TU Delft

Examination TPM

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

Course name:	**Simulation Masterclass**	**Course code:**	**SEN9110**
Date:	**Friday 10 November 2023**	**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, course materials, USB-stick**

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)
24 November 2023

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, with the exception of a USB stick, which is allowed.

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

1. **Systems Theory and Systems Specification** (30 points)
   a. DES as defined in the reader by Nance (Reader p.3) and Schriber et al. (Reader p.31) is different from DEVS as defined by Zeigler et al. (Reader p.49) and Van Tendeloo & Vangheluwe (Reader p.71). Provide the definitions for both terms, describe the differences, and indicate the relationship between DES and DEVS. (10 points)
   b. Models described using DEVS, DESS and DTSS all use transformations as defined by Ashby (Lecture 2). Describe the differences between the transformations in these three formalisms and give an example of a transformation for each of the three formalisms. (10 points)
   c. Schriber et al. (Reader p.31; Lecture 3) describe the possible states of an entity in DES. Explain why there is a 'Ready State' and how the 'Ready State' and 'Active State' work. (10 points)

2. **DEVS** (30 points)
   a. For the different variants of DEVS, the so-called 'Closure under Coupling' principle holds. Describe 'Closure under Coupling' in your own words, and why it is important. (10 points)
   b. It is possible to combine multiple DTSS-submodels (e.g., many ABM agent-models) in a Hierarchical DEVS model. The *select* function becomes very important in such a case. Explain what the *select* function does, and why it is needed in this case to accomplish reproducibility of the simulation study. (10 points)
   c. The δ_{EXT} function in Atomic DEVS (Reader p.71) is a function of (x, s, e) → s. What is *e*? Why is it important? Provide an example of your own (so not from a paper or from the lecture) that shows the importance and use of *e* when δ_{EXT} is called. (10 points)

3. **Real-Time Simulation** (30 points)
   a. Especially in real-time simulation, the concept of *dead reckoning* can be helpful. Explain what problem dead reckoning tries to solve, why it is especially important in real-time simulation, and provide a small example of how it works (your own example, not one that we covered in class). (10 points)
   b. Parallel Simulation and Distributed Simulation (Fujimoto, Reader p.139) are two different but related concepts. Describe parallel and distributed simulation, give the relation between the two concepts, and give a clear difference between the two concepts when we use them for a simulation study. (10 points)
   c. The High-Level Architecture (HLA) can be used in real-time settings with Human-in-the-Loop and Hardware-in-the-Loop federates. Describe two issues that these non-simulation components can cause, and provide a potential solution for these two issues. (10 points)

4. **Multi-Paradigm and Multi-Resolution Simulation** (30 points)
   a. Vangheluwe and De Lara (Reader, p.249) describe formalism transformations in their paper. On what level (model, meta-model, meta-metamodel) would a formalism transformation be defined, an on what level would it be practically executed? Explain clearly why. (10 points)
   b. Davis (Slides lecture 12) describes that the equivalence or consistency between an aggregated model and a disaggregated model can be tested in two different ways: weak and strong. Suppose we have a model of a particular highway with cars as a high-resolution model using detailed behavioral modeling in ABM, and as a low-resolution model that describes the traffic densities using SD. Use this example to clearly and precisely explain the difference between weak and strong consistency. (10 points)
   c. Use the example from question 4b to explain why disaggregation is hard. In other words, suppose we aggregate the individual cars to densities and disaggregate the model back later, what is the exact issue? (10 points)