CMPS 282 — Software Engineering
SAMPLE FINAL EXAM
2 hours

Please draw a horizontal line across the page between the answers to each question

You may refer to the following during the exam:

- the course textbook

- the course lecture notes

- your homework solutions

- any notes that you have taken in class

You may **not** refer to any other materials.

Good luck!

1. (20 points)
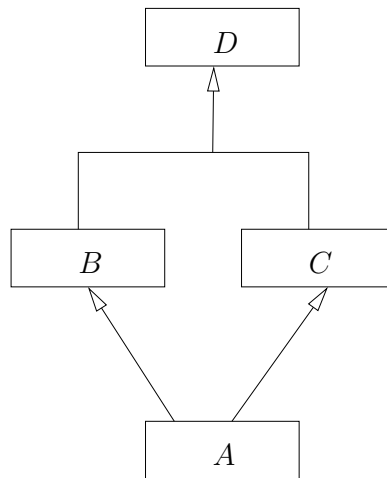
(a) (10 points) Consider the data model given in figure 1.

Figure 1: Data model for question 1 (a)

What can you say about the relationship between the sets A, B, C, and D?

Solution. From the data model graph, $A \subseteq B \subseteq C \subseteq D \subseteq A$. Hence $A = B = C = D$.

(b) (10 points) Consider the data model given in figure 2.

Consider the derived relation $r3(x, y) \triangleq (\exists z : r1(x, z) \land r2(y, z))$.

To how many elements of Y can an element of X be related to, in general?
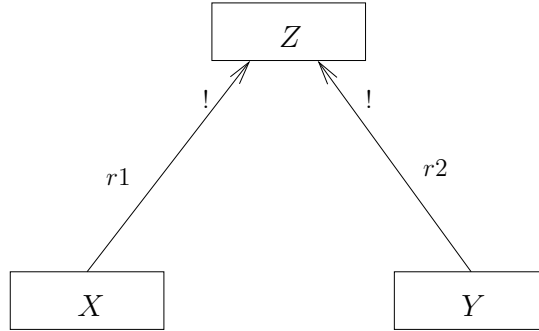
Figure 2: Data model for question 1 (b)

Solution. For each $x \in X$, there is exactly one $z \in Z$ that x is related to by $r1$. Many y can be related by $r2$ to this one z. Hence the answer is that x can be related to many y, i.e., 0 or more.

2. (20 points)

You are given the following

$takes(s, c)$ is a predicate that is true iff student s is taking course c
$level(c)$ is a function that gives the level of a student (freshman, sophomore, junior, or senior)

State the following in first order logic:

(a) (5 points) every course is taken by at least one student

Solution. $\forall c : Course \; \exists s : Student \; [takes(s, c)]$

(b) (5 points) every student takes at least two different courses

Solution. $\forall s : Student \; \exists c1, c2 : Course \; [c1 \neq c2 \wedge takes(s, c1) \wedge takes(s, c2)]$

(c) (10 points) if two students take the same course, then they are in the same level

Solution. $\forall s1, s2 : Student \; [\; (\exists c : Course \; [takes(s, c1) \wedge takes(s, c2)]) \Rightarrow level(s1) = level(s2) \;]$

3. (40 points) Consider the file system example discussed in class.

(a) (10 points) State the following constraint in logic:

No two directory entries in the system have the same contents

Solution. $\neg \exists e1, e2 : Entry \; [e1 \neq e2 \wedge e1.contents = e2.contents]$

Now suppose we wish to add links to the file system example. Assume that we now add a `Link` data type to the File system, We also add a relation `LinkName` from `Link` to `Name`, and a relation `LinkContents` from `Link` to `FSObject`. These give the name of the link, and the file system object that the link points to, respectively.

(b) (15 points)

State the following constraint in logic:

Every link points to a file system object that is reachable from the root

Solution. $\forall l : Link \; \forall o : FSObject[\; l.contents = o \; \Rightarrow \; Root \in ancestors(o) \;]$

(c) (15 points) We introduce a `deleteFile` operation that removes a file object from the system. What is an appropriate precondition for `deleteFile`? Make sure that all constraints are preserved.

The appropriate precondition is that no link points to the file. In logic:

Solution. $\forall l : Link \; [l.contents \neq f]$

4. (20 points) Let $/$ denote integer division with truncation, e.g., $11/2 = 5$. Assume that all variables are integer valued, and all ranges of quantification are over integers. Define $even(a) = (\exists b : a = 2 * b)$, $odd(a) = \neg even(a)$.

State which of the following Hoare triples are valid. Answer "valid" or "not valid" (5 points each).

(a) $\{even(y) \wedge x^y = c\} \, x := x * x; y := y/2 \, \{x^y = c\}$

Solution. valid

(b) $\{odd(y) \wedge x^y = c\} \, x := x * x; y := y/2 \, \{x^y = c\}$

Solution. not valid

(c) $\{x^y = c\} \, x := x * x; y := y/2 \, \{x^y = c\}$

Solution. not valid

(d) $\langle y > 0 \wedge odd(y)\rangle$ **while** $y \neq 0$ **do** $x := x * d; y := y - 2$ **endwhile** $\langle true \rangle$

Solution. not valid