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PERSPECTIVES ON SIMULATION USING GPSS

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ABSTRACT

GPSS (General Purpose Simulation System) is overviewed briefly. The approach taken in GPSS to model a one-line, one-server system is explained, implementation details are provided, and results are discussed. References and suggestions for further study are given. (This paper is an updated version of an identically named paper appearing in the *Proceedings of the 1994 Winter Simulation Conference,* pp. 496-501.)

1 GPSS IN BRIEF

GPSS (General Purpose Simulation System) is a simulation modeling language used to build computer models for discrete-event simulations. (A discrete-event simulation is one in which the state of the system being simulated changes at only a discrete set of time points.) GPSS lends itself especially well to modeling systems in which discrete units of traffic compete with each other for the use of scarce resources, and is useful in determining how well such systems will respond to the demands placed on them. GPSS has been applied, for example, to the modeling of manufacturing systems, communication systems, computing systems, transportation systems, inventory systems and health-care systems, among others.

2 GPSS SEMANTICS AND SYNTAX

GPSS offers rich semantics with sparse syntax. For example, only seven statements (plus several run-control statements) are required to model a one-line, one-server queuing system in GPSS. These statements take such simple forms as "GENERATE 18,6" and "QUEUE LINE". No read, write, format, or test statements appear in the model. And yet, when a simulation is performed with the model, fixed-form, fixed-content output is produced, providing statistics for the server (e.g., number of times captured; average holding time per capture; fraction of time in use) and the waiting line (e.g., average contents; maximum contents; average time in line), etc. This limited example is roughly suggestive of the character of GPSS. A GPSS model for a one-line, one-server system is given here in Appendix A.

The sparse syntax of GPSS, coupled with its block-diagram orientation, makes it possible for the beginner to learn a usable subset of the language quickly. Because GPSS is rich and versatile, however, serious study is required to master the language.

3 VARIOUS GPSS IMPLEMENTATIONS

GPSS is a multi-vendor language. Brief comments are provided here on several alternative sources and versions of GPSS.

MINUTEMAN Software (P.O. Box 171, Stow MA 01775-0171; fax: 508-897-7562; voice: 800-223-1430; email: minutemn@minutesoft.com) vends GPSS World, an OS/2 implementation of GPSS that provides 20 graphics and text windows for interacting with and viewing a simulation. GPSS World is optimized for Pentium, is multithreaded and uses OS/2's ability to multitask, so that multiple simulations can be run on one machine. Up to 512 megabytes of virtual memory can be accessed for simulations. The software also has built in distributions and its own internal programming language. A companion product, Simulation Server, provides networking options. MINUTEMAN also vends (for DOS) GPSS/PC (Cox 1988, Cummings 1988). GPSS/PC provides a high level of interactivity, 5 graphics windows, an animation capability, and interfaces with FORTRAN subroutines. There is an EMS version of GPSS/PC that can use random access memory exceeding 640K. Three textbooks with Student GPSS/PC included are Chisman (1992), Karian and Dudewicz (1991), and Thesen and Travis (1991). Contact the vendor for details about course offerings.

Wolverine Software Corporation (7617 Little River Turnpike, Suite 900, Annandale VA 22003-2603;

fax: 703-642-9634; voice: 800-456-5671 or 703-750-3910; email: wolvsoft@um.cc.umich.edu) vends GPSS/H, which runs on a wide range of hardware platforms from DOS machines through engineering workstations to mainframes (Henriksen and Crain 1989). GPSS/H is available in three forms: Personal GPSS/H; GPSS/H Professional; and Student GPSS/H. Two GPSS/H books (Banks, Carson and Sy 1989, and Schriber 1991) come with Student GPSS/H included. The vendor sponsors GPSS/H courses and a course on Proof Animation, the vendor's general purpose presentation and animation software that runs on PCs and for which a textbook (Wolverine Software 1992) is available with Student Proof Animation included. Run-time GPSS/H and Proof Animation are also available.

A Selected Additional Version of GPSS: Professor Ingolf Stahl of the Stockholm School of Economics (Box 6501, S-113 83 Stockholm, Sweden; fax: 46-8-304762; email: IIS@sehhs.bitnet) has implemented Micro-GPSS, a slimmed-down version of GPSS. Designed to minimize learning time, supported by a "Simulation in One Day with Micro-GPSS" tutorial booklet and disk (Stahl 1993), by a textbook (Stahl 1990), and providing animation through Wolverine Software's Proof Animation (Stahl 1992), Micro-GPSS has been used effectively in a range of teaching contexts. It is available for PCs, VAXs and the Macintosh.

4 THE GPSS TUTORIAL

In the GPSS tutorial at the Winter Simulation Conference, the fundamentals of queuing system logic and the elements offered by GPSS to implement this logic will be discussed. A GPSS model for a one-line, one-server queuing system is given below in Appendix A for interested persons unable to attend the tutorial.

APPENDIX A: A GPSS MODEL FOR A ONE-LINE, ONE-SERVER SYSTEM

This appendix presents a GPSS model for a one-line, one-server queuing system. Although the model is largely generic to GPSS, its implementation is shown in GPSS/H. Animation of the model is not discussed but could be accomplished in MINUTEMAN Software's GPSS/PC or by using Wolverine Software's animation product, Proof Animation.

The appendix consists of these sections:

A.1 Statement of the Problem
A.2 The Approach Taken in Building the Model
A.3 The GPSS Block Diagram for the Model
A.4 The GPSS Model File
A.5 Selected Simulation Output
A.6 Suggestions for Further Study

A.1 Statement of the Problem

In a manufacturing system, castings are sent to a drill, where each casting is to have a hole drilled in it. The interarrival time of castings at the drill is uniformly distributed over the interval 15.0 $\pm$ 4.5 minutes. The time required to drill a hole in a casting is 13.5 $\pm$ 3.0 minutes, uniformly distributed. Castings are processed in first-come, first-served order. Model this system in GPSS, making provision to collect queuing statistics for castings waiting their turn to be drilled. Perform a single simulation with the model, simulating until holes have been drilled in 100 castings. Briefly discuss the output produced at the end of the simulation.

A.2 Approach Taken in Building the Model

Consider the series of events experienced by a casting as it moves through the one-line, one-server system:

1. The casting arrives at the system.
2. The casting requests the drill.
3. The casting waits, if necessary, to capture the drill.
4. The casting captures the drill.
5. The casting holds the drill in a state of capture while a hole is drilled in the casting.
6. The casting gives up control of the drill.
7. The casting leaves the system.

Castings can be thought of as units of traffic (objects) that move through the castings-and-drill system. These units of traffic are conveniently simulated in GPSS by language elements known as "transactions." Transactions are units of traffic that are created and introduced into a model from time to time, move along a path in the model as the simulation proceeds, and then are destroyed (leave the model). The experiences of transactions as they go through their life cycle in the castings-and-drill *model* are analogous to the experiences of castings as they go through the castings-and-drill *system*. Positioned on the path along which transactions move are *blocks*. Movement of a transaction into a block causes the block to be executed. By choosing appropriate types of blocks, the GPSS modeler can easily build an appropriate path (sequence of blocks) for casting-transactions to move along to mimic the sequence of events outlined above.

The sequence of blocks begins with the type of block used to create transactions from time to time during a simulation and introduce them into a model, the GENERATE block. The time that elapses between introduction of consecutive transactions into a model by a GENERATE block is "interarrival time." In this model, the interarrival time is uniformly distributed over the interval 15.0 $\pm$ 4.5 minutes. (15.0 $\pm$ 4.5 describes the open interval ranging from 10.5 to 19.5.) The values

15.0 and 4.5 are provided in the model as GENERATE block *operands*. (In general, arbitrary interarrival-time distributions can be modeled at GENERATE blocks. This is done by using built-in or user-defined functions that describe the distribution, specifying these functions as GENERATE-block operands. See Schriber (1991), chapter 13, for particulars.)

The sequence of blocks ends with a TERMINATE block. When a transaction executes a TERMINATE block, the block destroys the transaction. A counter can be used with TERMINATE blocks so that, after a specified destroy count has been reached (a count of 100 in this problem), a simulation will stop. (More generally, arbitrarily complicated stopping conditions can be specified in GPSS models.)

A SEIZE block is included in the sequence. A transaction requests control of a single server by trying to execute a SEIZE block. A SEIZE block operand is used to identify the single server. If the server is idle when a transaction requests it, the requesting transaction executes the SEIZE without delay and takes control of the server. But if the server is currently under the control of one transaction when another requests it, the requesting transaction cannot execute the SEIZE block. Instead, it remains in its current block and waits its turn to capture the server. In the simplest case, turns come in the order of first-come, first-served. (In general, arbitrarily complicated service orders can be specified in GPSS.)

A RELEASE block is also included in the sequence. A transaction that is in control of a single server gives up control by executing a RELEASE block. A RELEASE block operand is used to identify the server being released.

GPSS automatically collects (and then, when a simulation stops, prints out) statistical information about single servers modeled with use of SEIZE and RELEASE blocks. (See section A.5.)

An ADVANCE block is used to delay movement of a transaction along its path for a specified simulated time. In this model, an ADVANCE block can be used to simulate the time required for the machine to drill a hole in a casting ("service time"). The service time in this model is uniformly distributed over the open interval 13.5 $\pm$ 3.0 simulated minutes. The values 13.5 and 3.0 are provided in the model as ADVANCE operands. (Arbitrarily complicated service time distributions can be modeled at ADVANCE blocks. This is done by using built-in or user-defined functions for the applicable distribution.) By placing an ADVANCE on the path between SEIZE and RELEASE, simulated time delays between server capture and release can be modeled.

By executing a QUEUE block, a transaction initiates membership for itself in a *queue*, or waiting line. This membership continues until the transaction brings its queue membership to an end by executing a DEPART block. An operand is used at the QUEUE and DEPART blocks to indicate the particular queue involved. By placing a SEIZE between QUEUE and DEPART blocks, transactions will be members of a queue while waiting their turn to capture a server. GPSS automatically collects and then prints out statistical information about such queues. (See section A.5.)

Seven block types have been commented on in this section (GENERATE; TERMINATE; SEIZE; RELEASE; ADVANCE; QUEUE; DEPART). In total, there are more than *fifty* types of blocks in GPSS. By appropriate use of these block types, models of very complex systems can be built with considerable ease.

A.3 The GPSS Block Diagram for the Model

The model described above is shown in the form of a block diagram in Figure A-1. The block diagram consists of a sequence of seven Blocks. (Each block type in Figure A-1 has its own unique, arbitrary geometry.)

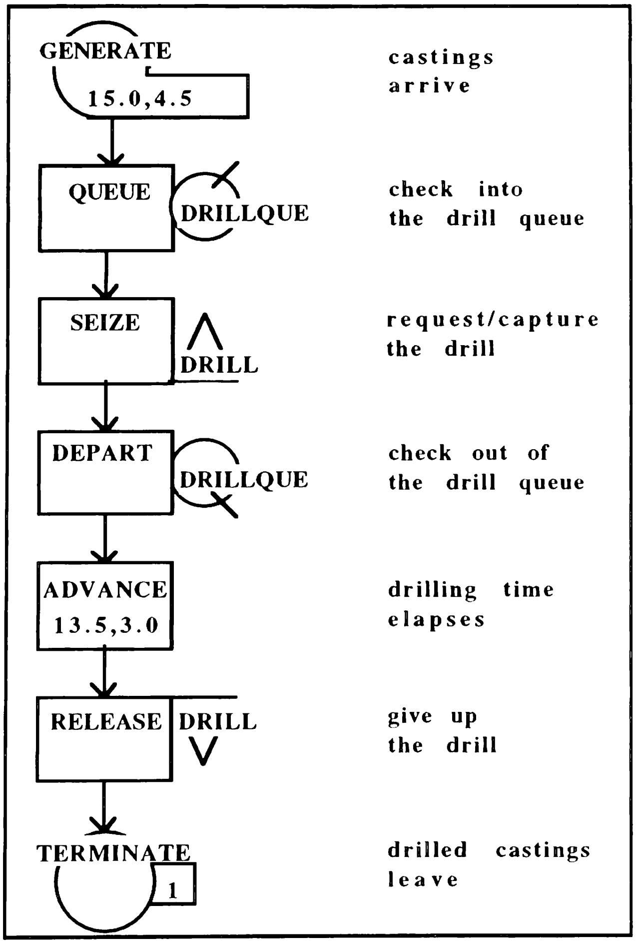

Figure A-1: GPSS Block Diagram for a One-Line, One-Server Queuing System

```
STMT #  Label   Operation   Operands     Comments

  1     ***************** One-Line, One-Server Model, WSC '95 ****************
  2              SIMULATE
  3     *                                               Base Time Unit: 1 Minute
  4     **********************************************************************
  5     *        Model Segment 1 (Movement of Castings Through the System    *
  6     **********************************************************************
  7     *
  8              GENERATE    15.0,4.5     castings arrive
  9              QUEUE       DRILLQUE     check into the drill queue
 10              SEIZE       DRILL        request/capture the drill
 11              DEPART      DRILLQUE     check out of the drill queue
 12              ADVANCE     13.5,3.0     drilling time elapses
 13              RELEASE     DRILL        give up the drill
 14              TERMINATE   1            drilled casting leaves
 15     *
 16     **********************************************************************
 17     *        Run-Control Statements                                      *
 18     **********************************************************************
 19     *
 20              START       100          start the simulation;  proceed until
 21     *                                 100 drilled castings have left
 22              END                      end of Model-File execution
```

Figure A-2: A GPSS Model File for the Figure A-1 Block Diagram

The text appearing next to the blocks in Figure A-1 (e.g., "castings arrive"; "check into the drill queue") is not part of the model, but is simply commentary that has been (optionally) provided in the spirit of documenting the block diagram.

A.4 The GPSS Model File

Figure A-1 shows the *block diagram* for a GPSS one-line, one-server model. To perform a simulation with this model, the *statement version* of the Figure A-1 block diagram must be prepared and then supplemented with additional types of statements used to control compilation and execution of GPSS models. The resulting collection of statements must then be arranged in a model file. A model file is simply a computer file that can be used as the basis for performing one (or more) simulations.

Figure A-2 shows a model file corresponding to the Figure A-1 block diagram. The Figure A-2 model file has been supplemented for discussion purposes here at the top with a row of column labels ("STMT #," "Label," "Operation," "Operands," and "Comments") and at the left with a column of statement numbers (1, 2, 3, ..., 22).

Statements 8 through 14 correspond to the Blocks in Figure A-1. Each of these block statements consists potentially of a "Label" (no Labels are used in Figure A-2), an "Operation," and zero or more "Operands," and can (optionally) include appended documentation text ("Comments"). For example, STMT #8 corresponds to the Figure A-1 "GENERATE 15.0,4.5" block (where the "Operation" is GENERATE and the "Operands" are 15.0 and 4.5) and carries the optional appended comment "castings arrive."

Statements 2, 20 and 22 in Figure A-2 are examples of statements used to control the compilation and execution of GPSS models. They have been specified in Figure A-2 in such a way that when the model file is executed, only one simulation will take place. The simulation will stop when the 100th casting has been drilled.

Each model-file statement beginning with an asterisk (*) is a *comments statement*. In Figure A-2, STMT #'s 1, 3 through 7, 15 through 19, and 21 are examples of such statements.

A.5 Selected Simulation Output

Selected output automatically produced at the end of the simulation when the Figure A-2 model file was submitted for execution is displayed in Figure A-3. The output in Figure A-3 consists of: (a) clock values; (b) server statistics; and (c) queue statistics. Portions of this output are discussed below. (For a full discussion of similar output, see Banks, Carson and Sy 1989, Henriksen and Crain 1989, or Schriber 1991.)

RELATIVE CLOCK:	1488.9629	ABSOLUTE CLOCK:	1488.9629

(a) Clock Values

(1)	(2)			(3)	(4)			
	--AVG-UTIL-DURING--							
FACILITY	TOTAL TIME	AVAIL TIME	UNAVL TIME	ENTRIES	AVERAGE TIME/XACT	CURRENT STATUS	PERCENT AVAIL	SEIZING XACT
DRILL	.917			100	13.655	AVAIL	100.0	

(b) Server (Drill) Statistics

(1)	(2)	(3)	(4)	(5)		(6)
QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/UNIT
DRILLQUE	2	.215	101	42	41.6	3.172

(c) Queue Statistics

Figure A-3: Selected Simulation Output

(a) Clock Values

As indicated in Figure A-3(a), GPSS maintains two simulated clocks: a RELATIVE CLOCK; and an ABSOLUTE CLOCK. Both clocks show that it took 1488.9+ simulated minutes to drill holes in 100 castings. (Limited space makes it impossible to explain here the difference between the two types of clocks.)

(b) Server (Drill) Statistics

Figure A-3(b) shows server (drill) statistics accumulated during the simulation. Several columns in the figure have been numbered here to make it easy to refer to the information they contain. The meaning of the information in the several numbered columns will now be indicated by column number.

(1) The FACILITY column lists the identifier used in the model for the single server (the DRILL, in this case) for which statistics are being reported.

(In GPSS, the *facility* entity is used to model single servers.)

(2) The --AVG-UTIL-DURING-- TOTAL TIME column shows the *fraction* of *total simulated time* that the server was captured. In this case, the DRILL was in use 91.7% of the time.

(3) The ENTRIES column indicates the number of times the server was put into a state of capture during the simulation. This statistic is a *capture count*. In Figure A-3(c), the capture count is 100.

(4) The AVERAGE TIME/XACT column shows the average holding time per capture of the server.

(c) Queue Statistics

Figure A-3(c) shows queue (waiting-line) statistics accumulated during the simulation. Several columns in the figure have been numbered here to make it easy to refer to the information they contain. The meaning of the information in the several numbered columns will now be indicated by column number.

(1) The QUEUE column lists the identifier used in the model for the queue (the DRILLQUE, in this case) for which statistics are being reported.

(2) The MAXIMUM CONTENTS column indicates the maximum length of the waiting line. (This DRILLQUE statistic has the value 2.)

(3) The AVERAGE CONTENTS column shows the average length of the waiting line (0.215 in the case of the DRILLQUE).

(4) The TOTAL ENTRIES column shows the count of the number of times transactions joined the waiting line (101 in the case of the DRILLQUE).

(5) The ZERO ENTRIES column shows the number of transactions which passed through the waiting line in zero simulated time (42 in this case).

(6) The AVERAGE TIME/UNIT column shows how much time transactions spent resident in the waiting line on average (3.172 in the case of the DRILLQUE). (Here, the term "UNIT" in the AVERAGE TIME/UNIT label means "transaction.")

A.6 Suggestions for Further Study

The preceding material provides a *glimpse* at the particulars of discrete-event simulation using GPSS. Those interested in further exploration can do the following:

1. Contact the vendors and obtain specific information about the various implementations.
2. When attending a conference (such as the Winter Simulation Conference) at which simulation vendors have booths in an exhibition area, talk with the vendors and look at vendor demonstrations.
3. Obtain and read a textbook for the implementation(s) of interest and, if the textbook(s) come with student software and sample models on an included disk, experiment directly with the software.
4. Read GPSS application papers in areas of interest.
5. Take an intensive GPSS short course.

REFERENCES

Ball, D. 1992. GPSS/VI. In *Proceedings of the 1992 Winter Simulation Conference,* eds. J. J. Swain, D. Goldsman, R. C. Crain and J. R. Wilson, 426-430. La Jolla, California: Society for Computer Simulation.

Banks, J., J. S. Carson, and J. Sy. 1989. *Getting Started with GPSS/H* (with Student GPSS/H on an included disk). Annandale, Virginia: Wolverine Software Corp.

Bobillier, P. A., B. C. Kahan, and A. R. Probst. 1976. *Simulation with GPSS and GPSS/V.* Englewood Cliffs, New Jersey: Prentice-Hall.

Brunner, D. T., and R. C. Crain. GPSS/H in the 1990s. 1991. In *Proceedings of the 1991 Winter Simulation Conference,* eds. B. L. Nelson, W. D. Kelton, and G. M. Clark, 81-85. La Jolla, California: The Society for Computer Simulation.

Brunner, D. T., N. J. Earle, and J. O. Henriksen. 1991. Proof Animation: The General Purpose Animator. In *Proceedings of the 1991 Winter Simulation Conference,* eds. B. L. Nelson, W. D. Kelton, and G. M. Clark, 90-94. La Jolla, California: The Society for Computer Simulation.

Chisman, J. A. 1992. *Introduction to Simulation Modeling Using GPSS/PC* (with Student GPSS/PC on an included disk). Englewood Cliffs, New Jersey: Prentice-Hall.

Cox, S. 1988. *GPSS/PC User's Manual.* Stow, Massachusetts: MINUTEMAN Software.

Cox, S. 1992. Simulation Studio. In *Proceedings of the 1992 Winter Simulation Conference,* eds. J. J. Swain, D. Goldsman, R. C. Crain and J. R. Wilson, 347-351. La Jolla, California: Society for Computer Simulation.

Crain, R. C., and D. T. Brunner. 1990. Modeling Efficiently with GPSS/H. In *Proceedings of the 1990 Winter Simulation Conference,* eds. O. Balci, R. P. Sadowski, and R. E. Nance, 89-93. La Jolla, California: Society for Computer Simulation.

Cummings, G. 1988. *GPSS/PC Simulation Tutorials.* Stow, Massachusetts: MINUTEMAN Software.

Gordon, G. 1975. *The Application of GPSS V to Discrete Systems Simulation.* Englewood Cliffs, New Jersey: Prentice-Hall.

Henriksen, J. O., and R. C. Crain. 1989. *GPSS/H Reference Manual,* Third Edition. Annandale, Virginia: Wolverine Software Corp.

Karian, Z. A., and E. J. Dudewicz. 1991. *Modern Statistical, Systems GPSS Simulation: The First Course* (with Student GPSS/PC on an included disk). New York: W. H. Freeman.

Schriber, T. J. 1974. *Simulation Using GPSS.* New York: John Wiley & Sons. (Published since 1990 by Krieger Publishing, Melbourne, Florida.)

Schriber, T. J. 1991. *An Introduction to Simulation Using GPSS/H* (with Student GPSS/H on an included disk). New York: John Wiley & Sons.

Schriber, T. J. 1992. Visualization of Simulated Systems Using Proof Animation. In *Visualisierung und Praesentation von Modellen und Resultaten der Simulation* (Vol. 31 in the ASIM Series: Mitteilungen aus den Arbeitskreisen), eds. V. Hinz, P. Lorenz, and T. Strothotte, 141-152. Magdeburg, Germany: Institute for Simulation and Graphics, Technical University of Magdeburg.

Smith, D. S., D. T. Brunner, and R. C. Crain. 1992. Building a Simulator with GPSS/H. In *Proceedings of the 1992 Winter Simulation Conference,* eds. J. J. Swain, D. Goldsman, R. C. Crain and J. R. Wilson, 357-360. La Jolla, California: Society for Computer Simulation.

Smith, D. S., and R. C. Crain, Industrial Strength Simulation Using GPSS/H, in *Proceedings of the 1993 Winter Simulation Conference,* eds. G. W. Evans, M. Mollaghasemi, E. C. Russell and W. E. Biles, 165-171. La Jolla, California: Society for Computer Simulation.

Stahl, I. 1990. *Introduction to Simulation with GPSS on the PC, Macintosh and VAX* (although Micro-GPSS does not come on a disk with the book, it is available from the author). Hemel Hempstead, United Kingdom: Prentice-Hall International.

Stahl, I. 1992. Animation with Micro-GPSS and Proof. In *Visualisierung und Praesentation von Modellen und Resultaten der Simulation* (Vol. 31 in the ASIM Series: Mitteilungen aus den Arbeitskreisen), eds. V. Hinz, P. Lorenz, and T. Strothotte, 164-175. Magdeburg, Germany: Institute for Simulation and Graphics, University of Magdeburg.

Stahl, I. 1993. *Simulation in One Day with Micro-GPSS: A Short Tutorial.* Stockholm: Stockholm School of Economics.

Thesen, A., and L. E. Travis. 1991. *Simulation for Decision Making* (with Student GPSS/PC on an included disk). St. Paul, Minnesota: West Publishing.

Wolverine Software. 1992. *Using Proof Animation* (with Student Proof Animation on an included disk). Annandale, Virginia: Wolverine Software Corporation.

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