Université d'Ottawa · University of Ottawa

SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

COURSE: CSI4124/SYS5110 Foundations on Modeling and Simulation

PROFESSOR: Gilbert Arbez

SEMESTER: FALL 2012

DATE: December 12, 2012

TIME: 14:00 to 17:00 (3 hours)

FINAL EXAMINATION
Solution

Name and Student Number: ____/______________________

There are four (4) parts in this examination.

Question 1	Conceptual Model	35 marks	
Question 2	Simulation Model	15 marks	
Question 3	Experimentation and Output Analysis	10 marks	
Total		60 marks	

All questions are answered in the examination paper. If you require more space, use the back of the pages.

Calculators are permitted.

Total number of pages: 16

Question 1 – Conceptual Modelling (30 marks)

Review the Gas Sation Project provided in the exam annex and complete the ABCmod Conceptual Model Sections.

1 ABCmod Conceptual Model

1.1 Project Goal

Find the number of attendants that provides the best daily profit to the gas station. In addition determine the amount of lost daily profit due to cars turning away from the station.

1.1.1 Parameters

numAttendants – the number of attendants servicing cars.

1.1.2 Experimentation

Base case: 2 attendants.
Alternate cases:

An additional case for each of the following values of numAttendants: 3, 4, 5, 6, 7, 8

1.1.3 Output

dailyProfit: The average daily profit.
revenuLost: The average revenu lost due to cars turning away.

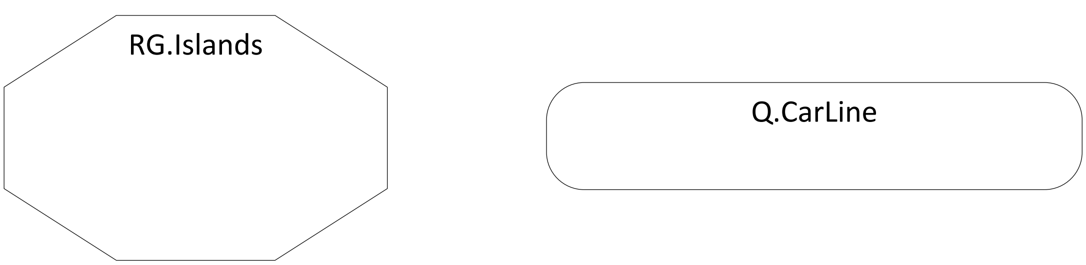
Note: The daily profit is calculated as DailyRevenu - FixCosts – AttendantSalairies, where the DailyRevenu is computed from the profit of sales to each of the cars, FixCosts is $300, and AttendantSalaries is calculated as numAttendants * 12 * 15.50.

1.2 High Level ABCmod Conceptual Model

1.2.1 Simplifications and Assumptions

- Gas pumps and attendants need not be modeled as entities. A group can be used to represent the cars being serviced by the attendants at the pumps.
- Cars need not be explicity modeled as entities. Rather, numbers of cars indicate the where cars are located in the model (see the queue and resource group entity categories.

1.2.2 Structural View

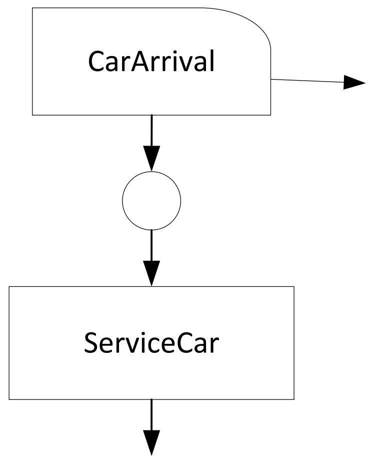


Entity Categories:

RG.Islands: This resource group represents the islands and attendants for servicing cars. The size of the group represents the number of cars being serviced as well as the number of attendants servicing the cars.

Q.CarLine: This queue represents the cars waiting in line to get service from the attendants. The size of the queue represents the number of cars in line. A list of car entities is not included in this entity.

1.2.3 Behavioural View



Car Life Cycle

Action Constructs
CarArrival: The arrivals of cars to the gas station. Note that cars may leave immediately if the station is too busy.
ServiceCar: The time to pump gas and receive payment for a single car, that is, the time to service a car..
Notes

- Life cyles for RG.Island entity is not shown (i.e. for the islands and attendants) since they are only involved in the ServiceCar activity.

1.2.4 Input

<u>Data Model</u>

- The interarrival times of cars approaching a gas station with the intention of possibly stopping for service are exponentially distributed with a mean of 5.8 minutes.
- Service time for cars follows the distribution is normally distributed with a mean of 450 and standard deviation of 200 seconds.
- Profit per car is Uniformly distributed between $5 and 15$.

Exogenous Input (Entity Stream)			
Variable Name	**Description**	**Domain Sequence Procedure**	**Range Sequence Procedure.**
uCarArr(t)	The input variable uCarrArr is the input entity stream variable that defines points in time that cars arrive at the station.	RVP.DuCarArr()	N/A, 1 customer arrives at each arrival.

Endogenous Input (Independent: implicit time dependence)		
Variable Name	**Description**	**Value**
uServiceCarTime(t)	Defines the time that it takes to service a car.	DVP.UServiceCarTime()
uProfit(t)	Profit from the sale of gas to a customer.	RVP.UProfit()

1.3 Detailed Conceptual Model

1.3.1 Structural Components (Entity Structures)

Constants		
Name	**Description**	**Value**
MEAN_ARRIVAL	Mean interarrival times for the cars.	5.8 minutes
MEAN_SRVTIME	Mean service time for servicing the cars.	7.5 minutes
STD_DEV_SRVTIME	Standard deviation for servicing the cars.	3.333 minutes
MIN_PROFIT	Minimum profit from the sale of gas to a car.	$5.00
MAX_PROFIT	Maximum profit from the sale of gas to a car.	$15.00
HOURS	Number of hours that attendants work during the day.	12.0
HOURLY_PAY	The hourly wages an attendant receives for working at the gas station.	15.50
FIXED_COSTS	The daily fixed costs to open the station.	300.0
Parameters		
Name	**Description**	**Value**
numAttendants	Number of attendants hired to service cars at the gas station.	2, 3, 4, 5, 6, 7, 8

Queue Class: Carline	
The line of cars waiting for service.	
Attributes	**Description**
n	Number of cars waiting for service.

Group Class: Islands	
Represents the gas pumps and attendants at the gas station islands. The number of cars that can be part of this group cannot exceed the paramter numAttendants.	
Attributes	**Description**
n	Number of cars being serviced at the station's islands.

1.3.2 Behavioural Components

Time units: Minutes

Observation interval: 0 until after 720 minutes (12 hours) and no cars are in RG.Islands.

Action: Initialise	
TimeSet	{ 0 }
Event	Q.CarLine.n ← 0 RG.Islands.n ← 0 SSOV.dailyProfit ← 0 SSOV.dailyRevenu ← 0 SSOV.revenuLost ← 0

Output

OUTPUTS	
Simple Scalar Output Variables (SSOV's)	
Name	**Description**
dailyProfit	The daily profit equals dailyRevenu – FIXED_COSTS - numAttendants*HOURS*HOURLY_PAY.
dailyRevenue	The total revenu from the sale of gas to all cars during the day.
revenuLost	The revenu lost during the day.

User Defined Procedures

None required

Input Constructs

Random Variate Procedures		
Name	**Description**	**Data Model**
DuCarArr()	Provides the arrival time of the next vehicle. The data model provides the interarrival times. The time of the first arrival t0 is determined by the exponential random variate generator(). No arrivals occur after the 12 hour day (i.e. 12*60 = 720 minutes)	Exponential(MEAN_ARRIVAL).
UServiceCarTime()	Detemines the time to service a car.	Normal(MEAN_SRVTIME, STD_DEV_SRVTIME)
UProfit()	Profit from the sale of gas to a single car.	Uniform(MIN_PROFIT, MAX_PROFIT)

Behavioural Constructs

Action: CarArrival	
The arrivals of cars to the station.	
TimeSet	RVP.DuCarArr()

Event	IF (Q.CarLine.n < RG.Islands.n)
	    Q.Car>ine.n +← 1
	ELSE
	    SSOV.revenuLost +← RVP.UProfit()
	ENDIF

Activity: ServiceCar	
Sale of gas to a car.	
Precondition	Q.CarLine.n ≠ 0 AND RG.Islands.n < numAttendants
Event	Q.CarLine.n -← 1

Activity: ServiceCar	
	RG.Islands.n +← 1
Duration	RVP.UServiceCarTime()
Event	SSOV.dailyRevenue +← RVP.UProfit() SSOV.dialyProfit ← SSOV.dailyRevenu - FixedCosts - numAttendants * HOURS * HOURLY_PAY RG.Islands.n -← 1

Question 2 – Simulation Modelling (15 marks total)

Translate the Entity Structures and Activity Constructs from the ABCmod Conceptual model to an Activity Object Simulation model in Java (using the ABSmod/J package).

```
      /*-------------Entity Data Structures-------------------*/
    // Because of simplicty of the Carline and Islands entity structures, implement
    // only the two attributes.
    int qCarline_n;
    int rgIslands_n;

      /*-------------Behaviour Constructs-------------------*/

public class CarArrival extends ScheduledAction
{
      GasStation model;

      protected CarArrival(GasStation m) { model = m; }

      public double timeset() { return (model.rvp.duCarArr()); }

      public void actionEvent()
      {
            if(model.qCarline_n <= model.rgIslands_n)  model.qCarline_n++;
            else model.output.ssovRevenuLost += model.rvp.uProfit();
      }
}

public class ServiceCar extends ConditionalActivity
{
      GasStation model;

      protected ServiceCar (GasStation m) { model = m; }

      protected static boolean precondition(GasStation m)
      {
            return (m.qCarline_n != 0 && m.rgIslands_n < m.numAttendants);
      }

      public void startingEvent()
      {
            model.qCarline_n--;
            model.rgIslands_n++;
      }

      public double duration() { return model.rvp.uServiceCarTime(); }

      public void terminatingEvent()
      {
            model.output.ssovDailyRevenue += model.rvp.uProfit();
            model.output.ssovDailyProfit = model.output.ssovDailyRevenue
                                    - Const.FIXED_COSTS
                                    - model.numAttendants*Const.HOURS*Const.HOURLY_PAY;
        model.rgIslands_n--;
      }

}
```

Question 3 – Experimentation and Output Analysis (15 marks total)

Output Analysis

The following tables show the results (confidence intervals) of 30 simulation runs.

	3 Attendants		4 Attendants		5 Attendants	
	Profit	Lost Revenue	Profit	Lost Revenue	Profit	Lost Revenue
$\bar{y}(n)$	1321.19	799.26	1690.98	260.86	1708.01	43.93
$s(n)$	68.70	162.72	111.91	113.44	180.16	46.34
$\zeta(n)$	35.73	84.62	58.20	58.99	93.68	24.10
CI Min	1285.47	714.64	1632.78	201.87	1614.32	19.83
CI Max	1356.92	883.88	1749.17	319.85	1801.69	68.03
$\zeta(n)/\bar{y}(n)$	0.02704	0.10587	0.03442	0.22613	0.05485	0.54858

	6 Attendants		7 Attendants		8 Attendants	
	Profit	Lost Revenue	Profit	Lost Revenue	Profit	Lost Revenue
$\bar{y}(n)$	1581.10	5.27	1388.34	0.00	1202.34	0.00
$s(n)$	205.11	10.74	204.34	0.00	204.34	0.00
$\zeta(n)$	106.66	5.59	106.26	0.00	106.26	0.00
CI Min	1474.44	-0.32	1282.08	0.00	1096.08	0.00
CI Max	1687.76	10.85	1494.60	0.00	1308.60	0.00
$\zeta(n)/\bar{y}(n)$	0.06746	1.06094	0.07654	N/A	0.08838	N/A

To obtain an overall confidence of 90%, what is the confidence required for each of the individual confidence intervals?

Let C = overall confidence and C_k = confidence of each individual confidence intervals. Thus C = 0.90 and C_k can be obtained using the Bonferroni equation. K, the number of confidence intervals is 12.

$C_K = 1 - \frac{1-C}{K} = 1 - \frac{0.10}{12} = 0.991667$, **Thus confidence in each interval is 99.2%**

The above results seem to show that 5 attendants will maximize profits. But notice that there exist overlaps in the profit confidence intervals for 4, 5 and 6 attendants. To investigate further, on the next page complete the confidence interval for the differences between cases with 4 and 5 attendants and also between the cases with 5 and 6 attendants. What can you conclude from your analysis? Use the value 2.84827 for $t_{n-1,a}$.

			Profit			
	Run	4 Attendants	5 Attendants	6 Attendants	Difference 4 and 5	Difference 5 and 6
	1	1519.21	1320.92	1168.65	198.29	152.27
	2	1626.11	1722.72	1550.58	-96.61	172.14
	3	1593.66	1591.36	1405.36	2.30	186.00
	4	1621.44	1540.03	1561.08	81.41	-21.05
	5	1795.88	1533.83	1375.15	262.05	158.68
	6	1528.41	1541.90	1271.13	-13.49	270.77
	7	1662.37	1640.55	1501.17	21.82	139.38
	8	1882.59	1843.05	1744.18	39.54	98.87
	9	1750.98	1831.82	1666.11	-80.84	165.71
	10	1779.82	1973.72	1821.99	-193.90	151.73
	11	1649.58	1616.95	1467.77	32.63	149.18
	12	1774.47	1752.83	1589.96	21.64	162.87
	13	1691.44	1916.79	1836.04	-225.35	80.75
	14	1659.56	1699.18	1513.18	-39.62	186.00
	15	1717.22	1711.81	1525.81	5.41	186.00
	16	1761.99	1698.34	1517.84	63.65	180.50
	17	1665.97	1682.67	1496.67	-16.70	186.00
	18	1587.86	1608.94	1528.81	-21.08	80.13
	19	1647.87	1796.81	1684.11	-148.94	112.70
	20	1646.2	1578.31	1411.43	67.89	166.88
	21	1460.21	1316.44	1166.80	143.77	149.64
	22	1775.38	1882.58	1746.29	-107.20	136.29
	23	1860.82	1980.11	1908.29	-119.29	71.82
	24	1854.1	2073.52	2017.57	-219.42	55.95
	25	1727.27	1755.77	1578.22	-28.50	177.55
	26	1479.49	1554.39	1414.47	-74.90	139.92
	27	1738.5	1667.16	1670.15	71.34	-2.99
	28	1669.62	1642.51	1770.08	27.11	-127.57
	29	1869.75	1950.54	1828.00	-80.79	122.54
	30	1731.52	1814.60	1696.21	-83.08	118.39
Sample Mean		1690.98	1708.01	1581.10	**-17.03**	**126.90**
Std Dev (s)		111.91	180.16	205.11	**112.54**	**75.94**
	ζ	58.20	93.68	106.66	**58.52**	**39.49**
CI Min		1632.78	1614.32	1474.44	**-75.55**	**87.41**
CI Max		1749.17	1801.69	1687.76	**41.50**	**166.39**

Clearly the case with 5 attendants provides a better profit than 6 attendants, but the difference between 4 and 5 attendants is not statistically difference since the confidence interval of the difference between these 2 cases contains zero.