Université d'Ottawa · University of Ottawa
SCHOOL OF INFORMATION TECHNOLOGY AND ENGINEERING

COURSE: CSI4124/SYS5110 Foundations on Modeling and Simulation
PROFESSOR: Gilbert Arbez

SEMESTER: FALL 2009
DATE: December 9, 2009
TIME: 9:30 to 12:30 (3 hours)
Room: Tabaret Hall Room 315

FINAL EXAMINATION
Solution

NAME and STUDENT NUMBER:_____/_____

1. There are four (4) parts in this examination.

Question 1	Short answer questions	20 marks	
Question 2	Conceptual Model	30 marks	
Question 3	Simulation Model	20 marks	
Question 4	Experimentation and Output Analysis	20 marks	
Total		90 marks	

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

You may detach the last two pages.

Calculators are permitted.

Total number of pages: 16

Question 1 – Short Answer Questions (20 points – 2 points each)

Complete the following questions using a few words or a simple phrase.

1) The ABCmod conceptual modeling framework is based on which DEDS World View?

   Activity Scanning

2) What list is used to advance time in Event Scheduling simulation programs?

   Future Event List

3) In the case of a steady-state study, an initial experimentation is required before experiements are used to generate output for final analysis. What does this initial step provide?

   Warm up time.

4) What construct is used in the ABCmod conceptual modeling framework to specify status changes that occur at points in time?

   Scheduled Action

5) Circle the three traditional World views used with DEDS modeling and simulation?

UML	Process Oriented	Event Notice
Activity Scanning	FEL	Transaction
Time Advance	Entity	Event Scheduling

6) Which intervention in the ABCmod conceptual modeling framework uses preconditions?

   Interruption.

7) ABCmod Entities are characterized by *scope* and *role*? Which one determines whether entities have a temporary or permanent existance in the model?

   Scope.

8) What are the two ABCmod output variable types used to specify the output values to be recorded during simulation?

   Sample Sets and Trajectory Set output variables.

9) An interaction between entities, which cannot be interrupted and is initiated under certain conditions, is modeled with what ABCmod framework behavioural construct?

   Activity construct.

10) Ensuring that the simulation model implements properly the conceptual model is called **Verification** or **Validation**?

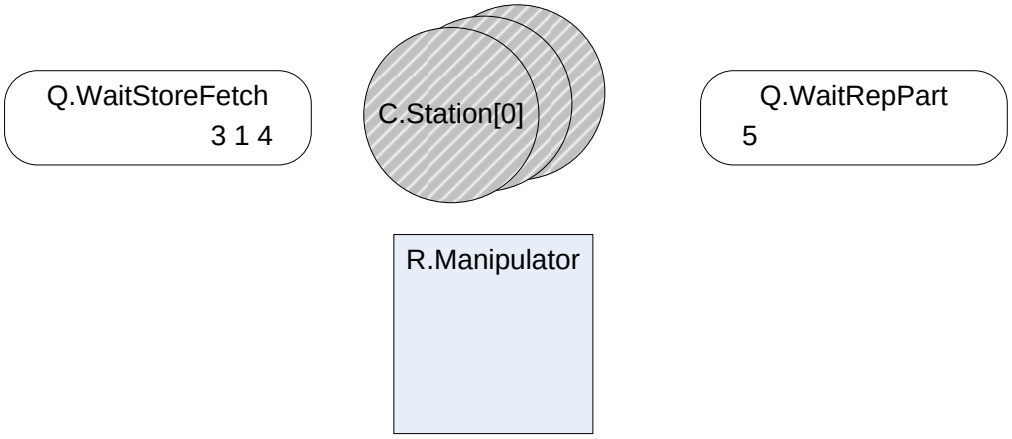
    Verification.

Question 2 – Conceptual Modelling (30 marks)

For the Painting Parts Project (see the description on page 15), provide an ABCmod conceptual model in the sections below. Note that the model will represent a closed system, that is, no inputs are defined in the model.

High Level Conceptual Model

Structural Diagram



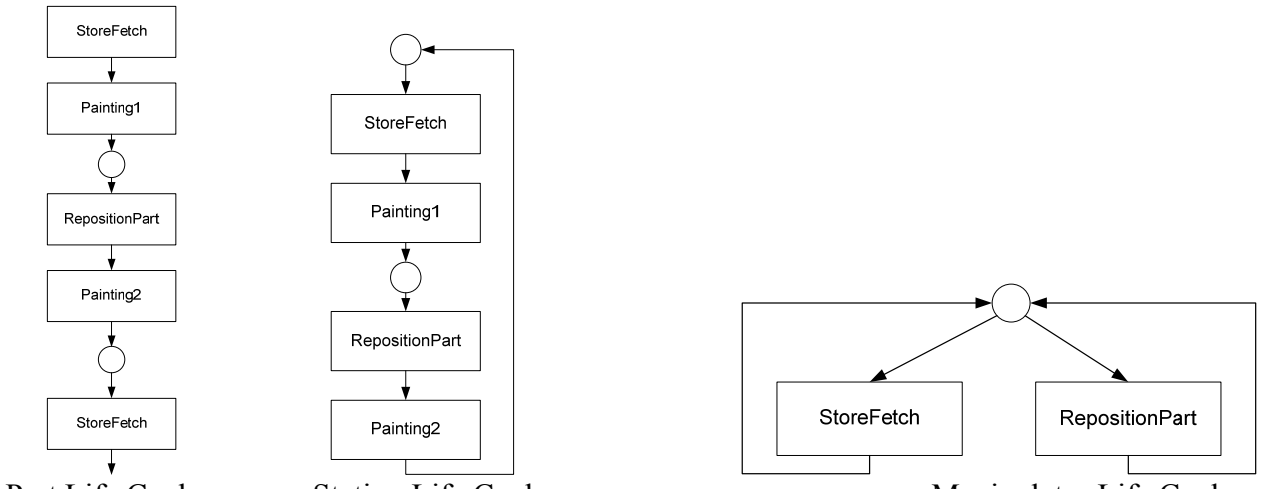
Entity Structures

- C.Station: This entity has a scope of Set with NumStations entities (NumStations is a paramter). The queues contain the station identifiers.
- Q.WaitStoreFetch, Q.WaitRepPart: These queue entities queue stations waiting for the Manipulator resource.
- R.Manipulator: This resource is used to reposition parts at stations or move/fetch parts to/from storage.

Notes

- Parts are not explicitly modelled.

Behavioural Diagram



Part Life Cycle Station Life Cycle Manipulator Life Cycle

Activities:

- StoreFetch: Store a completed part and fetch a new part.
- RepositionPart: Reposition part after the first painting step in preparation for the second painting step.
- Painting1, Painting2: The two painting steps. These are triggered activities.

Detailed Conceptual Model

Structural Components (Entity Structures)

Consumer Set[NumStations]: Station	
The painting stations for painting parts. Note that this entity is treated as a consumer that requires the services from the manipulator.	
Attributes	**Description**
Busy	Set to TRUE (value 1) when station is completing a painting operation and FALSE (0) otherwise.

Resource Unary: Manipulator	
Manipulator used to reposition, store and fetch parts.	
Attributes	**Description**
Busy	Set to TRUE (1) when involved in a manipulator operation and FALSE (0) otherwise.
StationID	The identifier (index) of the station entity being serviced.

Queue Unary: WaitRepPart	
The queue of stations waiting to have the parts repositioned. FIFO discipline	
Attributes	**Description**
N	The number of stations in the queue.
List	The list of station identifiers (indexes).

Queue Unary: WaitStoreFetch	
The queue of stations waiting to have a painted part removed and unpainted part fetched. FIFO discipline.	
Attributes	**Description**
N	Number of stations in the queue.
List	The list of station identifiers (indexes).

Data Modelling Components

Constants		
Name	**Description**	**Value**
RepPartMin	Minimum time to reposition the part at a station.	10
RepPartMax	Maximum time to reposition the part at a station.	20
StoreFetchMin	Minimum time to store and fetch parts.	25
StoreFetchMax	Minimum time to store and fetch parts.	35
Parameters		
Name	**Description**	**Value**
NumStations	Number of painting stations.	3 to 6

Data Modules		
Name	**Description**	**Data Model**
Painting1Time()	Time for the worker to complete the Painting 1 step.	Empirical continuous distribution f1 (in minutes) with the following cumulative distribution: f1 F(f1) 60 0.0 70 0.12 80 0.48 90 0.83 100 1.0
Painting2Time	Time for worker to complete the Painting 2 step	Empirical continuous distribution f2 (in minutes) with the following cumulative distribution: f2 F(f2) 80 0.0 90 0.24 100 0.73 110 1.0
RepPartTime()	Time to reposition the part on the at the station.	UNIFORM(RepPartMin, RepPartMax)
StoreFetchTime()	UNIFORM(StoreFetch Min, StoreFetchMax)	Time to store a part and fetch a new part.

Output Components

OUTPUTS			
Trajectory Sets			
Name	**Description**		
TRJ[R.Manipulator.Busy]	Reflects when the manipulator is in use.		
TRJ[C.Stations.Busy]	Reflects when a station is in use. A trajectory set exists for each station.		
Derived Scalar Output Variables (DSOV's)			
Name	**Description**	**Data Set Name**	**Operator**
ManipulatorUtil	Utilisation of the manipulator	TRJ[R.Manipulator.Busy]	AVG
StationsUtil	Average utilisation of all stations.	TRJ[C.Station.Busy]	ComputeStationUtil()

Behavioural Components

Time units: Minutes
Observation interval: Steady state study.

Initialize

Q.WaitRepPart.N ← 0
Q.WaitLoadFetch.N ← 0
n ← 0
WHILE(n < NumStations)
  C.Station[n].Busy ← TRUE
  TR.Painting1(n)
ENDWHILE

User Defined Modules	
Name	**Description**
ComputeStationUtil()	First compute the utilization of each station (AVG of TRJ[C.Station]). Then average the utilization over all stations and return this value.

Activity Construct: RepositionPart	
The Repositioning operation completed with the manipulator.	
Precondition	(R.Manipulator.Busy = FALSE) AND (Q.WaitRepPart.N ≠ 0)
Event	R.Manipulator.Busy ← TRUE R.Manipulator.StationID ← SM.RemoveQue(Q.WaitRepPart)
Duration	DM.RepPartTime()
Event	R.Manipulator.Busy ← FALSE TA.Painting2(R.Manipulator.StationID)

Activity Construct: StoreFetch	
The Store and Fetch manipulator operation.	
Precondition	(R.Manipulator.Busy = FALSE) AND (Q.WaitRepPart.N = 0) AND (Q.WaitStoreFetch.N ≠ 0)
Event	R.Manipulator.Busy ← TRUE R.Manipulator.StationID ← SM.RemoveQue(Q.WaitStoreFetch)
Duration	DM.StoreFetchTime()
Event	R.Manipulator.Busy ← FALSE TA.Painting1(R.Manipulator.StationID)

Triggered Activity Construct: Painting1(StnID)	
Painting 1 operation.	
Event	C.Station[StnID].Busy ← TRUE
Duration	DM.Painting1Time()
Event	C.Station[StnID].Busy ← FALSE SM.InsertQue(Q.WaitRepPart, StnID)

Triggered Activity Construct: Painting2(StnID)	
Painting 2 operation.	
Event	C.Station[StnID].Busy ← TRUE
Duration	DM.Painting2Time()
Event	C.Station[StnID].Busy ← FALSE SM.InsertQue(Q.WaitStoreFetch, StnID)

Question 3 – Simulation Modelling (20 marks total)

As part of creating an Activity Object Scheduling Simulation program for the Painting Parts Project, provide the Java Classes used to implement the Behaviour constructs (Activities, Triggered Activities, etc.) you specified in the conceptual model from Question 2. Please limit yourself to implementing the contents of the behaviour constructs, that is, it is not necessary to implement the initialization, data module, user-defined modules, etc.

Question 4 – Experimentation and Output Analysis (20 marks total)

A) Validation

Consider the following output for validating the model, where the number of machines was first set to 1 and then to 10. Explain how the output can be interpreted to validate the model.

		NumStations			
		1		10	
	Run	Manipulator Utilisation	Station Utilisation	Manipulator Utilisation	Station Utilisation
	1	0.200	0.796	0.9965	0.3895
	2	0.206	0.789	0.9969	0.3902
	3	0.199	0.796	0.9965	0.3878
	4	0.199	0.796	0.9968	0.3905
	5	0.202	0.793	0.9962	0.3910
	6	0.203	0.794	0.9968	0.3863
	7	0.203	0.793	0.9964	0.3895
	8	0.202	0.793	0.9964	0.3907
	9	0.204	0.792	0.9963	0.3888
	10	0.197	0.798	0.9965	0.3932
	11	0.202	0.793	0.9968	0.3918
	12	0.202	0.794	0.9964	0.3897
	13	0.202	0.793	0.9961	0.3897
	14	0.205	0.791	0.9965	0.3873
	15	0.205	0.791	0.9968	0.3895
	16	0.207	0.790	0.9968	0.3900
	17	0.205	0.790	0.9967	0.3900
	18	0.205	0.791	0.9963	0.3923
	19	0.200	0.796	0.9967	0.3926
	20	0.205	0.791	0.9965	0.3868
Sample Mean		0.203	0.793	0.997	0.390
Std Dev (s)		0.003	0.002	0.0002	0.002
	ζ	0.001	0.001	0.000	0.001
Min Value		0.202	0.792	0.996	0.389
Max Value		0.204	0.794	0.997	0.391

When the crane services a single machine, its utilisation is low as expected. In this case the machine is busy for close to 80% percent of the time (79.3 %). This value can be treated as the maximum utilization possible for a machine, given that it must wait for repositioning the casting and for storing/loading operation when a new casting is loaded onto the machine. This value is consistent with
1) the means times for the repositioning and loading/storing operations
2) The value of the utilization of the crane which is around 20%.

When the crane services 10 machines, as expected the crane is close to 100% busy. As expected, the utilization of the machines drop since it spends time waiting for the crane to become available.

B) Output Analysis

Consider the following results obtained from 20 simulation runs for the Balancing Equipment Project.

		NumStations							
		3		4		5		6	
	Simul. Run	Manipulator Utilisation	Station Utilisation	Manipulator Utilisation	Station Utilisation	Manipulator Utilisation	Station Utilisation	Manipulator Utilisation	Station Utilisation
	0	0.593	0.773	0.768	0.747	0.910	0.708	0.994	0.645
	1	0.593	0.769	0.768	0.747	0.914	0.712	0.990	0.644
	2	0.597	0.772	0.769	0.750	0.921	0.714	0.993	0.641
	3	0.596	0.773	0.769	0.751	0.921	0.718	0.994	0.647
	4	0.593	0.772	0.766	0.751	0.915	0.716	0.990	0.646
	5	0.598	0.774	0.772	0.748	0.918	0.710	0.994	0.641
	6	0.599	0.770	0.767	0.744	0.915	0.712	0.993	0.645
	7	0.590	0.773	0.767	0.751	0.912	0.714	0.990	0.645
	8	0.592	0.770	0.765	0.743	0.914	0.712	0.994	0.645
	9	0.587	0.777	0.759	0.751	0.908	0.717	0.992	0.651
	10	0.595	0.772	0.767	0.749	0.913	0.714	0.992	0.648
	11	0.593	0.773	0.768	0.752	0.910	0.711	0.992	0.645
	12	0.594	0.772	0.766	0.749	0.912	0.710	0.992	0.645
	13	0.595	0.772	0.764	0.743	0.921	0.715	0.993	0.642
	14	0.597	0.773	0.770	0.749	0.916	0.712	0.993	0.644
	15	0.595	0.767	0.766	0.746	0.917	0.715	0.993	0.646
	16	0.597	0.770	0.772	0.747	0.918	0.713	0.994	0.646
	17	0.590	0.772	0.766	0.754	0.912	0.715	0.991	0.649
	18	0.587	0.775	0.761	0.750	0.912	0.716	0.992	0.649
	19	0.601	0.771	0.772	0.744	0.921	0.712	0.994	0.642
Sample Mean		0.594	0.772	0.767	0.748	0.915	0.713	0.993	0.645
Std Dev (s)		0.004	0.002	0.003	0.003	0.004	0.003	0.001	0.003

- Provide output analysis of the above results (be sure to provide appropriate confidence intervals) and discuss the results relative to the project goal.
- Make a recommendation of another possible Modelling and Simulation Study to explore balancing the use of the equipment to provide better balancing of equipment (if possible).

The following table shows the confidence intervals based on the above data.

Sample Mean		0.594	0.772	0.767	0.748	0.915	0.713	0.993	0.645
Std Dev (s)		0.004	0.002	0.003	0.003	0.004	0.003	0.001	0.003
	ζ	0.00194	0.00118	0.00173	0.00165	0.00209	0.00136	0.00072	0.00145
Min Value		0.592	0.771	0.765	0.747	0.913	0.712	0.992	0.644
Max Value		0.596	0.773	0.769	0.750	0.917	0.715	0.993	0.647
	r	0.003257964	0.001527604	0.002253903	0.00220152	0.00227985	0.00190418	0.000728804	0.00224738

No additional simulation runs are required.

Having the crane service 6 machines makes the best use of the crane (its utilization is increased to 99.3 % which is close to 100 %). But the machine utilization drops from 77% to around 65%, as 12% drop. The option of having the crane service 5 machines must be considered, as the utilization of the 5 machines will increase by some 6% while the cranes utilization drops by 8%.

Additional simulation to be considered is to have 2 or 3 cranes service multiple machines to see if it is possible to maximize utilizations of both cranes and machines.