bits 27 to 28	142538	1.854	.9682
DNA for bin2.txt	using bits 26 to 27	142105	.577	.7181
DNA for bin2.txt	using bits 25 to 26	142143	.689	.7547
DNA for bin2.txt	using bits 24 to 25	141115	-2.343	.0096
DNA for bin2.txt	using bits 23 to 24	141557	-1.039	.1493
DNA for bin2.txt	using bits 22 to 23	141425	-1.429	.0765
DNA for bin2.txt	using bits 21 to 22	141338	-1.685	.0460
DNA for bin2.txt	using bits 20 to 21	141694	-.635	.2627
DNA for bin2.txt	using bits 19 to 20	141809	-.296	.3836
DNA for bin2.txt	using bits 18 to 19	141667	-.715	.2374
DNA for bin2.txt	using bits 17 to 18	141940	.090	.5360
DNA for bin2.txt	using bits 16 to 17	141635	-.809	.2092
DNA for bin2.txt	using bits 15 to 16	142054	.427	.6652
DNA for bin2.txt	using bits 14 to 15	141861	-.143	.4433
DNA for bin2.txt	using bits 13 to 14	141224	-2.022	.0216
DNA for bin2.txt	using bits 12 to 13	141928	.055	.5220
DNA for bin2.txt	using bits 11 to 12	142015	.312	.6224
DNA for bin2.txt	using bits 10 to 11	142376	1.377	.9157
DNA for bin2.txt	using bits 9 to 10	141542	-1.084	.1393
DNA for bin2.txt	using bits 8 to 9	142089	.530	.7019
DNA for bin2.txt	using bits 7 to 8	142450	1.595	.9446
DNA for bin2.txt	using bits 6 to 7	142020	.326	.6280
DNA for bin2.txt	using bits 5 to 6	141920	.031	.5126
DNA for bin2.txt	using bits 4 to 5	142257	1.026	.8475
DNA for bin2.txt	using bits 3 to 4	141615	-.868	.1926
DNA for bin2.txt	using bits 2 to 3	142641	2.158	.9845

:: up-run of (at least) 2, depending on the next values. The ::
 :: covariance matrices for the runs-up and runs-down are well ::
 :: known, leading to chisquare tests for quadratic forms in the ::
 :: weak inverses of the covariance matrices. Runs are counted ::
 :: for sequences of length 10,000. This is done ten times. Then ::
 :: repeated. ::

.....
 The RUNS test for file bin2.txt
 Up and down runs in a sample of 10000

Run test for bin2.txt :
 runs up; ks test for 10 p's: .497116
 runs down; ks test for 10 p's: .522927
 Run test for bin2.txt :
 runs up; ks test for 10 p's: .913122
 runs down; ks test for 10 p's: .322519

\$

.....
 :: This is the CRAPS TEST. It plays 200,000 games of craps, finds::
 :: the number of wins and the number of throws necessary to end ::
 :: each game. The number of wins should be (very close to) a ::
 :: normal with mean 200000p and variance 200000p(1-p), with ::
 :: p=244/495. Throws necessary to complete the game can vary ::
 :: from 1 to infinity, but counts for all>21 are lumped with 21. ::
 :: A chi-square test is made on the no.-of-throws cell counts. ::
 :: Each 32-bit integer from the test file provides the value for ::
 :: the throw of a die, by floating to [0,1), multiplying by 6 ::
 :: and taking 1 plus the integer part of the result. ::

.....
 Results of craps test for bin2.txt
 No. of wins: Observed Expected
 98580 98585.86
 98580= No. of wins, z-score= -.026 pvalue= .48955

Analysis of Throws-per-Game:
 Chisq= 30.94 for 20 degrees of freedom, p= .94399

Throws	Observed	Expected	Chisq	Sum
1	66912	66666.7	.903	.903
2	37501	37654.3	.624	1.527
3	26859	26954.7	.340	1.867
4	19392	19313.5	.319	2.186
5	13746	13851.4	.802	2.989
6	9757	9943.5	3.500	6.488



