OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG INF FAKULTÄT FÜR INFORMATIK

Simulation Research Group

xx.xx.2019

Exam *Introduction to Simulation*

Total number of points obtainable:	
Number of questions:	
Number of pages:	16
Time limit:	120 minutes
Additional material allowed:	Dictionary

Name:			
Student ID#:		Course of studies	

For your information:

You may answer the questions in either German or English.
Answer all questions according to the contents taught in the lecture.

Rules for written exams at the “Fakultät für Informatik”:

Cheating, attempted cheating (e.g. usage of prohibited additional material, copying from other students, etc.) and unruly behavior will result in a “failed” grade for the exam. Any violation of the rules will be recorded. In the case of cheating or attempted cheating the student may choose to continue the exam even though it will be graded as “failed”. In case of unruly behavior, students will be warned once, and in case of recurrence will not be allowed to finish the exam.

Question	Points	
1		
2.1 *or* 2.2		
MA 2.1 *or* 2.2		
3		
4		
5		
6		
7		
8		
Total:		

—— The simulation group wishes you good luck! ——

Question 1: Continuous Modeling [10 Points]. Fermentation.

A (simplified) model of a fermentation process using yeast considers the following positive real-valued quantities:

- Number of yeast cells **Y**
- Amount of glucose **G**
- Amount of liquid alcohol **A**
- Temperature in the reaction container **T**

Fermentation is a process in which (yeast) cells produce energy and alcohol out of glucose. The generated energy is required for the reproduction of the yeast cells. The following effects need to be considered:
N.B.: This is just an overview over the processes occurring. The concrete assumptions and interdependencies will be presented only in the actual exam.

The whole system is mainly driven by the fermentation rate, which depends on the number of yeast cells, glucose and the temperature. Alcohol is evaporating and the temperature changes due to cell activity.

a) [9 Points]
Define the fermentation rate *F*. **Describe** this model by writing an ordinary differential equation (ODE) for **each** of the above quantities (**Y**,**G**,**A**,**T**). Wherever possible use environmental variables (F, T_{Opt}, T_{room}). Use symbols a_1, a_2, etc. for **positive** constants.

F =

b) [1 Point]
Which of the following questions **cannot** be answered by such a model?
1.
2.
3.

Question 2.1: Semester Assignment „The Sims – Almost Normal Family Life" [20(30) Points].
IMPORTANT: Answer either Question 2.1 or 2.2, not both! Mark the question you want to have graded!

a) Continuous/Hybrid Behavior [8 Points]
Sketch (graphically) a typical development of . Briefly **explain why** the system behaves the way you sketched it. In your graph, **mark** and **name** at least five (in total!) different activities and states.

b) [6 Points]
In the Semester Assignment, your task was to determine . **Give** a statistically meaningful answer to this task. **Explain** what that answer means. **Describe** on what basis it has been obtained.

c) Family therapy strategy [6 Points]
Explain in short your strategy of using the available interventions to maximize the probability to stay together for 7 years. **State** the probability that was reached using this strategy.

Master Addition

IMPORTANT: Only answer question d) and e) if you are writing the exam for Master (6CP)!

d) [6 Points]

State the code fragment for detecting , including its location in the model structure. Also include the code for the effect that this incident has on the system state and explanations on the variables and the logic.

e) [4 Points]

Your task was to determine . Give a statistically meaningful answer and explain on what basis it has been determined.

Question 2.2: Semester Assignment „Star Trek – USS Enterprise in Danger" [20(30) Points].
IMPORTANT: Answer either Question 2.1 or 2.2, not both! Mark the question you want to have graded!

a) Continuous/Hybrid Behavior [8 Points]
Sketch (graphically) a typical development of the . Briefly **explain why** the system behaves the way you sketched it. In your graph, **mark** and **name** at least three (in total!) different activities and states.

b) [6 Points]
In the Semester Assignment, your task was to determine . **Give** a statistically meaningful answer to this task. **Explain** what that answer means. **Describe** on what basis it has been obtained.

c) Power distribution strategy [6 Points]
Explain in short your strategy for distributing the energy between the engine and shield. **State** the <u>survival</u> probability that was reached using this strategy.

Master Addition

IMPORTANT: Only answer question d) and e) if you are writing the exam for Master (6CP)!

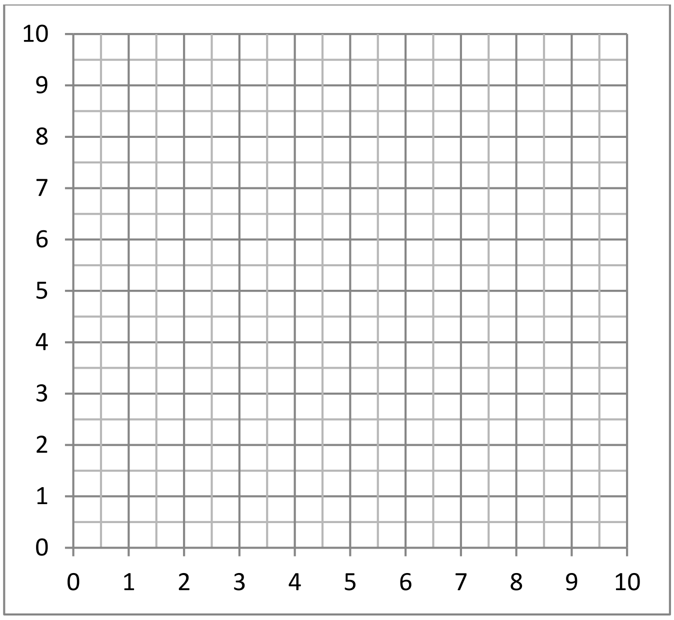
d) [redacted] [6 Points]
State the code fragment for [redacted], including its location in the model structure. Also include the code for the effect that this incident has on the system state and explanations on the variables and the logic.

e) [redacted] [4 Points]
Your task was to determine [redacted]. Give a statistically meaningful answer and explain on what basis it has been determined.

Question 3: Input Data Analysis [10 Points].

a) Quantile-Quantile-Plot [5 Points]
The following five numbers were obtained in a measurement:

You assume that these measurements are distributed according to a distribution. To check this assumption, **draw** a Quantile-Quantile-Plot in the empty graph below **and interpret** the result.



b) Chi-Square-Test [5 Points]
You receive a file containing numbers between 0 and 1. These are assigned to five intervals ("Observed") according to their value. Someone claims that these numbers were created by .

	xMin	***xMax***	***Expected***	***Observed***		
Sum						

What does the Chi-Square-Test say to this hypothesis? Do not merge any classes; round numbers to one decimal place. Use first $\alpha = 0.1$ and then $\alpha = 0.05$. What exactly do these results mean?

Question 4: Petri Nets [10 Points]. Lab Work.

We are looking at a chemical experiment, which students have to conduct on an individual basis in a lab. The experiment consists of two parallel processes analyzing a given substance. One sample of the given substance needs to be examined using a microscope. A second sample of the substance needs to be put into a centrifuge to separate the different components. These in turn have to be examined using a mass spectrometer. The results of the experiment have to be presented to a lab assistant, who can reject them, requiring the students to repeat the whole experiment.

N.B.: This is just an overview over the processes occurring. The concrete assumptions and interdependencies will be presented only in the actual exam.

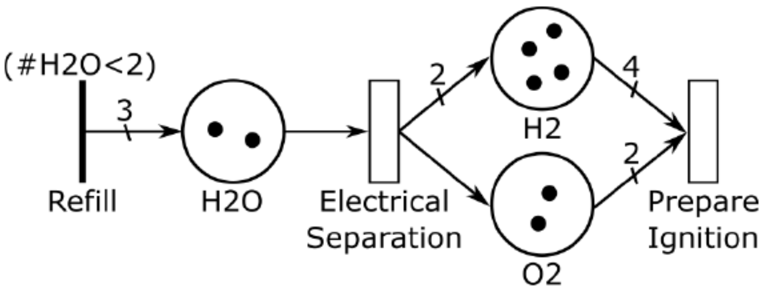
Draw a Petri net model of this system. **Assume** the following initial state:

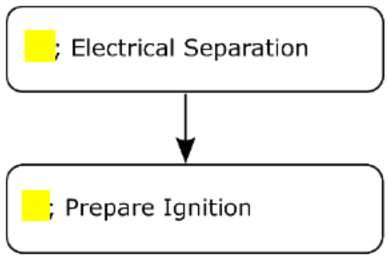
Mark all transitions that have a race age policy. **List** the transitions that are currently enabled.

Question 5: Progression of a Discrete Simulation [10 Points]. Electrolysis.

We are modelling an experiment demonstrating the separation of water into hydrogen and oxygen using electrolysis. There is a water reservoir that provides distilled water to an electrolytic cell. In this cell, a random amount of time is needed to separate one unit of water into two units of hydrogen and one unit of oxygen. The resulting hydrogen and oxygen is collected in separate containers. Once a certain amount of hydrogen and oxygen has been collected, the teacher explaining the experiment channels that amount from both containers into a chamber and ignites the gas mixture. For this preparation of the ignition, the teacher also needs a random amount of time. If the water in the reservoir falls below two units of water, it is refilled.

The following Petri net represents this process: At time , the water reservoir contains two units of water and there are 4 units of hydrogen and 2 units of oxygen in their respective containers. The teacher already started preparing the ignition. The *Future-Event-List* (FEL) of the system is the following:





The next three duration times for separating water:
The next three duration times for preparing the ignition:

a) Simulation progression [7 Points]
In order to sketch the progression of the simulation program from time to time , **show** the system state after ***each*** state change, as well as the events added to the FEL, if any. **Indicate** which events are primary and which are secondary (=conditional).

time					

b) Future Event List [3 Points]
Describe or draw the FEL for time , i.e. the FEL after all events for that point in time have been processed.

Question 6: Output Analysis [10 Points]. Fusion Reactor Design.

Researchers have developed two different designs for a fusion reactor. They aim for a high efficiency, i.e. they want the energy produced by the fusion to be higher than the energy used for keeping the fusion alive. To evaluate both designs, simulation models of each have been created. Using correlated sampling, several runs were simulated and the following values for the efficiency were recorded (higher efficiency values are better):

Run	Current Strategy	New Strategy	D_r	$\overline{D}$	$(D_r-\overline{D})^2$		
1							
2							
3							
4							
5							
6							

Statistically **compare** the two sets of replications. Which reactor design should be chosen? **Interpret** the results of your calculations, **justify** your decision and **state** a way to improve the results. (Hints: use empty table cells for your calculations. For the computation of square roots rough estimates are sufficient)

Question 7: Discrete Time Markov Chains [10 Points]. Solar Activity.

We want to build a simple model of the solar activity of the sun. We therefore define three different states that describe the overall solar activity (e.g. sunspots and solar flares) in a year:

(1) low (2) normal (3) high

We assume that the solar activity in a year only depends on the solar activity of the previous year. Therefore we can assume that the progression of solar activities can be represented by a discrete-time Markov chain (DTMC).

The following table contains the number of transitions of solar activity states of . (**NOTE: The values are not from the real world!).** We can use this data to build the DTMC.

Previous solar activity	**Solar activity**	**Number**		
low	low			
low	normal			
low	high			
normal	low			
normal	normal			
normal	high			
high	low			
high	normal			
high	high			

a) Modelling [4 Points]

Sketch the graphical representation of the discrete-time Markov chain (DTMC) that can be deduced from this statistic.

b) Transient Solution [4 Points]

Assume that this year has activity. Using the above model, **compute** the probability that years from now there will be activity.

c) *Beyond DTMCs - Hidden Markov Models* [2 Points]

Assume that the solar activity directly influences the occurrence of auroras (polar lights). The probability that an above average number of auroras occur in a year is if the solar activity is low, if the solar activity is normal and if it is high.

If there activity this year, **compute** the probability that there will be an above average number of auroras .

Question 8: Miscellaneous [10 Points].

a) Given the *initial value problem* y'(t) = with y(0) = . This problem is to be solved using the Euler method with step size 1. **Compute** the result at time t = 2. [3 Points]

b) A *random variable* is distributed with . How many of samples can be expected **<u>not</u>** to be ? [2 Points]

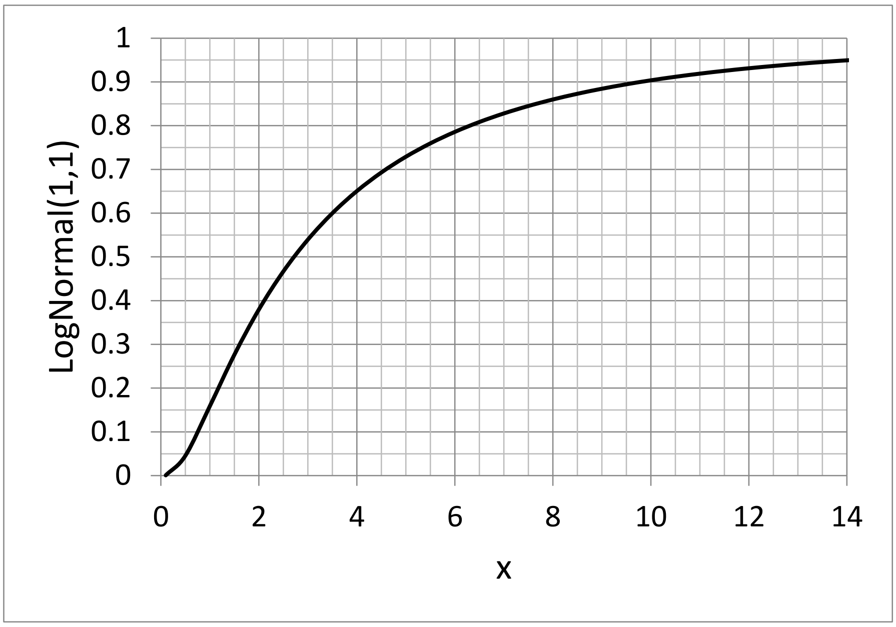
c) **Generate** (pseudo) random numbers that are distributed *using Linear Congruential Method*. What are the first two values r_1 and r_2 generated using parameters a= , c= , m= and the seed x_0= ? [2 Points]

c) We are considering . **Give** an example for each of the following [3 Points]
(<u>Refer to the definitions from the lecture!</u>)

- an event –
- an activity –
- a delay –
- an entity –
- an attribute –
- a state variable –

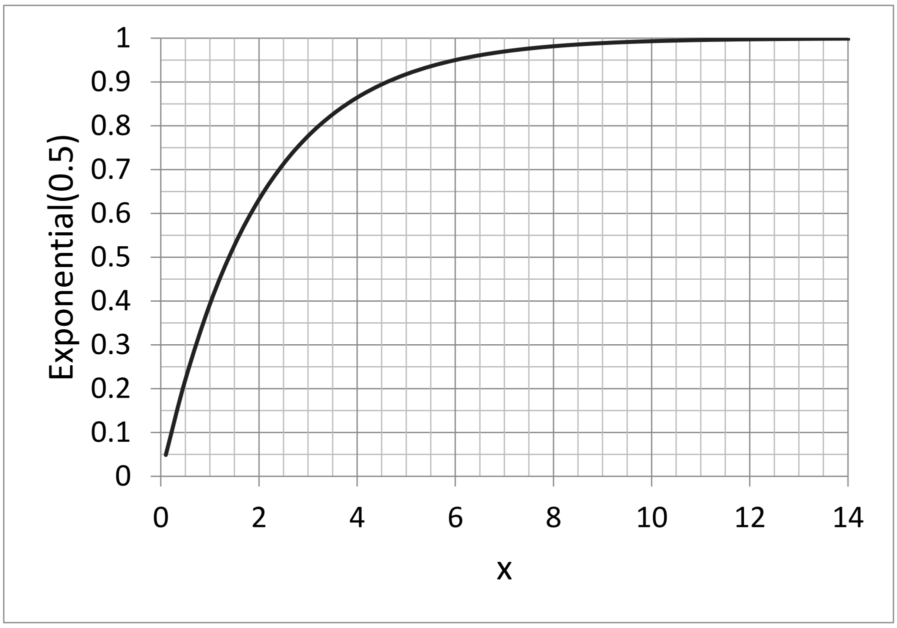
Appendix

LogNormal(1, 1) CDF



The value of the Student *t*-distribution for 5 degrees of freedom at position 0.05 is 2.57

Exponential(0.5) CDF



Some values of the χ^2-Distribution:

		#degrees of freedom					
		2	3	4	5	6	7
α	0,05	6,0	7,8	9,5	11,1	12,6	14,1
	0,10	4,6	6,3	7,8	9,2	10,6	12,0