Department of Computer Science
Core Graduate Comprehensive Exam
Spring 2019

- **Answer the questions on the paper supplied.**
- **Answer question 1 or 2. Answer question 3 or 4. Answer question 5 or 6 or 7 or 8 or 9. Answer question 10 or 11 or 12. You should answer a total of four questions. Please Note: If you answer more than one question in one group, only the one with the LOWEST score will be counted.**
- **Start each question on a new page. Write on only one side of the paper.**
- **Write your SIX-DIGIT Texas State ID in the top right corner of each page of your answer. Do NOT put your name anywhere on the answers.**
- **Put the number of the question being answered in the top left corner of each answer page. Put the CORRECT question number to avoid missing your answer.**
- **If the answer to a question is written on more than one page, number the pages consecutively.**

Group 1

1. **CS 5329 Algorithm Design and Analysis**
   { *From Dr. Hwang*}

   For the recurrence formula of Merge Sort and Max-subarray,

   ```
   T (n) =  2 T(n/2) + n    for n>1

    T(1) = 1
   ```

   (a) Derive the total running time T(n) by using Recursion Tree method, and

   (b) Derive the total running time T(n) by using Iteration method.

2. **CS 5329 Algorithm Design and Analysis**
   { *From Dr. Metsis*}

   Sorting

   The pseudocode below shows an implementation of the Quicksort algorithm.

   ```
   QUICKSORT(A, p, r)
   if p < r
      q = PARTITION(A, p, r)
      QUICKSORT(A, p, q-1)
      QUICKSORT(A, q+1, r)

   PARTITION(A, p, r)
     x = A[r]
     i = p - 1
     for j = p to r-1
       if A[j] <= x
          i = i + 1
          exchange A[i] with A[j]
          exchange A[i+1] with A[r]
     return i + 1
   ```

(a) Assume the following input array: A = <13, 19, 9, 5, 12, 8, 7, 4, 21, 2, 6, 11>
Show the state of the array A after the first call of the Partition algorithm. [10 pts]

(b) What is the worst-case and what is the expected run time computational complexity of the above algorithm? What type of input would case the worst case complexity? [5 pts]

(c) Modify the above algorithm in a way that it avoids the worst-case complexity with very high probability. Provide the pseudocode of your solution. [5 pts]

Group 2

3. **CS 5346 Advanced Artificial Intelligence**
{ *From Dr. Ali*}

(a) Consider a first- order logical knowledge base that describes worlds containing people, songs, albums. The vocabulary contains the following symbols:

- Sings (p, s, a): Album 'a' includes a recording of song 's' sung by person 'p'.
- Wrote (p, s): Person p wrote song s.
- Song (x): x is a song.
- Songs (x, y) song x is on y.
- Album (x): x is an Album.
- Recorded (x, y): x is recorded on y.
- Contains (a, b): a contains b.
- McCartney, Gershwin, Joe, The Man I Love, Revolver: Constants with the obvious meanings.

Express the following statements in first- order logic:

i. Either Gershwin or McCartney wrote "The Man I Love."
ii. Every song that McCartney sings on Revolver was written by McCartney.
iii. Gershwin did not write any of the songs on Revolver.
iv. Every song that Gershwin wrote has been recorded on some album. (Possibly different songs are recorded on different albums.)
v. There is a single album that contains every song that Joe has written.

(b) By generating truth tables, determine for each of the following sentences if it is valid, satisfiable or unsatisfiable:

i. $(\text{Smoke} \Rightarrow \text{Fire}) \Rightarrow ((\text{Smoke} \cap \text{Heat}) \Rightarrow \text{Fire})$
ii. $\text{Smoke} \cup \text{Fire} \cup \rightarrow \text{Smoke} \cup \rightarrow \text{Fire}$
iii. $(\text{Smoke} \Rightarrow \text{Fire}) \Rightarrow (\text{Fire} \Rightarrow \text{Smoke})$
iv. $P \cap (Q \cup R) \Leftrightarrow (P \cap Q) \cup (P \cap R)$

4. **CS 5391 Survey of Software Engineering**
{ *From Dr. Chen*}

Explain the following software process models and point out their pros and cons:

(a) Formal methods

(b) Agile development model

Group 3

5. **CS 5306 Advanced Operating Systems**
{ *From Dr. Tamir*} The enclosed table contains the first 21 digits of the decimal representation of Pi.

(a) Assume that the secret key is 9 and perform a digit by digit symmetric encryption on the message 9999

(b) Compute the estimated entropy of the four input digits, the four key elements, and of the four digits of the cypher.

(c) For the digits in the table produce a histogram of the digits 0 to 9 in the table.

(d) Use the histogram to compute the entropy of the digits [0-9] in the table.

Table 1 The first 21 digits of the decimal representation of Pi

```
0 3

1 1

2 4

3 1

4 5

5 9

6 2

7 6

8 5

9 3

10 5

11 8

12 9

13 7

14 9

15 3

16 2

17 3

18 8

19 4

20 6
```

6. **CS 5306 Advanced Operating Systems**
   { *From Dr. Chen* }

   Design a distributed algorithm to synchronize physical clocks in a distributed system in a room.

7. **CS 5332 Data Base Theory and Design**
   { *From Dr. Hwang*}

   For the following real world university project including information for Class, Course, Instructor, Student, and Classroom. Draw an E/R diagram by creating essential attributes for all needed information with pk's, fk's, and relationships. You may need to add additional information as needed. (The "Course" is the course in government inventory such as CS 5332; while the "Class" is in the class scheduling such as CS 5332 Fall 2016 Sec 1.)

   (Use Crow Feet Notation only; Do not choose this problem unless you are familiar with Crow Feet Notation.)

8. **CS 5332 Data Base Theory and Design**
{ *From Dr. Ngu*}

The customer database consists of the relations defined in the four tables shown below:

Customer(<u>custNo</u>, custName, state, phone)
Item(<u>itemNo</u>, ItemName, itemPrice, qtyOnHand)
Invoice(<u>invNo</u>, inDate, *custNo*)
Invitem(<u>*invNo, itemNo*</u>, qty)

Primary keys are underlined. Foreign keys are shown in italic font. Primary keys that are also foreign keys are shown in underline italic font. For example, the invNo and itemNo attributes in Invitem relation is the primary key for Invitem and is also foreign keys of tables Invoice and Item. Below are sample data from each of the above relation.

```
Customer table
--------------
custNo   custName    state     phone
211       Garcia      TX       732-555-1000
212       Parkin      NY       212-555-2000
225       Ellen       NJ       973-555-3333
239       Bayer       FL       401-555-7777

Item table
----------
itemNo     itemName   itemPrice     qtyOnHand
 1          Screw      5.00           50
 2          Nut        2.25           110
 3          Bolt       3.99           75
 4          Hammer     10.00          125
 5          Washer     6.00           300
 6          Nail       0.99           400

Invoice table
-------------
invNo      invDate        custNo
1001        05-Sep-07      212
1002        17-Sep-07      225
1003        17-Sep-07      239
1004        18-Sep-07      211
1005        21-Sep-07      212

invItem table
-------------
invNo        itemNo           qty
1001          1                5
1001          3                5
1001          5                9
1002          1                2
1002          2                3
1003          1                7
1003          2                1
1004          4                5
1005          4                10
```

Write SQL to answer the following queries:

(a) Find items which have the itemPrice between $5 and $10?

(b) Count the number of items ordered in each invoice.

(c) Find items that are cheaper than nut. You must display the itemName and the associated itemPrice. Beware that nut can be written in both upper and lower case.

(d) Find the invoices in which three or more items are ordered.

9. **CS 5310 Network and Communication Systems**
{ *From Dr. Peng*}

(a) Describe the steps and protocols used when you send an email message using a computer in CS lab to a friend of yours who uses an email server on a campus in California.

(b) Describe briefly why network layer is not an end-to-end layer.

Group 4

10. **CS 5338 Formal Languages**
{ *From Dr. Gao* }

For each of the following questions, circle all the correct statements or write "none" if none of them are correct.

(a) The correct statements are:
(a) A language can have infinite number of strings.
(b) Each string in a language must be finite.
(c) A string in a language must be non-empty.
(d) A language must be non-empty.

(b) The correct statements are:
(a) A DFSM must halt.
(b) A NDFSM must halt.
(c) A NDFSM without ε-transitions must halt.

(c) The correct statements are:
(a) A DPDA must halt.
(b) A NDPDA must halt.
(c) A NDPDA without ε-transitions must halt.

(d) The correct statements are:
(a) Let M be a DFSM. If $\varepsilon \in L(M)$, then the start state of M must be an accepting state.
(b) Let M be a DFSM. If the start state of M is an accepting state, then $\varepsilon \in L(M)$.
(c) Let M be a NDFSM. If $\varepsilon \in L(M)$, then the start state of M must be an accepting state.
(d) Let M be a NDFSM. If the start state of M is an accepting state, then $\varepsilon \in L(M)$.

(e) The correct statements are:
(a) Regular languages are closed under union.
(b) Regular languages are closed under intersection.
(c) Regular languages are closed under complement.
(d) Regular languages are closed under set difference.

(f) The correct statements are:
(a) Context free languages are closed under union.
(b) Context free languages are closed under intersection.
(c) Context free languages are closed under complement.
(d) Context free languages are closed under set difference.

(g) The correct statements are:
(a) A DTM must halt.
(b) A DTM must halt in at most $|w|$ steps.
(c) A NDTM must halt.
(d) A NDTM must halt in at most $|w|$ steps.

(h) The correct statements are:
(a) In terms of computability, DFSM = NDFSM < DPDA < NDPDA < DTM = NDTM.
(b) In terms of computability, DFSM = NDFSM < DPDA = NDPDA < DTM = NDTM.
(c) In terms of computability, DFSM < NDFSM < DPDA < NDPDA < DTM < NDTM.

(i) The correct statements are:
(a) Decidable languages are closed under union.
(b) Decidable languages are closed under intersection.
(c) Decidable languages are closed under complement.
(d) Semi-decidable languages are closed under complement.

(j) The correct statements are:
(a) SAT is the first language proved to be NP-complete.
(b) 3-SAT is the first language proved to be NP-complete.
(c) Both SAT and 3-SAT are NP-hard.

11. **CS 5318 Design of Programming Languages**
{ *From Dr. Shi*}

The following BNF specification defines the language of Roman numerals less than 1000:

```
<roman> ::= <hundreds> <tens> <units>
<hundreds> ::= <low hundreds> |  CD |  D <low hundreds> |  CM
<low hundreds> ::= e | <low hundreds>  C
<tens> ::= <low tens> |  XL |  L <low tens> |  XC
<low tens> ::= e | <low tens>  X
<units> ::= <low units> |  IV |  V <low units> |  IX
<low units> ::= e | <low units>  I
where e represents the empty string.
```

Define attributes for this grammar to carry out the two tasks:

(a) Restrict the number of X's in <low tens>, the I's in <low units>, and the C's in <low hundreds> to no more than three.

(b) Compute the decimal value of the Roman numeral defined in <roman>.
Also, decorate the parse tree for **CMVIII** to show how its decimal value is computed.

Note that you may define any other attributes needed for these tasks, but do not change the BNF grammar.

12. **CS 5351 Parallel Processing**
{ *From Dr. Burtscher*}

Assume a shared-memory parallel program that requires synchronization to avoid potential data races. Explain under which conditions a critical section, an atomic operation, or a lock can be used to eliminate the data races. Next, compare and contrast the three approaches in terms of performance, portability, and ease-of-use for the programmer.