THIS PAPER IS NOT TO BE REMOVED FROM THE EXAMINATION HALL

UNIVERSITY OF LONDON

CO2226 ZB

BSc EXAMINATION

COMPUTING AND INFORMATION SYSTEMS, CREATIVE COMPUTING and COMBINED DEGREE SCHEME

Software Engineering, Algorithm Design and Analysis

Tuesday 14 May 2019: 14.30 – 17.30

Time allowed: 3 hours

DO NOT TURN OVER UNTIL TOLD TO BEGIN

This paper is in two parts: Part A and Part B. There are a total of **THREE** questions in each part. You should answer **TWO** questions from Part A and **TWO** questions from Part B.

Full marks will be awarded for complete answers to a total of **FOUR** questions, **TWO** from Part A and **TWO** from Part B. The marks for each part of a question are indicated at the end of the part in [.] brackets.

Only your first **TWO** answers from Part A and first **TWO** answers from Part B, in the order they appear in your answer book, will be marked.

There are 100 marks available on this paper.

A handheld calculator may be used when answering questions on this paper but it must not be pre-programmed or able to display graphics, text or algebraic equations. The make and type of machine must be stated clearly on the front cover of the answer book.

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PART A: answer TWO questions

Question 1

a) Who would be the main audience for a state diagram and what would you be trying to capture in it? Use an example to justify your answer.

[5]

b) LearnOnYourOwn.com is a new online company specialising in the provision of online courses for users who do not have the time to attend a traditional university course, or are not interested in an academic qualification and they just want to extend their knowledge in one specific area (*e.g.* C++ programming).

- Before the user can use the site to register for any courses, they will need to create an account. This is done by providing their personal details (*e.g.* first name, last name, phone number, e-mail address) as well as choosing a username and password that they will be using to identify themselves once they log in to the site.
- LearnOnYourOwn.com will be providing either individual courses (identified by a course ID, title, number of credits and a summary) or a bundle of courses leading up to a qualification. The courses will be related to one or possibly multiple subjects (*e.g.* a course on C++ might be relevant to both software development and software engineering).
- In the case of courses leading up to a qualification, each will be described by an ID, its name, a short summary and the number of credits it will be carrying towards obtaining the qualification. Furthermore, within a qualification, a specific course can be either compulsory or optional (*e.g.* C++ would be compulsory for a Programming qualification, but optional for a Testing one).
- Any time that the user logs in to LearnOnYourOwn, they should be able to see all courses that they are enrolled on and how far they have progressed on each one of them. It could be that the user initially bought courses as individual ones and then realised that they can get a qualification out of them, so they might change their registration and group them together (of course, there could be a mixed situation where the user is taking some courses as a qualification bundle, *e.g.* Programming, and some others out of personal interest, *e.g.* video making). Some of the qualifications, due to statutory requirements, might be only valid for a certain time period so the time that the user obtained the qualification should be recorded as well.
- When the user decides to register for a course, they will need to pay a fee depending on the course they chose. LearnOnYourOwn does not deal with the payment itself, but simply passes the information on to an external payment gateway. The LearnOnYourOwn system would still, however, need to keep information about the payment such as method

of payment, end result, and the authorisation code if they need to trace it later on.

- The company allows for the registration of individual as well as corporate accounts; in the case of corporate accounts, the buying organisation gets a number of places either on a specific course or a qualification at a discounted rate. The discount will depend on the number of places bought, as LearnOnYourOwn has pre-defined discount rates for bands of places bought (*e.g.* up to five places 2%, five to ten 5%, and so on).

- A course might have multiple instructors (there needs to be at least one) and if there are multiple instructors, one has to be nominated as the module leader. LearnOnYourOwn.com operates a feedback system for each course which is available at a read-only level to everyone considering purchasing the course. Every registered student of the course (either as an individual course or as part of a qualification) can write comments. Registered students can contribute many comments for one course, as they might have one opinion for one part of the course (or a particular instructor) and another for another part (or a different instructor if there are many).

- A few courses might hold some face-to-face sessions, either for practice exercises where it is not possible to provide students direct access to the software (*e.g.* due to licensing constraints or security requirements) or for networking reasons. In this case, there will be a number of sessions on offer and users on the course will have to confirm attendance by registering for them. These sessions are included in the fee for the course, so no new payment is required, but for planning purposes, the number of people attending will need to be known in advance.

- Some courses might be offering 'add-ons' (*e.g.* a Web Development course might provide a discounted offer for a contract with a hosting provider). These are not part of the course services and if the student wishes to purchase them, then they will be able to do so at any time after they have purchased the course. Some might have an end date, as is the case with the hosting discount, some may not, *e.g.* a discounted perpetual license for a software.

- At the end of every month the system should generate a number of reports to be made available to management; these reports would include the number of users to courses, the number of enrolments (broken down by courses, qualifications, individual or corporate accounts) and the feedback for the course itself. The report's data is not saved as it can all be extracted by the information already in the database, but the system should keep information of the report's metadata (*e.g.* type of report, when created and by whom). Administrators can create those reports on demand if there is a specific request by the management. A corporate administrator will have the option to generate reports — either for individuals or collective ones, for all users on a given account.

Develop a **class** diagram for the above scenario using the appropriate naming conventions (*e.g.* class names starting with a capital letter) and suggest class attributes with name and type, as well as methods with name and return type. Illustrate associations, aggregations, and generalisation relationships between the objects. State any assumptions you make about the system.

[20]

Question 2

a) Why would you use a composite state in a state diagram? Illustrate your answer with an example.

[5]

b) Prepare an activity diagram to accommodate the specification of the LearnOnYourOwn.com system described in **Question 1** for the activity of enrolling on an individual course. The following rules apply:

- The process starts when the individual customer is logged in and selects the option for enrolling on a course.
- The system should ask the user what category the user is interested in.
- The user selects the category they are interested in.
- The system simultaneously searches for all the courses in the category selected and the courses that the user is already registered in.
- The system displays the available options to the user.
- The user selects the course that they are interested in.
- The system asks the user to confirm the choice they made.
- The user confirms their choices.
- The system loads up the payment page with all the information that the user needs to input.
- The user provides the information requested by the system.
- The system, in parallel, displays the processing page to the user and sends the information entered to the third-party payment gateway.
- If the result returned by the payment gateway is successful then the system displays the 'Thank You!' page, and an e-mail is sent out to the user confirming their module choice and informing them that they can start their learning as soon as they want.
- If the result returned by the payment gateway is not successful, then the system displays a page informing the user that something went wrong and they would need to type their details again.
- The system provides the user three attempts to type their payment information correctly. If they get it wrong three times, it is considered to be a breach of security and the system will lock the user's account.
- An e-mail will be sent out to the user explaining why this happened, and the user will have to contact the Customer Support HelpLine to get their account unlocked.

Show on the activity diagram the flow of control using specialised UML components, like activities, decisions, merges, forks and joins.

[20]

Question 3

a) Briefly explain the concept of Extreme Programming – how can it be used?

[5]

b) Prepare a use case diagram to accommodate the specification of the LearnOnYourOwn.com system specified in **Question 1**. Your answer should include all use cases, actors and any associations between different use cases, different actors or use cases and actors. State any assumptions you make about the system.

[20]

PART B: answer TWO questions

Question 4

This question focuses on abstract data types and graphical representations.

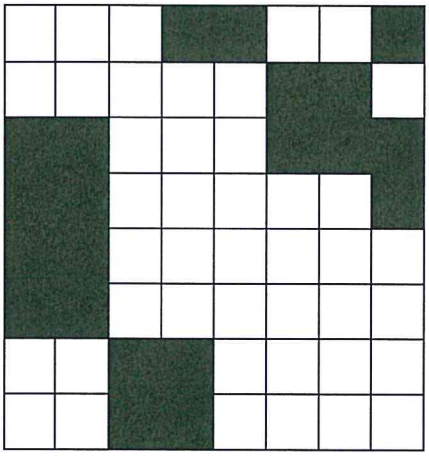
a) Using matrices as an example, distinguish between the concepts of Abstract Data Types and Data Structures. Briefly explain why the concept of an Abstract Data Type is useful in software development.

[7]

b) Describe briefly what a Quadtree is and its use.

[2]

c) Convert the pixel-grid below into a Quadtree.



[6]

d) Describe the Abstract Data Type for a Quadtree.

[5]

e) Describe how the above representation can be extended to three dimensions and state what it is called.

[2]

f) Explain what is meant by a Parameter Space representation and its advantage over Quadtrees.

[3]

Question 5

This question focuses on optimisation.

a) In the context of optimisation, what is meant by a greedy algorithm? Contrast it with an exhaustive search and give one advantage for each.

[4]

The following optimisation task is called the bin packing problem:

Given a set of objects of different volumes, $v_1, \ldots, v_n$, and a set of bins of capacity C, place the objects into the bins so that the number of bins used is as small as possible.

b) What would the optimal solution be if the capacities were 10 and the volumes were: {2,2,2,2,6,6}?

[4]

c) A greedy algorithm to get a (not necessarily) optimal solution to this problem is to go through the list of objects, placing them one-by-one in the first bin that has enough spare capacity for it. Show whether this will produce the best result with the data in part (a).

[5]

d) The bin packing problem is known to be NP Complete. Briefly explain what that means.

[4]

e) Adapt the algorithm to one that would produce an optimal solution to the data in (a) above.

[4]

f) Check to see if your adapted algorithm produces an optimal solution with the following data: the bin capacities are all 20 and the objects have volumes: 3, 8, 7, 11, 2, 9.

[4]

Question 6

This question focuses on trees, heaps and their applications.

a) Describe what is meant by the terms Binary Tree and Binary Search Tree.

[4]

b) Draw the binary search tree for the sequence below inserted from left to right.

A B C D E F G

[2]

c) What is the difference between a full and a complete tree? Is the tree from (b) full and/or complete? You will need to fully justify your answer.

[4]

d) Briefly explain how binary search works, and provide the pseudocode for its implementation. How would you use it to search for 19 in the following list of numbers?

3, 4, 5, 8, 9, 12, 17, 19, 21, 25, 29, 32, 41, 55

[8]

e) What is a binary heap? State the two main properties of a heap. Give one example of where a binary heap would be a useful data structure.

[4]

f) A binary heap can be implemented as an array. Given a heap stored on the array below, draw the heap structure as a diagram. Explain briefly how the array and tree are mapped to each other.

11 17 15 29 141 14 88 12 77

[3]

END OF PAPER