406.311 Simulation
Fall 2007

Final Exam
Monday, December 10, 2007
(75 minutes; closed book)

Problem 1 (15 points)
True/False

____ In next-event simulation, an event occurs over an interval of time. (For example, an event might be repairing a machine from 2:15 pm until 3:35 pm).

____ *Monte Carlo* simulation refers to numerical solution of one or more deterministic differential equations; for example, to simulate a bouncing ball.

____ A `DELAY` block with `NORM(5,3)` delays has a true mean that is less than 5.

____ In a `TALLY` block, "`INT(InTime)`" and "`TNOW - InTime`" have the same meanings.

____ The `DISPOSE` block is used to destroy resources.

____ "Initial-condition bias" is a problem that arise primarily when simulating terminating systems.

____ If the `DSTATS` "`NR(workstation)*100/9`" is the utilization of the resource "workstation", then the capacity of the resource is 9.

____ A `TALLY` block (module) should have any expression involving one or more variables with values defined over time, such as `NQ`(Queue ID) or `NR`(Resource ID), etc.

____ In a general replication structure of simulation, we can usually have independence across runs.

____ Batch means is robust in that the bias will reduce in successive batches.

____ A future is the right, but not the obligation, to buy or sell an asset at a specified price some time in the future.

____ A European option must be exercised on the expiration date.

____ You can earn money with put options only if the stock price goes up.

____ The call options are frequently used to hedge the downside risk.

____ The 'Expected Value' and 'True EV' options for *Standard Recalc* setting in `@RISK` display the same values when the samples are from the continuous probability distributions.

Problem 2 (10 points)
Short answers.

(a) Explain how a dynamic simulation model is implemented with @RISK and EXCEL.

(b) Let P_T be the stock price at the expiration date T and let S be the strike price.

1. Describe the condition that the holder of a call option can make money.

2. How much profit can he/she realize?

3. According to the financial theory, how much is the fair price of the option when the risk-free rate used to discount the cash flow is r.

4. Explain how simulation can be used to determine the fair price of an option.

Problem 3 (10 points)

Which of the following data types or performance measures are related to "observational (O)" statistic or "time-dependent (T)" statistic?
(*Note*: An observational statistic is also called *tally* statistic in ARENA).

____ Total production (number of parts that complete their services and leave) during the simulation run.

____ Expected number of parts waiting in the queue.

____ Expected time in system (flow time).

____ Probability that the service time at Machine 1 is greater than 10 minutes.

____ Expected fraction of the time that Queue 2 is empty.

Problem 4 (15 points) Batch-means method.

(a) Let $y_1, y_2, \ldots, y_n$ denote the original simulation output data from a single long simulation run. The ARENA Output Analyzer can create batch means of size m automatically. The first batch mean is $\sum_{h=1}^{m} y_h/m$. What is the second batch mean?

(b) What is the batch means point estimator of $\mathrm{E}(Y)$?

(c) Suppose we partition the output data into twenty batches with batch mean values $\bar{y}_1, \bar{y}_2, \ldots, \bar{y}_{20}$. What is the value of the point estimator of the mean $\mathrm{E}(Y)$?

(d) What is the value of the estimated standard error $\frac{s}{\sqrt{n}}$ of the point estimator in (c)?

(e) Do we batch the output data to obtain a better point estimator or to obtain a better standard error estimator?

Problem 5 (15 points)
For output data Y, consider

$$\bar{y} = \frac{\sum_{i=1}^{n} t_i y_i}{\sum_{i=1}^{n} t_i}.$$

(a) What does $\bar{y}$ estimate?

(b) What is n? (It is *not* the number of observations).

(c) Is $\bar{y}$ observational or time-dependent statistic?

(d) For how long was the simulation run?

(e) Give two or more examples of the output data of this type.

Problem 6 (15 points) Answer the following questions.

(a) The ____(A)____ of a system model is defined to be a collection of variables containing all information necessary to operate the model and record relevant changes in it over time. A(n) ____(B)____ is defined to be any occurrence that causes an instantaneous change in the system ____(A)____. A(n) ____(C)____ specifies exactly how the system ____(A)____ changes when a(n) ____(B)____ of the given type occurs.

Specify the terms corresponding to blanks (A), (B), and (C).

(b) Explain the procedures involved in the *event scheduling* in a discrete-event simulation.

(c) Explain the procedures involved in the *timing routine* in a discrete-event simulation.

(d) Explain the steps involved in *event routine* `arrival` for the single-server queue example discussed in the textbook.

(e) Suppose the followings are the randomly sampled observations for interarrival and service times for a single-server queue model.

Interarrival times	.5	1.4	.1	1.7	.8	...
Service times	1.0	.2	.8	.8	.4	...

Keeping in mind the event execution and stage changes, fill the table below listing the first seven scheduled *events* in the same order as they are scheduled.

Sequence	Type of scheduled event	Time
1st event scheduled:	Arrival	0.0
2nd event scheduled:		
3rd event scheduled:		
4th event scheduled:		
5th event scheduled:		
6th event scheduled:		
7th event scheduled:		

Problem 7 (4 points)
TALLY statistics must be defined by a TALLIES element as well as by one or more TALLY blocks (modules). DSTATS statistics are only defined using a DSTATS elements. Why is there no DSTATS block (module)? Choose the best answer.

(a) The DSTATS element contains more information than the TALLIES element.

(b) DSTATS statistics are updates automatically by Arena at each state change.

(c) DSTATS are updated based on the STORAGE block.

(d) The TALLY block is used with the DSTATS element.

(e) The values of DSTATS variables never change.

Problem 8 (6 points)
Consider the following segment of SIMAN code:

```
CREATE: EXPO(10): MARK(TimeIn);
DELAY: TRIA(1,5,9);
TALLY: Tally1, INT(TimeIn);
DISPOSE;
```

(a) If the simulation experiment is run for a long time, what value will appear in the TALLY VARIABLES portion of the output report under Average for TimeIn?

(b) If "10" is changed to "20" in the code, what is the answer to part (a)?

(c) As the first entity enters the DISPOSE block, what is the value of its attribute "TimeIn"?

Problem 9 (10 points)
The following questions concern the Arena/SIMAN model and the summary reports for Sample Problem 3.3, shown below.

(a) In "`DELAY: TRIA(5,8,10),JobType`", is the storage referenced by *number* or *name*?

(b) (4 points) How many entities were *created* in this run of the experiment? Justify your answer.

(c) Which combination of "`JobType`" and "`STATUS`" yield the `NORM` delay with the greatest probability of being zero?

(d) Which state variable corresponds to "`Inspector Util`" in the summary report? What is the set of possible values for this state variables?

```
                                ARENA Simulation Results
                                     PRODUCT_ADMIN

                               Summary for Replication 1 of 1

Project: Sample Problem 3                                    Run execution date :12/13/2006
Analyst: Professor Hong                                      Model revision date:12/13/2006

Replication ended at time      : 480.0 Minutes
Base Time Units: Minutes

                                       TALLY VARIABLES

Identifier                              Average   Half Width  Minimum    Maximum   Observations
-------------------------------------------------------------------------------------------------

Type 1 Time in Sys                       19.036     (Insuf)    13.246     34.003         12
Type 2 Time in Sys                       51.123     (Insuf)    12.998     210.46         28

                                   DISCRETE-CHANGE VARIABLES

Identifier                              Average   Half Width  Minimum    Maximum   Final Value
-------------------------------------------------------------------------------------------------

Inspector Util                           .86699     (Insuf)    .00000     1.0000     1.0000
Inspector Queue                         2.6601      (Insuf)    .00000     7.0000     2.0000
Machine Queue                            .18220     (Insuf)    .00000     3.0000     .00000
Insp.Type 1 Util                         .21991     (Insuf)    .00000     1.0000     .00000
Insp.Type 2 Util                         .64709     (Insuf)    .00000     1.0000     1.0000
Machine Util                             .43861     (Insuf)    .00000     1.0000     1.0000

                                        COUNTERS

Identifier                               Count   Limit
-------------------------------------------------------

Rejects                                      3  Infinite
```

```
0$              CREATE,         1:EXPO(9):MARK(TimeIn):NEXT(1$);

1$              ASSIGN:         JobType=DISC(0.3, 1, 1.0, 2):
                                Status=1:
                                Priority=JobType;
Merge           QUEUE,          MachineQ;
2$              SEIZE,          1,Other:
                                Machine,1:NEXT(3$);

3$              DELAY:          NORM(Mean(JobType,Status),Std(JobType,Status)),,Other:NEXT(4$);

4$              RELEASE:        Machine,1;
5$              QUEUE,          InspectQ;
6$              SEIZE,          1,Other:
                                Inspector,1:NEXT(7$);

7$              DELAY:          TRIA(5,8,10),JobType,Other:NEXT(8$);

8$              RELEASE:        Inspector,1;
9$              BRANCH:         With,.8,12$,Yes:
                                With,.1,Reject,No:
                                With,.1,Repair,No;
12$             TALLY:          JobType,INT(TimeIn),1;
10$             DISPOSE:        No;

Reject          COUNT:          Rejects,1;
11$             DISPOSE:        No;

Repair          ASSIGN:         Status=2:
                                Priority=3:NEXT(Merge);
```

```
PROJECT,        "Sample Problem 3.3","Professor Hong",,,No,Yes,Yes,Yes,No,No,No,No,No;

ATTRIBUTES:     TimeIn:
                Priority:
                Status:
                JobType,;

STORAGES:       1,InspType1:
                2,InspType2;

VARIABLES:      Mean(2,2),CLEAR(System),CATEGORY("None-None"),5,3,4,2:
                Std(2,2),CLEAR(System),CATEGORY("None-None"),2,1,1,1;

QUEUES:         InspectQ,LowValueFirst(Priority),,AUTOSTATS(Yes,,):
                MachineQ,LowValueFirst(Priority),,AUTOSTATS(Yes,,);

RESOURCES:      Machine,Capacity(1),,Stationary,COST(0.0,0.0,0.0),,AUTOSTATS(Yes,,),EFFICIENCY(1,):
                Inspector,Capacity(1),,Stationary,COST(0.0,0.0,0.0),,AUTOSTATS(Yes,,),EFFICIENCY(1,);

COUNTERS:       Rejects,,Replicate;

TALLIES:        1,Type 1 Time in Sys:
                2,Type 2 Time in Sys;

DSTATS:         NR(Inspector),Inspector Util:
                NQ(InspectQ),Inspector Queue:
                NQ(MachineQ),Machine Queue:
                NSTO(InspType1),Insp. Type 1 Util:
                NSTO(InspType2),Insp. Type 2 Util:
                NR(Machine),Machine Util;

REPLICATE,      1,,MinutesToBaseTime(480),Yes,Yes,,,,8,Minutes,No,No,,,Yes;
```