

Please answer the following questions in the answer sheet available on the class webpage. Please do not answer in this questionnaire. You may use your notes, papers, books, or Internet sources to answer questions. Many questions are open-ended and will be graded based on your argument as opposed to some “ground truth”. The exam should be answered individually. You may not discuss the questions and answers with others. Please return by 11:59pm Friday, May 9th by e-mail.

I. Interactive Complexity and Coupling: Choose the single best answer to each of the following questions. Observe that multiple answers may be applicable to different degrees. If you feel it’s a close call, please explain your choice. **(5 points)**

1) Interactive complexity and coupling are some of the most important reasons for failures in large-scale embedded systems. Which of the following statements most closely describes failures in a system of high interactive complexity but low coupling?

- a) Once some system function fails, the failure propagates quickly through the rest of system causing other related failures.
- b) The failure may be hard to attribute to an error or bug in any single component.
- c) The failure involves a positive feedback loop that increases performance error over time.
- d) The failure typically occurs due to operator error.

2) Which of the following statements most closely describes failures in a system of high coupling?

- a) Once some system function fails, the failure propagates quickly through the rest of system causing other related failures.
- b) The failure may be hard to attribute to an error or bug in any single component.
- c) The failure involves a positive feedback loop that increases performance error over time.
- d) The failure typically occurs due to operator error.

3) Which of the following design practices would typically contribute to interactive complexity and/or coupling in modern cyber-physical systems?

- a) Resource sharing mechanisms such as priority scheduling.
- b) Increased networking of individual components.
- c) Implicit assumptions made in component design that are not reflected in the interface
- d) All of the above.

4) You are invited to the StarVoyager Corporation to debug and possibly redesign their most recent solar navigation vehicle, which currently exhibits an unpredictable failure mode. All critical tasks of the system have already been diligently tested but no bugs were found. Looking for features that contribute to high interactive complexity and coupling, which of the following design choices about the above vehicle would concern you most?

- a) The use of EDF scheduling of different criticality tasks to improve schedulability.
- b) The lack of hardware memory protection on some of the embedded processors used.
- c) A wireless MAC that instructs low priority senders to yield to critical communicating tasks.
- d) All of the above

5) Which of the following systems exhibits the least coupling:

- a) A parallel search algorithm performed by multiple machines, each searches a subset of the search space for matches with a user's query then reports found matches to the user.
- b) A data aggregation algorithm that returns the minimum temperature in a sensor network.
- c) A radar data processing pipeline composed of target tracking, threat assessment, and weapon assignment stages.
- d) A clock synchronization algorithm where each node periodically sets its clock to the maximum clock value received from its immediate neighbors.

II. State of the Art: The questions below address your perception of the current state of the art in cyber-physical computing research. Each question asks your opinion on the most novel or needed research topic out of a set of multiple alternatives. In every case, please choose the best single direction in your opinion. Explain your choice, specifically stating why you excluded the other directions. For example, you may cite previous related work similar to the choices you eliminated as evidence of their lack of novelty. **(10 points)**

6) Programming sensor networks is notoriously difficult. Many research efforts addressed programming abstractions but the state of the art in literature remains lacking in many aspects. In your opinion, which of the following possible research contributions would best fill an existing void?

- a) A high-level language that abstracts the network by a collection of node objects and methods.
- b) A Java-like general-purpose language that exports a virtual machine abstraction to facilitate wireless code download and code migration among network nodes.
- c) A programming language that exports rich abstractions for modeling the physical world without favoring a particular application domain.
- d) A programming language that exports a database abstraction of the network.

7) Task scheduling is a key element that must be properly done in software that interacts with the physical world. Which of the following, in your opinion, would constitute the best contribution to scheduling in cyber-physical systems?

- a) A theory that provides sufficient schedulability conditions for uniprocessors.
- b) A theory that accommodates aperiodic tasks into periodic task schedulability analysis.
- c) A scheduling algorithm that explicitly incorporates performance parameters of the physical world into the scheduling problem.
- d) A language for specifying timing constraints to the real-time system compiler and scheduler.

8) In your opinion, which of the following gaps is the more serious deficiency in the current state of the art of embedded systems?

- a) A gap between the best effort nature of available operating systems and the real-time requirements of embedded applications.
- a) A gap between system modeling abstractions used by embedded system designers and the state of the art of current embedded system programming languages.
- b) A gap between the advanced capabilities of modern hardware and the state of the art in compiler optimization.
- c) A gap between the centralized target tracking literature and the distributed nature of modern surveillance systems.

9) Troubleshooting tools for sensor networks are most in need of which of the following:

- a) Simulation platforms for embedded sensing systems.
- b) GDB-like source-level debugging tools for sensor nodes.
- c) Hardware probes to monitor node energy consumption.
- d) Debugging tools that expose distributed event sequences that lead to failure states.

10) In your opinion, what is the dominant source of discrepancy between real performance and simulated performance of present sensor network localization algorithms?

- a) A highly irregular sensing range
- b) A highly irregular radio range
- c) Lack of good time synchronization algorithms for sensor nodes
- d) Inaccurate simulation of the routing layer

III. General. Choose the single best answer to each of the following questions. Observe that multiple answers may be applicable to different degrees. If you feel it's a close call, please explain your choice. (15 points)

11) Which of the following adaptive sampling techniques would you recommend for monitoring the physical environment in a way that both saves energy and achieves low sampling error?

- a) Sampling at longer intervals when energy is lower.
- b) Sampling at a rate that varies with the expected rate of change of the measured phenomenon.
- c) Sampling at a rate that is proportional to the absolute value of the measured phenomenon.
- d) Sampling at a rate that is proportional to the number of user queries.

12) In tracking problems, data association refers to:

- a) Attributing observations to the right targets.
- b) Classifying the type of target from measured data.
- c) Computing the probability that a given measurement is not a false alarm.
- d) Correlating multiple data measurements to determine target speed.

13) Which of the following is NOT true of EDF scheduling?

- a) It scheduled important tasks at a higher priority than less important tasks.
- b) If the system is overloaded, failure of one task to meet its deadline may cause others to miss their deadlines.
- c) It is the optimal real-time scheduling policy for independent periodic tasks on a uniprocessor in the sense of meeting all deadlines whenever the resource capacity constraint is met.
- d) None of the above.

14) Which of the following algorithms minimizes the response times of aperiodic tasks amongst all algorithms that allocate spare capacity immediately while meeting all periodic task deadlines?

- a) Deferrable server
- b) Priority exchange server
- c) Slack stealing server
- d) Sporadic server

15) Amorphous computing draws inspiration from

- a) Information theory
- b) The motion patterns of amorphous organisms like the Amoeba
- c) Laws of thermodynamics
- d) Cell bio-differentiation

16) Mobiscopes make which of the following explicit or implicit assumptions?

- a) A useful array of sensors is or will soon be readily available to the common person.
- b) Value can be derived by sharing an individual's sensory data with others.
- c) The lack of control over sensor mobility does not constitute a serious impediment to usability.
- d) All of the above

17) Control theory was successfully applied to the control of software performance. Which of the reasons below explain why this might be the case?

- a) Control theory is robust to modeling errors.
- b) Software usually has linear models.
- c) Some common software constructs have difference equation models.
- d) Both (a) and (c)

18) QoS optimization subject to resource constraints in an NP-hard problem (that can be reduced to multiple-choice knapsack). Nevertheless, a polynomial solution is possible in the following special case:

- a) The case where there is only one resource to allocate.
- b) The case where resources are allocated in multiples of a fixed quantum.
- c) The case where all resource requirements can be expressed by natural numbers.
- d) None of the above.

19) In the Simplex architectural pattern, the notion of recoverable region refers to which of the following system state subspaces?

- a) A region in which the system can always return to the set point.
- b) A region of unstable states in which stability can be recovered by switching to the trusted controller
- c) An unstable region
- d) A region bounded by safety constraints on system state.

20) Which of the following statements are NOT made nor implied by the authors of the Simplex architectural pattern?

- a) Redundancy does not necessarily increase reliability.
- b) All projects have finite budgets.
- c) The reliability function is monotonically increasing with respect to development effort.
- d) A simple backup to a complex primary significantly improves system reliability.

21) TinyOS encourages which of the following programming styles?

- a) Object-oriented
- b) Multithreaded

- c) Event-driven
- d) Database-centric

22) Delay control and queue size control are two problems in software systems that can be addressed using feedback control techniques. Which of the following statements best describe these problems?

- a) Both are examples of linear control problems.
- b) Both are examples of nonlinear control problems.
- c) Delay control is linear but queue size control is not.
- d) Queue size control is linear but delay control is not.

23) Managing concurrency in embedded systems is inherently difficult and error prone. How does TinyOS approach this problem?

- a) It encourages the programmer to think in terms of state machines as opposed to concurrent threads.
- b) It offers a rich semaphore library to simplify concurrency management.
- c) It handles resource locking and unlocking transparently on behalf of the programmer.
- d) It prevents programs from posting more than one task to the scheduler queue at any given time.

24) Which of the following sensor network programming systems rely on different types of sensor groups are the fundamental programming abstraction?

- a) Hood
- b) Envirotrack
- c) TinyDB
- d) State-centric programming

25) Which of the following sensor network programming paradigms is inspired by a control engineer's view of the physical system?

- a) Hood
- b) Envirotrack
- c) TinyDB
- d) State-centric programming

Thank you very much.
Tarek