TU Delft

Examination TPM

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

Course name:	**Simulation Masterclass**	**Course code:**	**SEN9110**
Date:	**Friday 11 November 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)
25 November 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

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. Write using pen only: officially anything written in pencil should be ignored for grading. Only use the computer in the computer room; use of your own electronic devices is prohibited.

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

1. **Systems Theory and Systems Specification** (30 points)
   a. Briefly describe the "Levels of System Knowledge" as defined by Klir and expanded by Zeigler (Reader p.58) in your own words. Since a simulation model can be seen as a generative model, the development of a simulation model should fit the framework as well. Carefully describe how each step of the framework applies to the development of a simulation model. (10 points)
   b. According to the formalism transformation graph of Vangheluwe (papers from Vangheluwe, reader p.245/251), any discrete-event model can be transformed into DEVS. Schriber et al. describe 5 entity states for discrete-event simulation (Reader p.33). Describe precisely for all 5 entity states how these would be implemented or embedded in (Atomic) DEVS. (10 points)
   c. We sometimes say that the actual time base of Discrete Event Simulation is continuous, while the actual time base of Continuous Simulation is discrete. Explain precisely why this is the case, and use notions of the theoretical and the actual time base in your answer. (10 points)

2. **Hierarchical DEVS** (30 points)
   a. Give an example (your own, not from the Reader, lectures, or Wikipedia) of a hierarchical DEVS model consisting of two atomic DEVS models. Describe your time domain, internal, external and confluent transition functions, *ta*, and the output function lambda for both atomic models in a formal way using set theory where appropriate, and indicate the input, output, connectors, ports, and *select* function for the overarching (composite) model. Also clearly describe the *meaning* of each input variable, state variable, and output variable. (15 points)
   b. Why is there a *select* function in a hierarchical DEVS model? Explain clearly what the function of the *select* function is, and why it is needed. (5 points)
   c. Suppose that we would construct a hierarchical DEVS model that contains a DESS atomic model and a DEVS atomic model, where the DEVS atomic model needs the value of a differential equation variable of the DESS model, and the DEVS model can update a variable of the DESS model. Is this possible? If yes, show how it works. If no, explain why not. (10 points)

3. **Distributed and Real-Time Simulation** (30 points)
   a. HLA is the standard industry method for implementing distributed simulation, and it uses the RTI as its main component. Present and explain 5 functions of the RTI that you would consider the most important. Also, explain what you would consider the main issue or shortcoming of using an RTI in distributed simulation. (10 points)
   b. The concept of "dead reckoning" is sometimes used in distributed and real-time simulation. Explain clearly how dead reckoning works, including an example, and explain why we do it, i.e., what problem is solved by dead reckoning. (10 points)
   c. Real-time simulation is different from general distributed simulation. Present the three main issues of real-time simulation as compared to distributed simulation, and clearly present solutions for each of the three identified issues. (10 points)

4. **Simulation Languages** (30 points)
   a. Present the main advantages of activity scanning simulations. Activity scanning based simulation languages died out pretty quickly according to the paper of Nance on simulation languages (Reader p.292). Explain the main reasons why this happened. (10 points)
   b. (1) In a sense, there is a relation between activity scanning and agent-based simulation. Explain the relationship and clearly show how agent-based simulation uses the activity scanning method (locality of state). (5 points). (2) The same holds for Atomic DEVS models; these also seem to have a relation to activity scanning. Show the relation between activity scanning and DEVS models in detail as well. (5 points)
   c. Simulation packages like Simio, Arena, Plant Simulation, and Enterprise Dynamics (lectures 13 and 14) pretend to use simulation objects from their libraries. Compare the 9 principles of object orientation with the "simulation objects" from these simulation languages. (10 points)