Using Excel to Demonstrate Random Numbers

by Rick Hesse, Feature Editor, and Russ Laher, Jet California Institute of Technology

One of the interesting things about teaching in a fully employed MBA program is the broad range of backgrounds of the students in the program. It is not unusual to find PhDs in chemistry, biology, and physics in the Los Angeles area. Such is the case with my co-author, Russ Laher of CalTech, with his PhD in physics. After taking my statistics and management science classes, which require the use of Excel, Russ has become proficient in Excel and verified several programs he had written in Perl for the Space Infrared Telescope Facility, which was successfully launched on August 25, 2003, and is now sending back images from space. As a sidenote, when I was demonstrating Monte Carlo simulation in Excel, Russ wrote a Perl program to simulate the proportion of the area of a circle inscribed within a unit square. Perl is an interpretive, freeware software originated by Larry Walls and supported by thousands of volunteers. Russ and I then wrote the routine in Excel that is described below.

Estimating Pi

To illustrate how uniform random numbers can be used in a Monte Carlo simulation in Excel, let us use RAND() to estimate the value of p. Figure 1 shows a circle with a diameter of 1 (radius of 0.50) within a unit square (1 X 1). The area of the square is obviously 1.000 and the area of the circle is πr^2 or $\pi/4$.

Now if we select two uniform random numbers, it would be a point somewhere in the square, and perhaps in the circle. To determine if it is in the circle, we subtract 0.5 from each random number, square these differences and if the result is < 0.25, it is in the circle. By multiplying this probability by 4, we can get an estimate of π, as shown in Figure 2 from the spreadsheet.

Spreadsheet Program for Estimating Pi

The spreadsheet in Figure 3 shows the initial trials to determine if the two random numbers (X,Y) are within the circle.

B4: = **RAND**() **C4**: = **RAND**() **D4**: = (**B4**-0.5)^2+(**C4**-0.5)^2 **E4**: = (**D4**<= 0.25)*1 through row 103. The expression in E4 is multiplied by 1 so that it becomes numeric instead of a logic result.

For this set of 100 trials, there were just 70 successes out of 100, and thus an estimate of 4(70/100) = 2.800 in **F4**. A data table is setup to the right of these trials in

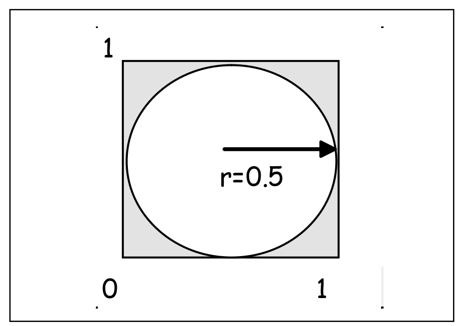


Figure 1: Circle within square.

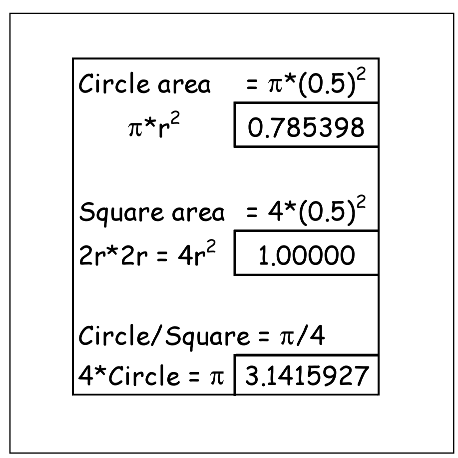
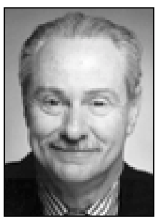


Figure 2: Mathematics of estimating π.



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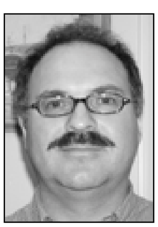

Russ Laher *is currently downlink-software deputy task lead and systems engineer of Caltech's Space Infrared Telescope Facility Science Center, a NASA space-borne infrared astronomical observatory, launched in August 2003. He has over 30 papers published in journals such as* Astronomy & Physics, Astrophysical Journal Letters, Journal of Geophysical Research *and conference proceedings. Presentations have been given at NASA/Goddard Space Flight Center, ARPA, and the Defense Nuclear Agency and international colloquium. He received a BS and PhD in physics, both from Utah State University.*

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	A	B	C	D	E	F	G
1	Simulation of						
2	-Sim	RN	RN	$(X-.5)^2 + (Y-.5)^2$			
3	Trial	X	Y	r^2	$r^2 \leq 0.25$?		
4	1	0.236816	0.985968	0.30543	0	2.8000	Run
5	2	0.402937	0.452807	0.011648	1	-10.8732%	Run error
6	3	0.229659	0.694131	0.110771	1	3.1736	Rep
7	4	0.271163	0.304736	0.090495	1	1.0188%	Rep error
8	5	0.018731	0.168063	0.341802	0	3.1415927	

Figure 3: Spreadsheet trials for π.

	F	G	H	I
2			Data	
3	8		Replications	2.8000
4	2.8000	Run	1	3.1200
5	-10.8732%	Run error	2	3.0400
6	3.1736	Rep	3	3.0800
7	1.0188%	Rep error	4	3.2000
8	3.1415927	8–	5	3.6000
9	0.0100	Accuracy	6	3.0800
10	3.6400	Max Value	7	3.3200
11	2.6800	Min Value	8	3.3600
100			97	3.2800
101			98	3.4000
102			99	3.0800
103			100	2.9600

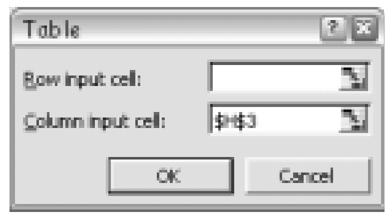

Figure 4: One-way data table for replications.

columns H and I. The formulas for the estimate and the top of the One-way data table are shown in Figure 4. The average of the 100 replications of 100 trials (10,000 in all) of 3.1736 (**F6**) is much closer than the single run (although occasionally a single run might be 3.1400). The maximum value computed with a run of 100 was 3.6400 and the minimum 2.6800, which is quite a wide range of values.

The One-way data (**H3:I103**) "fools" Excel into running our simulation 100 times by putting the numbers 1→100 in cell **H3** (which does nothing except basically run the simulation). Cell **I4** points to cell **F4** and the Data Table range is **H3:I103**.

F4: =4***AVERAGE**(**E4:E103**) **F5**: -(**PI**()-**F4**)/**PI**() **F6**: =**AVERAGE**(**I4:I103**) **F7**: =-(**PI**()-**F6**)/**PI**() **F8**: =**PI**()

Every time <**F9**> is pressed, the whole worksheet is recalculated with 10,000 trials (100 runs of 100) which illustrate the variation found in using "only" 1,000 trials to determine π.

Speed, Accuracy and Number of Trials

For the spreadsheet simulation of 10,000 trials, there is an accuracy of only 2 decimal places guaranteed (cell **F9**). The standard deviation of the replication average (**F6**) can be derived theoretically by assuming a Poisson distribution (which is appropriate for counting experiments): $\sigma = 1/\sqrt{n}$. Using Crystal Ball or @Risk with this spreadsheet would speed up the process, but it would become computational intensive very quickly to gain accuracy. Thus, to achieve accuracy to six digits (3.14159), you would need 1.0E+12 iterations, which on a 2.0 gigahertz PC would take about 110 days in Perl and "only" 3.2 days to compute using C. Anyway, for compute-intensive work like this, Perl should not, in general, be used. Instead, the best performance can be ob-

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ing rooms, track and session chairs, scheduling, generation of preliminary and final programs).

The new CIS is currently in the requirements gathering and design phase.

Service to members: Once completed, the CIS would serve as a portal to the annual meeting—a consistent Web address, a system to create personalized conference schedules, and more!

How Does DSI Measure up?

DSI has advanced immensely technologically over the last two years. DSI members now enjoy the same level of technology-assisted services as many other technically advanced communities such as ACM and AIS. Services such as online membership directory, online secure conference registration, online paper submission and review has placed DSI technically at par with these other organizations. In fact, some of the services that DSI members enjoy are highly innovative and not available in many other organizations. These services include online placement services and the ability to provide preferences to help schedule the conference sessions. Once the new CIS is completed, DSI should be one of the premier technically advanced organizations.

Summary

The projects mentioned here are only some of the advances in information technology in DSI. Recent developments in the Decision Sciences Institute have shown the commitment of the Institute to keep up with the challenges of the growing IT community, and certainly newer projects will be undertaken in the immediate future to strengthen the IT infrastructure of DSI. ■

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expanded to include more representation from outside the U.S.

Second, I would ask the Institute to consider expanding its objectives to not only disseminating new knowledge through its journals and conferences, but also to sponsor the discovery of new knowledge through large, global research initiatives. For example, many in the U.S. are discussing the continued "hollowing" of U.S. manufacturing, especially as companies continue to move or develop new manufacturing in China and software development in India, for example. Perhaps, if we took a global view of this phenomenon, we might see more advantages than disadvantages. (Again, I am asking the question, not suggesting the answer.) Possibly, DSI could take a leading role by sponsoring research activities in areas such as this. At the very least, it could consider sponsoring such activities and/or providing linkages between interested faculty and businesses who might be interested in such a pursuit. I am certain that the membership, if surveyed and listened to, could come up with many more ways that DSI could "Build and Sustain a Stronger International Presence and Acceptance." ■

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is director of the Institute for Manufacturing Enterprise Systems and an associate professor of operations in the College of Business at Arizona State University. Previously he was associate dean for student support services in the Graduate College. His disciplinary research interests are in process analysis and improvement in manufacturing, particularly in the electronics industry. He has published in a number of the top journals in his field. Dr. Callarman is certified by the Institute for Supply Management as a certified purchasing manager and by the American Production and Inventory Control Society as a certified production and inventory manager at the Fellow level. His research interests in the areas of faculty review, reward and post-tenure review stem from his term as president of the Faculty Assembly and Senate at Arizona State. During this time, he worked with representatives from the faculty and administrations of the other three major universities in Arizona, as well as the Board of Regents, to develop the statewide post-tenure review plan for Arizona. Dr. Callarman's Ph.D. is from the Krannert Graduate School of Management at Purdue University.
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tained by writing the code in C or Fortran and compiling it with "optimization" turned on. Attached as extra files with this article on the Web site are codes Russ wrote for Perl and C.

Conclusion

The whole purpose of this Excel simulation exercise is to show students how much variation exists with even a simple simulation, and that it takes a long time for the Law of Averages to be effective. This spreadsheet can be changed to expand the number of runs and also the number of replications to demonstrate the error in even a large number of trials and the variation inherent in Monte Carlo simulation. Crystal Ball or @Risk could also be used with the spreadsheet to show how many trials are needed to make the estimate of pi more accurate. ■

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