

## **TEAMING DISCRETE-EVENT SIMULATION AND GEOGRAPHIC INFORMATION SYSTEMS TO SOLVE A TEMPORAL/SPATIAL BUSINESS PROBLEM**

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### **ABSTRACT**

Although discrete-event simulation has pedagogically been rooted in computer science, and the practicality of geographic information systems in geography, the combined use of both in the business world allows solving some very challenging temporal/spatial (time and space dependent) business problems. The discrete-event simulation language WebGPSS, an ideal simulation environment for the business person, is teamed with Microsoft MapPoint, a GIS (geographic information system) designed to bring powerful mapping and analysis techniques to corporate office desktops. The result is the ability to solve innovative business strategy problems before implementing them in the real world. This paper focuses on one such problem by using WebGPSS to drive a simulation that provides geographic data for display by MapPoint, and ultimately map animations showing spatial and temporal business changes.

### **1 INTRODUCTION**

The roots of discrete-event simulation are pedagogically found in computer science, most notably (Schriber 1974). The practicality of geographic information systems (GISs) is found in the discipline of geography (Chrisman 1997), (Clarke 1997), (Davis 1996), (DeMers 1997), (Worboys 1997). When discrete-event simulation and GISs are combined, extremely challenging temporal and spatial business problems can be solved in very innovative ways. In this paper we discuss teaming the discrete-event simulation language WebGPSS with Microsoft MapPoint, a GIS designed to provide mapping and analysis techniques to the desktops of the business person. This results in the ability to solve business strategy problems before implementing them in the real world. This paper focuses on one such problem by using WebGPSS to drive a simulation that provides geographic data for display by MapPoint, and ultimately map animations showing spatial and temporal business changes.

WebGPSS (Ståhl 2003) is the most modern implementation of micro-GPSS, a streamlined version of GPSS, the General Purpose Simulation System, which originated more than 40 years ago. WebGPSS has been in existence for about five years and has been used by students in Sweden (Herper and Ståhl 2003) and in the United States (Born 2003). In addition, I. Ståhl, developer of WebGPSS, has taught simulation modeling using WebGPSS to students from a score of countries in international programs in Sweden and Norway. A variety of features of WebGPSS make it particularly appropriate for use by business analysts. First, it has a Graphical User Interface that allows building models graphically in the form of block diagrams, supplying operands by double-clicking on the blocks within the block diagram. Second, it is available both on the Web and as a stand-alone version on a CD. Third, it has many pedagogical simplifications, including fewer block symbols, making it much easier to learn than traditional GPSS. Fourth, it has an extensive error trapping and reporting mechanism with more than 500 error codes, accomplished with the help of several thousand GPSS students over the years who have been asked to report any errors for which the error code is not understandable or helpful. Fifth, a multi-language focus has made it relatively straightforward to develop WebGPSS systems in Swedish and English, and there is now interest in the development of both French and Spanish versions. Sixth, WebGPSS has a complete teachware package (Born and Ståhl 2003) containing more than 500 PowerPoint slides designed for learning all of the material covered in (Ståhl 2003). Some of the features of this teachware package can be found in (Schriber et al. 2003).

Microsoft MapPoint has been available since 1999 and was selected for use in this study for a number of reasons, the major one being that it has the most business intuitive user interface of all of the GIS products in existence in the marketplace. In addition, it fits in well with the other widely used Microsoft Office products, including Excel, Access, Word, and PowerPoint. The North American ver-

sion has built-in demographic information for a variety of geographies including country, state, metropolitan area, county, ZIP code, and census tract, as well as similar geographies for Canada. There is also a European version of MapPoint available for those with a need to extend their business analyses there.

The remainder of this paper is organized as follows. Section 2 briefly discusses business strategy issues and provides a motivation for the business problem solved in this paper. Section 3 provides a statement of the problem. With a basic understanding of the problem, Section 4 discusses the assumptions that underlie the problem's solution. Section 5 investigates a number of business geographics concepts that are essential for understanding the solution to the problem. Section 6 elucidates the WebGPSS simulation model designed to simulate the business model, while Section 7 teams the simulation results with MapPoint for display and animation purposes. Finally, section 8 wraps up our discussion with some conclusions.

## 2 BUSINESS STRATEGY AND MOTIVATION FOR THE PROBLEM

The essence of business strategy is innovation, so one of the best ways to achieve competitive advantage is to try a strategy that no one has tried before, or at the very least, to consider a new twist on an existing strategy. Advantage will last only until others in the industry begin offering similar products or services at a comparable or lower price. Hence, being a first mover is critical for initial success (Oz 2004).

Computers have resulted in the introduction of products for the consumer that are built for one, a kind of mass customization. As early as the 1970s, one could get his or her picture taken at a booth at a theme park and have it printed in black-and-white on a t-shirt. Upon careful examination of the printed image, it was seen to be made of alphanumeric characters superimposed on top of one another in a way that approximated the required shading for facial features. By the mid to late 1990s, one could print full-color pictures using home deskjet printers onto special papers that could be transferred by ironing to t-shirts, puzzles, and computer mouse pads.

One of the newest twists on this, not generally available for production by the home consumer, is the transfer of photos, either black-and-white, or full-color, to cookies. The time is still ripe for imaginative individuals to enter this market with innovative strategies, luring consumers to buy tasty, colorful cookie treats. These cookies can contain personalized photos for special birthdays, bridal and baby showers, anniversaries, graduation parties, christenings, bar/bath mitzvahs, special corporate events, and holidays, just to mention a few. Figure 1 shows, for example, how a photo looks when transferred using edible food coloring to a 3" round, iced sugar cookie.



Figure 1: An Example Photo-to-cookie Transfer

## 3 PROBLEM STATEMENT

As an innovative entrepreneur in the United States, you have decided to investigate the possibility of entering the market as a nationwide provider of custom photo cookies. While many advertising approaches could be employed to promote your product, you have decided to place a one-day advertisement in a very small number of select newspapers in major cities in some large metropolitan areas of the country. Your hope is that these advertisements will result in enough initial sales to *get* the ball rolling. In order to *keep* the ball rolling, you plan to rely upon word of mouth. Each cookie will be wrapped separately in a clear cellophane bag. The bag will be sealed with a decorative label containing your company name, mailing address, telephone number, and Web address. You believe that when these cookie favors are given to guests at parties, there is a reasonable probability that additional orders will eventually be generated. After all, the cookies are made from a *delicious* homemade shortbread recipe and glazed with a white icing on which the photos are imaged in 100% edible food color. In addition, your well-designed Web site makes placing an order a breeze.

With this strategy in mind, you have a number of questions that need to be answered before proceeding. How rapidly can you expect growth in the number of orders and total revenue from photo cookie sales? How will your national presence grow with time? How long before you are selling cookies in virtually every state in the union? How will the total number of orders placed in each state increase with time? How will the answers to the above questions be affected by the number and locations of major cities in which the initial newspaper advertisements are placed? The answer to these questions will help in long-range planning associated with equipment such as ovens, cookie printers, and preparation tables, as well as in staffing requirements. The temporal nature of this business problem should be clear by the very nature of the questions posed. In addition, many of the questions are location-based, suggesting that a geographic information system would be ideal for visualization of results.

#### 4 MODEL ASSUMPTIONS

We assume that advertisements will be placed initially in a major newspaper in one city on the west coast and one city on the east coast, Los Angeles and New York City, respectively. We may, however, need to make adjustments to the list of cities where the advertisements are placed, if doing so would significantly improve our national rate of corporate growth.

It is assumed that the initial orders, generated as a result of the newspaper advertisements, will be placed within six months of the day that the ads appear in their respective newspapers, uniformly distributed over that six-month period. It seems reasonable that it could be as much as six months before an order is placed, as many people will hold on to the information contained in the ad until a special event such as a birthday, graduation party, etc. occurs for which they plan on ordering the photo cookies.

Every time that an order is placed, it is assumed that there is a given probability that the order will result in the placement of another order within the same state. In addition, it is assumed that there is a given probability that another order will be placed in an adjacent state, i.e., a state sharing a boundary. This seems reasonable, as people that are invited to parties in which such cookie favors are given, are more likely to come to the party if the travel distance to the party is not excessive. We also assume that if there are *several* adjacent states, which is almost always the case, then the probability that the visitor comes from a *specific* adjacent state is proportional to the populations of the adjacent states. It should be clear from the preceding discussion that it is possible for a given order to result in the placement of as many as two additional orders, one in-state and/or one in an adjacent state. Again, as was the case for the initial orders generated from the newspaper ads, we assume that any succeeding orders placed either within the state of the parent order, or from a state adjacent to that of the parent order, will be placed within six months of the time that the parent order was placed.

For simplicity and clarity in displaying maps for the purposes of this paper, we will assume that all orders are placed within the 48 contiguous states of the United States. We, therefore, exclude Alaska, Hawaii, and the District of Columbia.

With these general statements regarding model assumptions in place, we now present a list of the interactive questions that our model should provide the user, along with initial values, based upon our best current estimates, as shown in Table 1.

Table 1: Interactive Questions for the Simulation Model

Interactive Question	Current Estimate
What is the selling price per dozen cookies?	\$22.50
What is the average size of an order of cookies (in dozens)?	4
How many initial orders are there in total for the cities in which newspaper ads are placed?	60
What is the probability that an order will generate another order within the same state?	0.8
What is the probability that an order will generate another order in an adjacent state?	0.5
How many years of sales do you want to simulate?	4
What is the percent increase in price per dozen cookies each year?	3.5

#### 5 SOME BUSINESS GEOGRAPHICS CONCEPTS

We next investigate some business geographics concepts that will be useful in preparing our simulation model of the custom photo cookie business described in the preceding two sections of this paper.

FIPS (Federal Information Processing Standard) codes are used extensively in United States government data products, especially those of the Census Bureau. In addition, many non-government firms and organizations make use of these codes. Most GIS software is designed to recognize FIPS codes so that data can readily be mapped to the correct states when it is associated with these codes. The FIPS numeric and alpha codes for the 48 contiguous states are given in Table 2. Some of the "missing" codes are reserved for the territories and possessions of the US, in case they later become states. If this happens the numeric and alphabetic order of the FIPS scheme can be preserved.

Additionally, Table 2 indicates the fraction of the total US population in 2002 for each of the states. These fractions were obtained from United States demographic data that is packaged with MapPoint<sup>®</sup> 2004, the current flagship business GIS desktop software from Microsoft<sup>®</sup>. These fractions will prove quite helpful in determining the probability that a visitor to a party giving photo cookie favors comes from a specific state adjacent to that of the party's location.

For those readers who are interested in developing simulation models similar to the one described in this paper, but having an international bend, it should be noted that MapPoint<sup>®</sup> also recognizes SGC (Canadian Standard Geographical Classification) codes, NUTS (European nomenclature des unités territoriales statistiques) codes, ISO-3166 (International Organization for Standardization) codes, and a variety of additional abbreviations and codes used in Brazil, Canada, France, Germany, Italy, Mexico, Poland, Spain, and Switzerland (Slayden 2004).

Table 2: FIPS codes and US population statistics in 2002

State	State FIPS Numeric Code	State FIPS Alpha Code	Fraction of Total US Population in 2002
Alabama	1	AL	0.015852
Arizona	4	AZ	0.018987
Arkansas	5	AR	0.009585
California	6	CA	0.121453
Colorado	8	CO	0.015762
Connecticut	9	CT	0.012005
Delaware	10	DE	0.002825
Florida	12	FL	0.058080
Georgia	13	GA	0.029854
Idaho	16	ID	0.004731
Illinois	17	IL	0.044641
Indiana	18	IN	0.021661
Iowa	19	IA	0.010349
Kansas	20	KS	0.009559
Kentucky	21	KY	0.014398
Louisiana	22	LA	0.015819
Maine	23	ME	0.004496
Maryland	24	MD	0.018902
Massachusetts	25	MA	0.022459
Michigan	26	MI	0.035241
Minnesota	27	MN	0.017603
Mississippi	28	MS	0.010148
Missouri	29	MO	0.019922
Montana	30	MT	0.003231
Nebraska	31	NE	0.006084
Nevada	32	NV	0.007553
New Hampshire	33	NH	0.004415
New Jersey	34	NJ	0.029935
New Mexico	35	NM	0.006581
New York	36	NY	0.067121
North Carolina	37	NC	0.029173
North Dakota	38	ND	0.002250
Ohio	39	OH	0.040098
Oklahoma	40	OK	0.012293
Oregon	41	OR	0.012383
Pennsylvania	42	PA	0.043271
Rhode Island	44	RI	0.003701
South Carolina	45	SC	0.014412
South Dakota	46	SD	0.002684
Tennessee	47	TN	0.020485
Texas	48	TX	0.075702
Utah	49	UT	0.008175
Vermont	50	VT	0.002164
Virginia	51	VA	0.025403
Washington	53	WA	0.021353
West Virginia	54	WV	0.006341
Wisconsin	55	WI	0.019107
Wyoming	56	WY	0.001757

## 6 THE WEBGPSS SIMULATION MODEL

We now discuss the WebGPSS model that was designed to simulate the photo cookie business. We begin by identifying the model variables that are input interactively by the user. Then we look at tasks that need to be done at time zero, quarterly, yearly, and at the end of the simulation. Next, we study the user-defined functions that are critical to the simulation model. Finally, we will explain the WebGPSS segment that drives the simulation by placing orders for photo cookies.

### 6.1 Interactive Input of Model Variables

The interactive questions for our simulation model were indicated earlier in Table 1 along with our estimated answer to each question. WebGPSS allows the user to enter these initial values via Input windows. Each such window has a question prompt and text box in which the user enters a value. Figure 2, for example, shows the Input window for obtaining an initial value for the price charged for a dozen cookies.

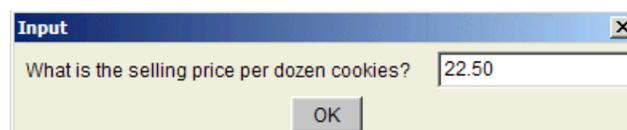


Figure 2: An Example Input Window

These initial values are stored in savevalues, the name used in WebGPSS for global user-defined variables. These savevalues all begin with  $X\$$  and can be referenced and changed in the WebGPSS model as necessary. The savevalues in our model that are initialized via Input windows are as follows:

- $x\$price$ , the selling price per dozen cookies
- $x\$ordsiz$ , the average size of an order of cookies, in dozens
- $x\$iniord$ , the number of initial orders placed in total for all cities in which newspaper ads are initially placed
- $x\$pinst$ , the probability that an order will generate another order within the same state
- $x\$poust$ , the probability that an order will generate another order in an adjacent state
- $x\$years$ , the number of years of sales to be simulated
- $x\$rate$ , the percent increase in price per dozen cookies each year.

### 6.2 Tasks at Time Zero, Quarterly, Yearly, and at Simulation End

In our custom photo cookie business model, there are variables that must be initialized to zero at simulation time zero, tasks that need to be done at the end of each quarter of the year, at the end of each year, and at the end of the simulation. Looking at these tasks now will familiarize us with a large number of variables used throughout the simulation model.

First, we need to initialize the counters that keep track of the total number of orders placed in each state to the value zero. These counters are represented by savevalues  $x\$cntAL$ ,  $x\$cntAZ$ , ...,  $x\$cntWI$ , and  $x\$cntWY$ . The last two letters in the names of these savevalues correspond to the state FIPS alpha codes given in Table 2. There are 48 such variables in our model, corresponding to the 48 contiguous states of the United States. Figure 3 shows the WebGPSS segment that accomplishes this task for us. In this segment, a single transaction is created by the GENERATE block at time zero. This transaction then enters all of the LET blocks, which assign the value zero to each of the counters. The transaction is finally removed by the TERMINATE block. The vertical ellipsis in this and any subsequent diagrams simply means that similar blocks have been omitted to save space when it should be clear what these omitted blocks are.

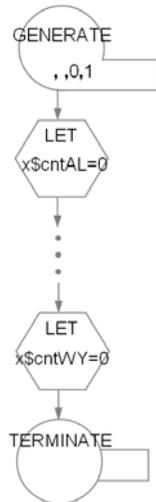


Figure 3: Segment Initializing State Order Counters to Zero

At the end of each quarter of a year, a report is produced that gives information regarding the nationwide growth of our photo cookie business over the previous quarter. Figure 4 shows the WebGPSS segment that produces these quarterly reports. A high priority transaction is generated every 91.25 days, representing a quarter of a year on a 365 day year. It should be noted that the assumed unit of time throughout our model is the *day*. The first PRINT block prints the elapsed simulation time in

years by dividing the simulation clock  $CL$  by 365. The next two PRINT blocks print the total number of orders received and total revenue since the simulation began,  $x\$totord$  and  $x\$revenu$ , respectively. A blank line is printed followed by column headings and then a report containing the number of orders to date for each of the 48 contiguous states. Production of this report each quarter gives us data that can be used to monitor the growth of our business over time and is in a format that can readily be imported into MapPoint for visualization purposes.

One of the factors that was included in our discussion of model assumptions was to allow a percentage yearly increase in the price that is charged for each dozen cookies sold. This is accomplished in WebGPSS by the segment shown in Figure 5. A transaction is created at the end of each year (365 days). This transaction then moves to a LET+ block that increases the price in the savevalue  $x\$price$ , in accordance with the yearly percentage rate of increase specified in the savevalue  $x\$rate$ .

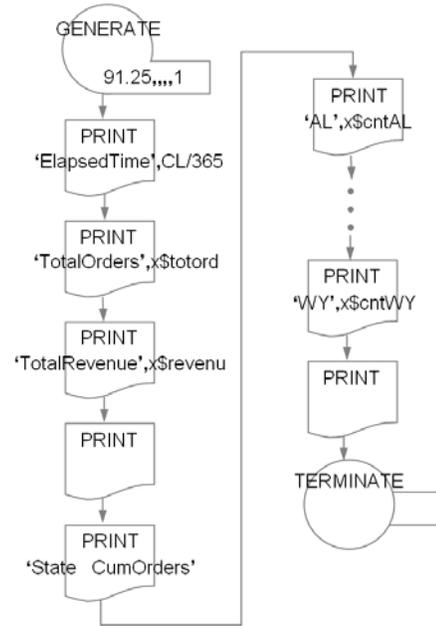


Figure 4: Segment Generating Quarterly Reports

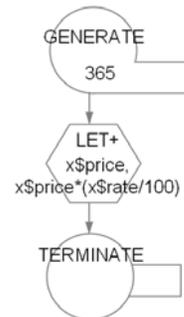


Figure 5: Segment Increasing Price Each Year

The simulation is shut down after we have simulated the requested number of years, which was interactively input and is stored in the savevalue  $x\$years$ . Figure 6 shows the WebGPSS segment that accomplishes this. The GENERATE block creates a transaction at  $365*x\$years$  days. This transaction then moves to a TERMINATE block that decreases the termination counter by 1. Since our model includes a START control statement that initializes the termination counter to the value 1, the simulation will then stop. WebGPSS simulations stop when the termination counter becomes zero or negative.

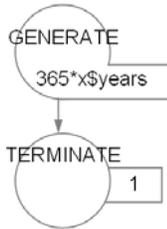


Figure 6: Segment Stopping the Simulation

### 6.3 Functions Used in the WebGPSS Model

A total of 51 user-defined functions were created for this simulation model. Of these, 48 are stochastic functions that are used to determine a random state that is adjacent to a given state and to do so with probabilities that are proportional to the populations of the adjacent states. As an example, Figure 7 shows a map of the state of Alabama as well as the Random function window in WebGPSS in which its function was defined. It is seen from the map that there are four states adjacent to Alabama (AL). These states are Florida, Georgia, Mississippi, and Tennessee. The FIPS numeric codes for these four states are 12, 13, 28, and 47, respectively. The Random function window shows that the name of the function is  $fn\$adjAL$  and that the function uses random stream number 7. (There are eight random streams in WebGPSS.) The values returned by the function are 12, 13, 28, and 47, with probabilities that are proportional to the frequencies. The frequencies are simply the fractions of the total US population in 2002 from Table 1, multiplied by  $10^6$  to make the frequencies whole numbers. Thus,  $fn\$adjAL$  will return the FIPS code for a state that is adjacent to Alabama, with probabilities in proportion to the population of those adjacent states. Similar functions have been defined for the remaining 47 contiguous states.

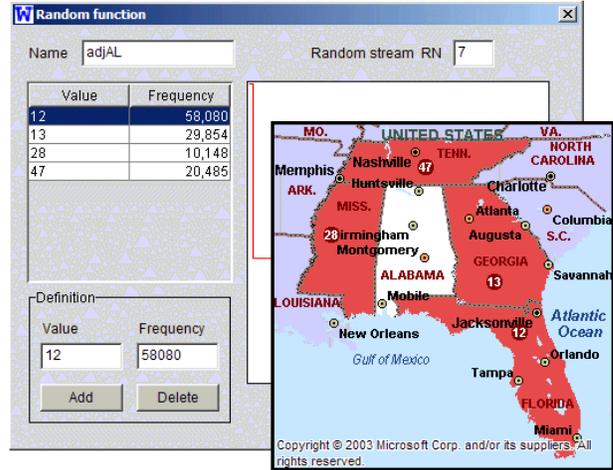


Figure 7: Function for Determining Adjacent States

Two of the user-defined functions for our model are address functions, i.e., they return the address of a block as the dependent variable. Figure 8 shows the windows in which these two functions were defined for our photo cookie business simulation. We see that the independent variable for both of these functions is the parameter  $p\$state$ . Parameters, which always start with  $p\$$ , are attributes for which different transactions can have different values. The parameter  $p\$state$  contains the FIPS numeric code for the state from which a given order is placed. The address function  $fn\$detins$  will return the address  $insCA$  (for “in the state of California”) if  $p\$state$  has the value 6. Similarly, the address function  $fn\$detst$  will return the address  $stFL$  (for “state of Florida”) if  $p\$state$  has the value 12. These functions can be used instead of an ordinary address, and are most useful in an unconditional GOTO, as we shall see when we begin looking at the WebGPSS segment that creates orders for photo cookies.

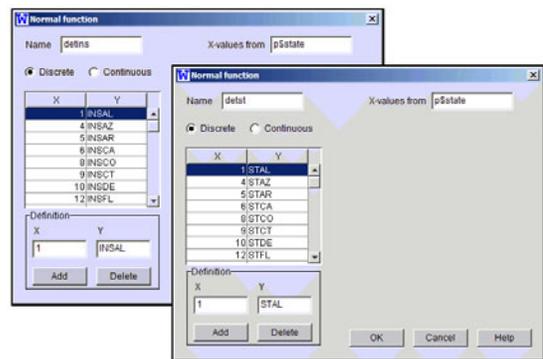


Figure 8: Address Functions Defined for Our Model

There is one more function that is used in our model, but it will be discussed in the next section, in which we look at the WebGPSS segment that creates photo cookie orders.

### 6.4 The WebGPSS Segment that Creates Orders for Photo Cookies

Now that the stage has been set, we can discuss the WebGPSS segment that drives the simulation. This segment is responsible for placing the random orders for photo cookies, keeping track of the total number of orders placed and total revenue generated, and maintaining statistics regarding the number of orders that are placed in each of the states of the US. The block diagram for this segment is shown in Figure 9. The blocks have been numbered from 1 through 20 to aid in the discussion of this segment.

Block 1 creates  $x\$iniord$  initial transactions, which will ultimately be used to create the total of  $x\$iniord$  orders to be placed in Los Angeles and New York City. These transactions are held for random times uniformly distributed between zero and six months (180.5 days). This is accomplished in block 2, an ADVANCE block that holds

the transactions for  $91.25 \pm 91.25$  days. Block 3 increases the savevalue  $x\$neword$  by one for each transaction entering this block. The WebGPSS system automatically initializes  $x\$neword$  to zero, so the first transaction to enter this block has increased the value to 1. Block 4 computes the remainder when  $x\$neword$  is divided by 2 and places this remainder in  $x\$nwsmap$ . Therefore,  $x\$nwsmap$  will alternate between 0 and 1 for each transaction entering block 4. The intent is that when  $x\$nwsmap$  is 0, an order will be placed in New York City, and when  $x\$nwsmap$  is 1, an order will be placed in Los Angeles, alternating between these two cities in a round-robin manner. This is carried out in block 5, which makes use of a user-defined function  $fn\$nwssta$  and places the FIPS code 36 for New York in the parameter  $p\$state$  if  $x\$nwsmap$  is 0, or places the FIPS code 6 for California in  $p\$state$  if  $x\$nwsmap$  is 1. The WebGPSS window that defines this function is shown in Figure 10. Via the address function  $fn\$detins$  in the unconditional GOTO of block 6, the transaction is sent either to the block whose address is  $insNY$  or  $insCA$ , as appropriate, where either the order counter  $x\$cntNY$  or  $x\$cntCA$  is incremented by 1, as appropriate. Blocks similar to those in Inset A of Figure 9 accomplish this for us.

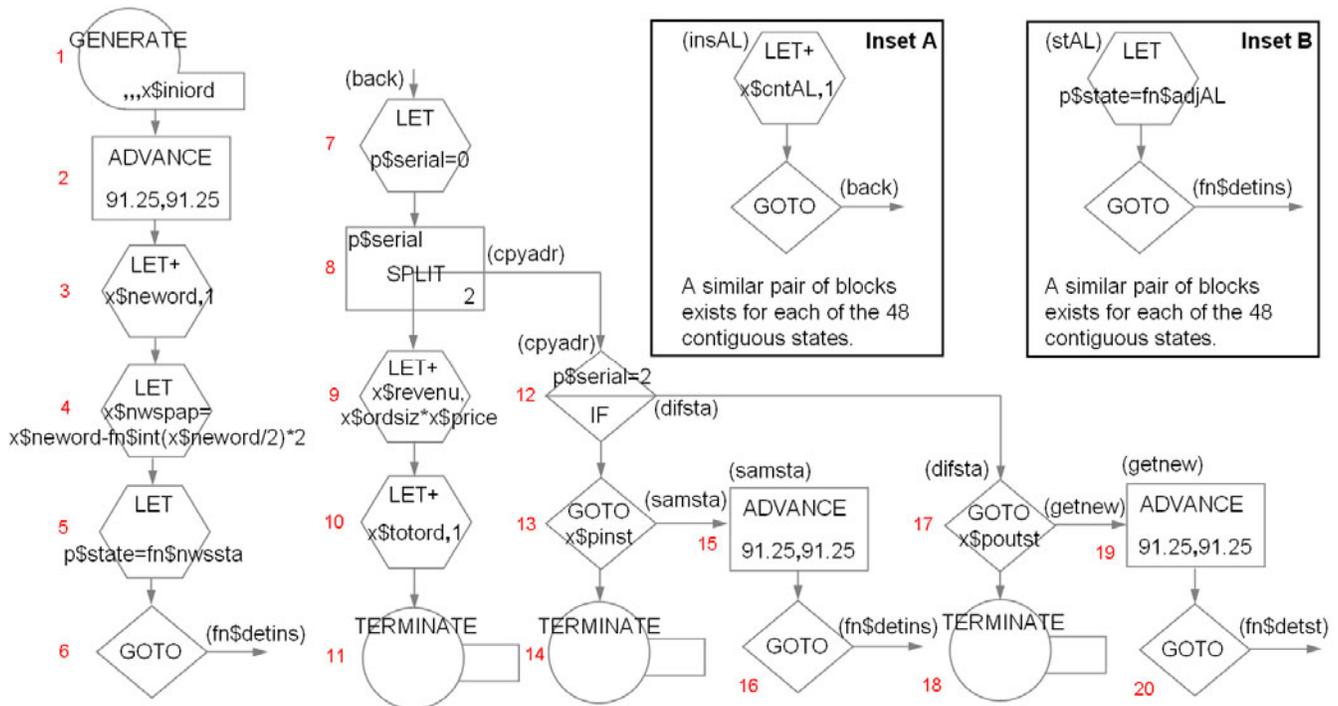


Figure 9: The Block Diagram for the WebGPSS Segment that Creates Orders for Photo Cookies

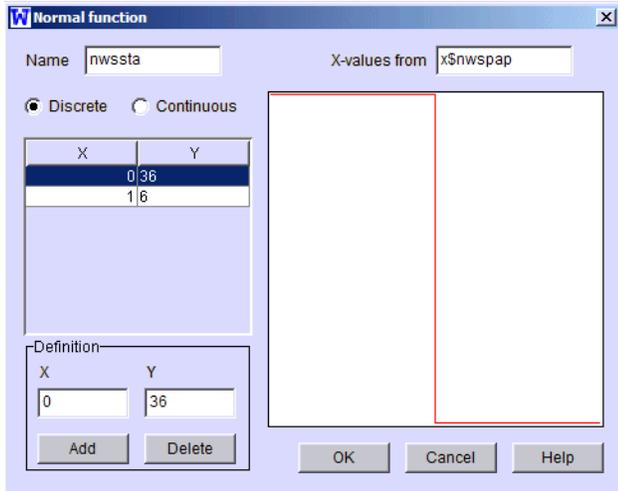


Figure 10: WebGPSS Definition

The unconditional GOTO block in Inset A in Figure 9 then sends the transaction back to block 7, where a user-defined parameter  $p\$serial$  is set to the value 0. Block 8 is a SPLIT block that then creates two copies of the transaction. The serialization parameter  $p\$serial$  is increased by 1 for the parent (to the value 1), by 2 for the first copy (to the value 2) and by 3 for the second copy (to the value 3). The copies go to block 12 and the original goes to block 9. In block 9 the original then increases the total revenue to date for all orders placed by the product of the order size in dozens and the price per dozen. In block 10 the total number of orders placed to date is increased by 1. With this transaction complete, TERMINATE block 11 removes it from the system.

Meanwhile, the copies created by the SPLIT block allow the possibility of future orders from a state that is adjacent to the parent or within the same state as the parent.

First, we consider the possibility of future orders from a state that is adjacent to the parent, i.e., when  $p\$serial$  is 2. The copy for which  $p\$serial$  is 2 goes to block 17. With probability  $1-x\$poutst$  (the probability that an order is not placed in an adjacent state), this copy enters TERMINATE block 18 and leaves the system. With probability  $x\$poutst$  (the probability of placing an order in an adjacent state), the statistical GOTO block 17 sends the copy to the ADVANCE block where it must wait for up to a half-year before placing an order. After waiting this random time, the copy, via the address function  $fn\$detst$ , goes to the LET block in Inset B in Figure 10 (more specifically, to the group of blocks identified by its current state  $p\$state$ , which we will assume for discussion purposes is Alabama). There, the function  $fn\$adjAL$  selects a state adjacent to Alabama in proportion to the populations of those adjacent states, and assigns the FIPS code to  $p\$state$ , which becomes the state for this new photo cookie order. The transaction then moves, via the unconditional GOTO with address function  $fn\$detins$ , to

the appropriate state pair of blocks in Inset A, where the order counter for the state is incremented by 1. Then it goes back to block 7, where the possibility of placing an order again starts all over.

Finally, we consider the possibility of a future order being placed within the same state as the parent, i.e., when  $p\$serial$  is 3. With two copies, the serialization parameter can only take the values 2 and 3 for a copy, and hence if it is not 2, it must be 3 at block 13. The copy for which  $p\$serial$  is 3 goes to block 13. With probability  $1-x\$pinst$  (the probability of not generating an order within the parent state), the transaction moves to TERMINATE block 14, where it leaves the system. With probability  $x\$pinst$  (the probability of generating an order within the parent state), the transaction moves to ADVANCE block 15, where it must wait for up to a half-year before placing an order. The unconditional GOTO block, via the address function  $fn\$detins$ , then sends the transaction to the appropriate state's pair of blocks in Inset A, where the order counter for the state is incremented by 1. Then it goes back to block 7, where the possibility of placing an order again starts all over.

## 7 TEAMING SIMULATION RESULTS WITH A GEOGRAPHIC INFORMATION SYSTEM

Now that the simulation model has been discussed in detail, we are ready to begin looking at some of the simulation results. Much of the output data from the simulation model has been imported into MapPoint to provide a more visual and animated account of how we can expect the photo cookie business to grow over time.

For comparison purposes, results were obtained for two different scenarios:

- *Scenario 1.* A total of 60 initial orders generated as a result of running newspaper ads in Los Angeles and New York City (30 ads per city).
- *Scenario 2.* A total of 150 initial orders generated as a result of running newspaper ads in Los Angeles, Dallas, Chicago, Atlanta, and New York City (again, 30 ads per city).

It should be noted that the first scenario can be run directly from the simulation model described in Section 6 of this paper. Two very small changes are required in the simulation model when running the second scenario. First, in block 4 of Figure 10, we must find the remainder when dividing by 5, since we have five cities in the second scenario. Second, the function  $fn\$nwsssta$  must be modified to have five data pairs, with integers 0 through 4 as values for the independent variable and the FIPS codes for the five states containing the five cities where newspaper ads are placed as values for the dependent variable.

One of the original questions dealt with how rapidly one could expect growth in revenue from photo cookie

sales. Figure 11 shows a logarithmic chart of total nationwide revenue (in thousands of dollars) to date for four years for the two scenarios. It is seen that after four years, revenue will be more than \$3.5 million for scenario 2 while only about \$1.5 million for scenario 1. The cost of placing the ads in five cities will be more, but the increase in revenue is likely to pay off in the long run.

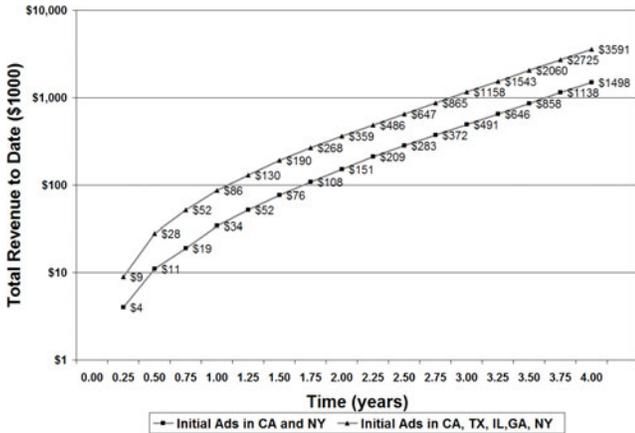


Figure 11: Total Revenue to Date for the Two Scenarios

Let us now address the questions that relate to the business geography of this problem. Generally, we are interested in growth in national presence over time, and we wanted to know how long before our business has reached every state as well as the growth in number of orders over time for each of the states. Our simulation model provided us with a quarterly report that contains the total number of cookie orders to date for each state. A portion of this quarterly report for Scenario 1 at time 4.00 years is shown in Figure 12, where the ellipsis indicates states that have been left out to conserve space in this paper.

ElapsedTime	4.00
TotalOrders	15249.00
TotalRevenue	1497705
State	CumOrders
AL	9.00
AZ	1835.00
AR	34.00
CA	3360.00
CO	61.00
CT	275.00
...	
WV	127.00
WI	46.00
WY	1.00

Figure 12: Sample Simulation Output

The data from this report was imported into Excel where it was easily formatted for direct import into MapPoint. Full-color animations were made by saving the re-

sultant maps from MapPoint as Web pages and then combining the maps via an animated GIF generator. To view the animations created from MapPoint snapshots at quarter-year intervals from time 0 to 4 years, the reader can go to the following link on the World Wide Web: <http://www.niu.edu/~m10rgb1/simgis/animate.htm>.

The reader will note that there is a legend in the lower right corner of the animated map in which the total number of orders placed to date increases as the colors change from purple, to green, to yellow, and finally to red (rainbow order). In addition, the lower right corner of the map contains a text box that updates the simulation time, total orders placed nationwide, and total revenue collected nationwide in thousands of dollars.

As suggested from intuition, orders begin in and near states where ads are initially placed. As time progresses, orders spread to additional states near those already having placed orders. In scenario 1 every state with the exception of North Dakota has placed orders within 4 years, with the highest number of orders from states closer to California and New York. A clear advantage of scenario 2 is that after only 3 years, a much higher penetration of orders has reached more states, and there appears to be a much more evenly spread national presence for our company. When four years have elapsed, every state has placed orders in scenario 2.

## 8 CONCLUSION

Through the sequence of interactive questions for the photo cookie business simulation, we have created an interface that allows the user to investigate a large number of different scenarios. In particular, the user might be interested in changing the number of initial orders placed as a result of newspaper ads. Maybe the user wants to see the effect on revenue and corporate nationwide growth if there are smaller probabilities for an order being generated within the same state as the parent order or from an adjacent state. With some minor modifications to the model, one could also adjust the percent increase in price so that it varies over time with known or projected inflation rates.

Discrete-event simulation has the power to add value to virtually any discipline one can imagine. This paper has demonstrated, in specific, the symbiotic relationship that can be established when teaming discrete-event simulation with geographic information systems. A tremendous synergy develops that allows finding solutions to complex business problems. The simulation provides us with a large amount of geographic information that is time dependent. The GIS, in turn, allows us to visualize this data through a time animated sequence, quickly identify patterns, and derive new questions requiring answers. These questions then lead us back to discrete-event simulation where the cycle begins all over.

Finally, the connection between discrete-event simulation and GIS is not limited to the products used by the author of this paper. Avenues for additional research would clearly lie in development of more automated procedures for interfacing simulation output with GIS.

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