Spring 2018 PhD Qualifying Exam in Languages

Illinois Institute of Technology

Department of Computer Science

Monday, January 29, 2018

Instructions

- This exam is closed book and closed notes. Read each problem very carefully and do all the listed problems.
- Write your exam id at the top of every page, in the indicated space.
- Write your answers only on the fronts of the pages. Wrote only within the dashed rectangles.
- Extra pages appear at the end of the exam — you may use them as extra space for answers.
- Use the back of each sheet for scratch work; you aren't allowed extra paper for scratch work.
- You may unstaple the exam, but you must return all the exam pages.
- To pass the entire exam, you must pass both halves of the exam.

Problem	Points	Score	Problem	Points	Score
1	20		4	6	
			5	5	
2	10		6	9	
			7	15	
3	20		8	15	
CS 440 Total	**50**		**CS 536 Total**	**50**	
Grand Total	**100**				

Part I: CS440

Question 1: Languages (20 points)

Please do NOT use more than three sentences to answer each of the following questions. We will NOT grade anything after the third sentence in your answer sheet.

Some languages such as Python and Java are compiled to a byte code instead machine code.

1a. [3 points] What advantages does this have? *Solution*:

1b. [3 points] What disadvantages? *Solution*:

(Closures)

1c. [3 points] What is a closure? *Solution*:

1d. [3 points] What advantages does it give a language to have them? *Solution*:

1e. [4 points] We can divide languages roughly into two classes: statically typed (e.g., Java, Haskell, C++) and dynamically typed (e.g., Lisp, Clojure, Ruby). Explain the tradeoffs between these two systems.
Solution:

1f. [4 points] Many languages support parametric polymorphism. Examples include Haskell's type variables, Java generics, and C++ templates. What advantage does parametric polymorphism give to the programmer?
Solution:

Question 2: Abstraction (10 points)

Make your answers concise and to the point. Write at most three sentences for each answer. You will lose points for excessively long-winded answers.

2a. [5 points] What is an abstract data type? (Please note, an abstract type, not an abstract class.)

Solution:

2b. [5 points] Give three distinct advantages that abstract data types provide.

Solution:

Question 3: Grammars (20 points)

Consider the following grammar:

$S \rightarrow E$ `x` | `a b`

$E \rightarrow E\ S$ | `c` S

3a. [5 points] Give the First and Follow sets for the non-terminals.

Solution:

3b. [7 points] Construct the Characteristic Finite State Machine.

Solution:

3c. [4 points] Convert the above grammar to an LL grammar, explain why it's already LL, or explain why it cannot be converted to LL.

Solution:

3d. [4 points] Is the above grammar ambiguous? Give a proof with your answer.

Solution:

Part II: CS536

Question 4: Meaning of Programs (6 points)

4a. [3 points] Let $W \equiv$ **while** `i` $\leq$ `n` **do** S **od**, where $S \equiv$ `y := y+1 ; i := i+1`, and $\sigma = \{$`i` $= 1$, `y` $= 1$, `n` $= 2\}$. Calculate $M(W, \sigma)$ (or $M[[W]](\sigma)$, depending on the notation you learned)

Solution:

4b. [3 points] Let $W \equiv$ `i := i+1 ; b[i] := b[1]+5`, and $\sigma = \{$`i` $= 0$, `b`$[0] = 3$, `b`$[1] = 4\}$. Calculate $M(W, \sigma)$.

Solution:

Question 5: Validity of Hoare Triples (5 points)

Each part below is worth a maximum of 2.5 points if correctly answered, 0 points of left unanswered, and –1 point if answered incorrectly. Let `x` be an integer variable (positive, negative, or zero). For each triple below say whether it is partially correct, totally correct, both, or neither.

5a. $\{$`x` $> 0\}$ `x := x-1` $\{$`x` $> 0\}$

Solution:

5b. $\{$`x` $< 0\}$ **while** `x` $\neq 0$ **do** `x := x+1` **od** $\{$`x` $= 0\}$

Solution:

Question 6: Deterministic and Nondeterministic wp and sp (9 points)

Calculate the weakest preconditions and strongest postconditions as requested. Please show your work.

6a. [3 points] *wp*(**if** x > 0 **then** s := x * y **else** s := -x * y **fi** {s > 0}

Solution:

6b. [3 points] *sp*(y ≥ 1, y := y+5)

Solution:

6c. [3 points] Let *p* be *wp*(*S*, *q*). Suppose also that there is a state σ that *does not* satisfy *p*, but nonetheless, running *S* in σ terminates successfully but in a memory state that *does satisfy q*. Explain how this could happen.

Solution:

Question 7: Deterministic Loop Programs (15 points)

The greatest common divider (*gcd*) of two *positive integers* x and y is the largest value that divides both x and y evenly (without remainder). For example, $gcd(30, 18) = 6$. The relevant *gcd* properties are:

- if $x > y$, then $gcd(x, y) = gcd(x-y, y)$
- if $y > x$, then $gcd(x, y) = gcd(x, y-x)$
- if $x = y$, then $gcd(x, y) = x\ (= y)$

For example, $gcd(30, 18) = gcd(12, 18) = gcd(12, 6) = gcd(6, 6) = 6$

7a. [8 points] Write the gcd(`a`, `b`) program. Include a precondition and postcondition, but omit other conditions.
Solution:

7b. [7 points] Now expand your program from the previous part into a full proof outline for total correctness.
Solution:

Question 8: Synchronization (15 points)

Consider the following concurrent program

$\{\texttt{true}\}\ \texttt{x} := 1\ \texttt{;}\ \texttt{y} := 1\texttt{;}\ \{\texttt{true}\}$

$[\ \{\texttt{true}\}\ \textbf{await}\ \texttt{y} > 0\ \textbf{then}\ \texttt{x} := 2\ \textbf{end}\ \{\texttt{x} \neq 0\}$

$\|\ \{\texttt{true}\}\ \textbf{await}\ \texttt{x} > 0\ \textbf{then}\ \texttt{y} := 2\ \textbf{end}\ \{\texttt{y} \neq 0\}\ ]\{\texttt{x} \neq 0 \wedge \texttt{y} \neq 0\}$

8a. [5 points] List all its potential deadlock predicates

Solution:

8b. [10 points] Strengthen the conditions and get an new outline that is deadlock-free. Write out the new outline and list the new potential deadlock predicates.

Solution:

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