Network Application Diagnostics - Examinations

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1 BE2M32DSAA test and its evaluation, valid from 1. 1. 2021

- Only students who have obtained a credit from the exercises can be examined.
- The exam has two parts, written and oral. The oral part is conducted as a written defense work with any additional questions.
- The written work also consists of two parts.
  1. The first part deals with two examples derived from examples solved in exercises. It is allowed to solve examples use teaching materials. 60 minutes are provided for elaboration.
  2. In the second part you need to answer 4 questions according to the topics below. Teaching materials cannot be used. The student can used her/his brain and a pencil. Each answer is expected to be a half of A4 page long describing the most important points related to the question. 60 minutes are provided for elaboration.
- Each answer and solution of examples is graded. The final grade of the exam is determined according to the sum of all points obtained in this course in a given semester according to the CTU classification scale.
- The following questions are listed with regards to the presentation for the lecture.

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2 Question Topics

1. **Introduction to Complex Networks**
   (a) Name several examples of complex networks application domains?
   (b) What are the two difficult issues linked with processing of complex networks?
   (c) What is the range of complex network volume?
   (d) Name several drawing layouts used for complex network visualizations?
   (e) Define a complex network and its basic features.
   (f) Define asymptotic bounds used for assessment of algorithm complexity.
   (g) Describe DFS-tree search edge classification.
   (h) Describe depth-first search algorithm.
   (i) Describe breath-first search algorithm.
   (j) Describe the Dijkstra's single source shortest paths.
   (k) Describe the Floyd-Warshall all pairs shortest paths.

2. **Fundamental Characteristics of Networks. Models of Random Graphs**
   (a) Describe the network perspective approach to problem solutions.
   (b) What are the typical characteristics of complex networks?
   (c) Describe the meaning of degree hetergeneity.
   (d) Define graph density and sparsity.
   (e) Define graph degree distribution and show some its typical examples.
   (f) List the four basic models of complex networks and their characteristics.
   (g) List basic graph topologies.
   (h) Describe Erdös-Renyi graph model.
   (i) Describe Watts-Strogatz graph model.
   (j) Describe Barabási-Albert graph model and its scale-free property.
   (k) What is the meaning of "the rich-club phenomenon".

3. **Network Properties**

   (a) Define adjacency matrix, cocitation matrix, and bibliographic coupling

   (b) Define bi-adjacency matrix, incidence matrix, edge incidence matrix

   (c) Define one-mode projection and its relation to bi-adjacency matrix.

   (d) Show how to compute degree of vertex, the number of edges, the mean degree, and graph density based on the adjacency matrix for undirected and directed graphs.

   (e) Show how to compute number of paths and cycles based on the adjacency matrix.

   (f) Define degree centrality.

   (g) Define closenes centrality.

   (h) Define betweenness centrality.

   (i) Describe an algorithm for betweenness centrality computation.

   (j) Define eigenvalue centrality.

   (k) Define Katz centrality.

   (l) Define PageRank index.

4. **Network structure identification**

   (a) What are the basic roles of nodes?

   (b) How is it possible to assess a role of a given nodes?

   (c) Provide definitions of authorities and hubs.

   (d) How are the hub and authority centralities defined?

   (e) What is the goal of clustering?

   (f) What are the two fundamental approaches to data clustering?

   (g) What are the typical steps of a cluster analysis?

   (h) What ate the basic forms of node memberships in clusters?

   (i) Describe k-means clustering.

   (j) Define a triplet and triangle.

   (k) Describe a diffusion equation.

   (l) What is the graph Laplacian?

(m) Name basic properties of the graph Laplacian eigenvalues?

5. **Network Community Detection**

   (a) Describe the concept of community.

   (b) What is null model of a graph?

   (c) What types of community dection methods do you know?

   (d) Describe Kernighan-Lin algorithm.

   (e) Describe graph partitioning using the spectral bisection method.

   (f) What is modularity of graph proposed by Newman?

   (g) How can modularity be used for community detection?

   (h) Describe principles of the Louvain algorithms.

   (i) What is the resolution limi in community detection based on modularity?

   (j) Describe principles of overlapping community detection.

6. **Alloy. Specification using relational logic**

   (a) Define the concept of atom, relation, signature. What is the difference between extension, subset of signature, top-level and abstract signature?

   (b) How are relations defined? Define their possible multiplicities.

   (c) Define a collection of Alloy quantifiers, logical and set operators.

   (d) Define Alloy relational operators.

   (e) How to use the "let" command? How are scalar values ??represented? Give an example of a constraint expressed using the structure "fact". How are functions and predicates written and used?

   (f) How is the specification analyzed using Alloy?

7. **Model validation**

   (a) Describe principle and basic characteristics of model verification methods.

   (b) Define Kripke's structure and its extension.

   (c) Describe UPPAAL system architecture and its basic properties.

   (d) Define time automaton and its semantics

(e) Explain the basic modeling entities in UPPAAL: synchronization and its types, positions and their special properties, guard, invariant.

(f) Explain the concept of reachability, security and liveliness and how these features are verified in the UPPAAL system.

(g) Describe using of invariants and guards over timer clocks in the UPPAAL system. When and how are used urgent and commited positions.

8. **Temporal logics**

   (a) Describe calculation path and time concepts.

   (b) Describe CTL * logic and its temporal operators.

   (c) Describe CTL logic and its temporal operators.

   (d) Describe LTL logic and its temporal operators.

   (e) Describe UPPAAL temporal logic.

9. **FSM Checking Sequences**

   (a) Describe Chow's W method for constructing test sequences for automata with a finite number of states.

   (b) Define the characterization set of a finite state machine and describe the algorithm for its calculation.

   (c) Define distinguishing sequence of a finite state machine and the algorithm of its preset form determination.

   (d) Define homing sequence of a finite state machine and the algorithm of its preset form determination.

   (e) Define synchronizing sequence of a finite state machine and the algorithm of its preset form determination.

   (f) Define state verifying sequence of a finite state machine and the algorithm of its preset form determination.

10. **FSM Learning**

    (a) Define an observation table and specify the conditions under which the table is closed and when it is consistent.

    (b) Describe the Angluin's L^* algorithm.

    (c) Describe the principle of the Hidden Markov Model (HMM) and state its three basic tasks.

(d) What are the two basic learning techniques used to learn the Markov Decision Process?