TU Delft

Examination TPM

Delft University of Technology - Faculty of Technology, Policy and Management

Course name:	**Simulation Masterclass**	**Course code:**	**SEN9110**
Date:	**Friday 21 January 2022**	**Time:**	**09:00 – 12:00**
Module manager:	**Prof.dr.ir. A. Verbraeck**		

Examination questions:

Number of open questions: **4 (*)** questions
Number of multiple choice questions: **0** questions
Max. number of points: **90** points

☐ **all questions have the same weight**
☒ **the questions have different weights** (indicated per question)

Total number of pages (incl. cover page): **2** pages

Use of tools and information sources:
During the examination, the use of any tools or information sources (this includes mobile phones, smartphones or any devices with similar functions) is strictly forbidden unless stated below.

Permitted tools and information sources:
☒ **books** ☒ **notes** ☒ **dictionaries** ☒ **readers** ☐ **formulae sheets**
☒ **calculator** ☐ **computer** ☒ **slides, papers, all course materials**

Additional instructions: *(optional)*
(*) Students have to choose 3 out of 4 questions to answer (30 points each, total 90 points + 10 points = 100 points). Indicate clearly on your answer sheet which question you are answering. Don't answer all 4 questions.
This mark contributes for 50% to your final mark, and has to get a mark ≥ 5.8 to be averaged with the term paper (30%, including presentation) and simulation package (20%) for the overall mark.

Final marking date:
(the maximum marking period is 10 working days)
4 February 2022

To be handed to the examiner or invigilator:
☒ Examination work with name and student number on each page.
☐ Examination documents

Any suspicion of fraud or any breach of the exam rules will be immediately reported to the Board of Examiners

For more information about fraud:
TU Delft Student portal> TPM> Rules and Guidelines

Start each question on a new sheet. Don't forget to write your name, student number, and question number clearly on every page you hand in. Also indicate on the first page how many separate sheets you have handed in in total. Do not write in pencil -- use a blue and/or black pen for your answers.

CHOOSE 3 OUT OF 4 QUESTIONS TO ANSWER. CLEARLY INDICATE WHICH QUESTIONS YOU CHOSE.

1. **Systems Theory** (30 points)
   a. We often say that the way scientists process the results of a simulation experiment is no different from processing data gathered from a controlled experiment in a lab or in society. Give a clear argumentation why these two are similar, but also provide two major differences between a real experiment and a computer simulation experiment. (10 points)
   b. Based on the cybernetics work of Ashby, one could state that the behavior of a simulation model can be fully characterized by a transformation. Explain in your own words how each of the eight different components of the DEVS Atomic Model can or cannot be characterized by Ashby's operands, operators, transforms, transitions, and transformations. (10 points).
   c. Describe as precisely as possible what the purpose is of the "Levels of System Knowledge" (lecture 4) as defined by Klir, and extended by Zeigler. How do the Levels of System Knowledge relate to doing science in general, and to simulation experiments in particular? (10 points)

2. **Hierarchical DEVS** (30 points)
   a. Give an example (your own example, not one from the papers in the Reader, the lectures, or Wikipedia) of a hierarchical DEVS model with two atomic DEVS models and at least one connection between the models. Describe your time domain, internal, external and confluent transition functions, *ta*, and the output function lambda for both atomic models, as well as the *select* function, in a formal way using set theory where appropriate. Also clearly describe the *meaning* of each input variable, state variable, output variable, and port. (15 points)
   b. Explain in your own words what 'closure under coupling' for hierarchical DEVS models exactly means, and why this concept is important. (5 points)
   c. Suppose we have a hierarchical DEVS model with many port-based atomic model components. How is it determined which model component executes its δ_{int} first? Make a distinction between the situation where all atomic models have a different next execution time based on their respective *ta*'s, and where some of the execution times are the same. (10 points)

3. **Distributed and Real-Time Simulation** (30 points)
   a. Explain as clearly as possible how relaxed time synchronization for distributed simulation works, and what problem it tries to solve. Give 2 examples where it is a bad idea to use this form of time synchronization. (10 points)
   b. Why do federates typically get behind (later than the real-time clock) in real-time simulations? Describe two methods to solve the problem that federates get behind. (10 points)
   c. In both the Object-Oriented Simulation lecture and the Real-Time Simulation lecture we discussed the importance of 'asynchronous communication'. Explain what it is, why it is important, and how it help to solve problems in distributed simulation. (10 points)

4. **Multi-formalism simulation** (30 points)
   a. Describe what the formalism transformation graph of Vangheluwe and De Lara from 2002 tries to show. Also explain the difference between unidirectional arrows and bidirectional arrows in the diagram. (10 points)
   b. In the formalism transformation graph, almost all model formalisms have a path towards the DEVS&DESS model. What exactly is the DEVS&DESS model, and what does it mean that most paths in the transformation graph end there? (10 points)
   c. Metamodeling is "making a model of a model". Why is that useful? Explain as clearly as possible what the different forms of metamodeling are within the field of simulation, and for what purpose each of them is used. (10 points)