Quizzes for General CS II (320201) Spring 2011

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For Course Purposes Only

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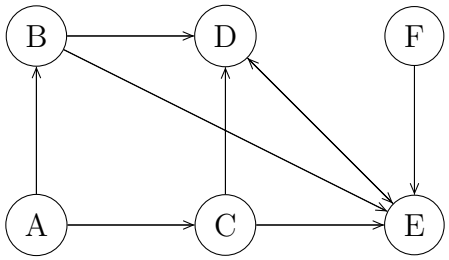
Contents

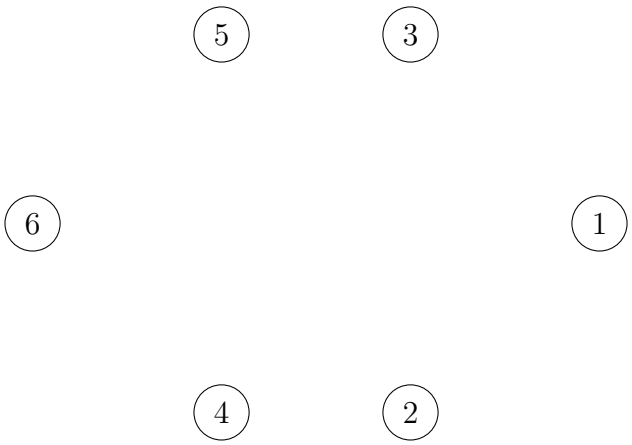
Quiz 1: Basic Graph Properties(Given Feb. 7. 2011)

12pt

Problem 1.1 (Graph Properties)
Given the digraph G below:

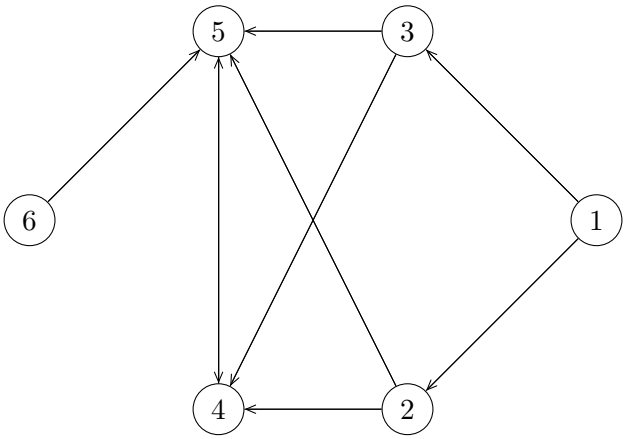


- What is the node with the highest in-degree and what is the out-degree of this node?
- Specify all the initial and terminal nodes.
- Draw the edges in the following diagram such that the result is a digraph isomorphic to G.



Solution:

- The node with the highest in-degree is E and its out-degree is 1.
- Initial nodes: A, F. Terminal node: none


5
3
6
1
4
2

Quiz 2: Binary Circuits(Given Feb. 14. 2011)

12pt

Problem 2.1 (N-ary Logic Gate)
What is the cost of implementing an n-ary logic gate (an AND/OR gate with n binary inputs)? Prove your answer!

Solution: The n-ary logic gate can be implemented as a balanced binary tree due to the associativity of the operation. A balanced binary tree with N leaves has $2N-1$ nodes (theorem), but we ignore the leaves, as they are not gates. Therefore the final number is N.

Quiz 3: Positional Number Systems(Given Feb. 21. 2011)

6pt

Problem 3.1 (Base Conversion)

Consider the following two numbers. A will be the day of your birthday, so for example for May 15^{th} you would take 15 and for April 2^{nd} you would take 02. B represents the number of the starting letter of your first name in the alphabet, so C is 3 and M is 13. Concatenate the two such that you obtain a decimal number, BA. Convert this number to hexadecimal, binary and octal representation.

Solution: The solution is dependent on each person's data, however once the binary form is deduced, the octal and hexadecimal are trivial by taking groups of three or four binary bits.

Problem 3.2 (Negative Numbers) 6pt

Give the definitions (formulas) of the following representations of negative numbers:

1. $(\langle\!\langle a_n, \ldots, a_0 \rangle\!\rangle^-)$
2. $\langle\!\langle a_n, \ldots, a_0 \rangle\!\rangle_n^{2s}$

What is the first positional number system and why was it introduced? Briefly discuss the advantages and disadvantages of each method.

Solution:

1. $\langle\!\langle a_{n-1}, \ldots, a_0 \rangle\!\rangle$ if $a_n = 0$ $-\langle\!\langle a_{n-1}, \ldots, a_0 \rangle\!\rangle$ if $a_n = 1$
2. $-a_n \cdot 2^n + \langle\!\langle a_{n-1}, \ldots, a_0 \rangle\!\rangle$

The sign-bit system was introduced in order to extend the binary number sytem such that we can support subtraction. In the first approach zero is represented twice (10000 and 00000). Second approach represents zero in an unique way. Can use adders without modifications.

Quiz 4: Assembler(Given Feb. 28. 2011)

12pt

Problem 4.1 (Assembler fun)

You are given **three** numbers placed sequentially somewhere in the memory. Let us consider that the address of the first number is found in $P(0)$.

You are required to replace $P(0)$ with the value of the sum of the three numbers.

For example, consider that you have $P(0) = x$ and $P(x) = 1$, $P(x+1) = 3$, $P(x+2) = 9$. Then, after running your program, the output should have $P(0) = 13$.

Note: It is always a good idea to comment your code!

Solution:

```
LOAD 0
MOVE ACC IN1
LOADIN 1 0
STORE 0
LOADIN 1 1
ADD 0
STORE 0
LOADIN 1 2
ADD 0
STORE 0
STOP 0
```

Quiz 5: VM(Given Mar. 7. 2011)

12pt

Problem 5.1 (A sum in $\mathcal{L}(\texttt{VM})$)
Compute the following sum in $\mathcal{L}(\texttt{VM})$ using an **iterative** approach (i.e. you may not compute the result using a formula):

$$\sum_{i=1}^{N} i \cdot (i-1)$$

You have $\mathcal{S}(0) = N$ and you should "output" the result of the sum in $\mathcal{S}(1)$. For example, for $N = 3$, your program should halt with $\mathcal{S}(1) = 8$.

Also, simulate the execution of your program (including the stack evolution), for $N = 3$.

Note: It is always a good idea to comment your code!

Solution:

```
con 0
loop: peek 0 con 1 peek 0 sub mul
add
con 1 peek 0 sub poke 0
peek 0 con 1 leq cjp 3
jp loop
halt
```

Quiz 6: VM and SW(Given Mar. 14. 2011)

6pt

Problem 6.1 (Simple While)

Write a SW program that computes the sum of the first n natural numbers **without** using the formula. You can take $n = 10$ for example.

Write your program in both abstract and concrete syntax.

Solution:

```
var n:=10; var s:=0;
while 0<=n do
 s := s+n;
 n := n-1;
end
return s;
```

```
( [("n", 10), ("s", 0)],
While(
       Leq(0, n),
       Seq([
              Assign("s", Add(Var "s", Var "n")),
              Assign("n", Sub(Var "n", Con 1))
       ]),
Var "s")
```

Please turn over

6pt

Problem 6.2 ($\mathcal{L}$(VM) procedures)

Write a $\mathcal{L}$(VM) **recursive procedure** that computes the integer value of a/b, where a is the first argument and b is the second argument.

Note: The recursive formula for integer division is:

$$div(a,b) = \begin{cases} 0 & \text{if } a < b \\ ,div(a-b,b)+1 & \text{else} \end{cases}$$

Solution:

```
div: proc 2 23
     arg 1 arg 2 leq cjp out
     arg 2 arg 2 arg 1 sub call div
     con 1 add return
out: con 0 return
```

Quiz 7: Turing Machines(Given Mar. 28. 2011)

6pt

Problem 7.1: Give a detailed description of a Turing Machine with all of its components.

Solution: A Turing Machine consists of

- An infinite tape which is divided into cells, one next to the other each cell contains a symbol from a finite alphabet $\mathcal{L}$ with $\#(\mathcal{L}) \geq 2$ and $\mathtt{0} \in \mathcal{L}$
- A head that can read/write symbols on the tape and move left/right.
- A state register that stores the state of the Turing machine.(finite set of states, register initialized with a special start state)
- An action table (or transition function) that tells the machine what symbol to write, how to move the head and what its new state will be, given the symbol it has just read on the tape and the state it is currently in.

Please turn over

6pt

Problem 7.2 (OR the Tape)

Design a TM that implements the n-ary OR operator on its tape: Started with a sequence of 0s and 1s on the tape, it writes the results at the end of this input and halts. For example, a tape with 111 on it will be transformed in 1111. Your TM needs to have at most 3 states, halting state included. Also, what you TM returns on the empty input is not important.

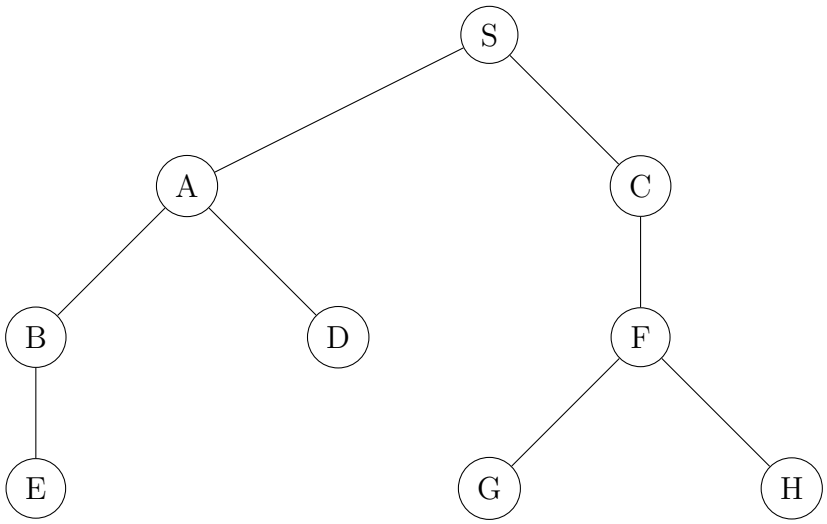
Solution:

```
1,_ H,0,>
1,1 2,1,>
1,0 1,0,>
2,_ H,1,>
2,1 2,1,>
2,0 2,0,>
```

Quiz 8: Graph Search(Given Mar. 28. 2011)

12pt

Problem 8.1 (Search Comparison)
Given the digraph G below:



- Write the sequence of nodes in the order visited by the specified methods, until node H is reached.
  1. BFS
  2. DFS
  3. IDS with step 1
- If F were the goal state, which would be the optimal choice in this case?
- Describe a state space in which iterative deepening search performs much worse than depth-first search.

Solution:

- 1. BFS: S, A, C, B, D, F, E, G, H
  2. DFS: S, A, B, E, D, C, F, G, H
  3. IDS: S; S, A, C; S, A, B, D, C, F; S, A, B, E, D, C, F, G, H.
- In this case, BFS is the best solution for finding F.
- Depth-First search strategy performs great if the solutions are dense. Consider an abstract situation where we have many possible solutions and they are roughly at the same depth. Furthermore let the solution with minimal depth be at a high depth level. Here depth-first will find a solution extremely fast while iterative-deepening will take much more time to reach the optimal solution.

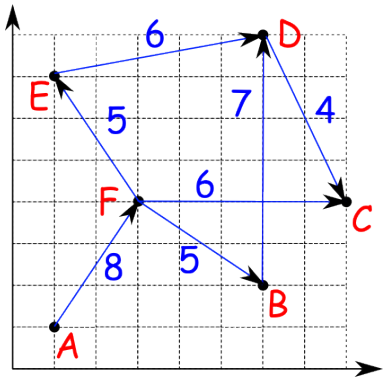
Quiz 9: General Revision(Given Apr. 04. 2011)

Quiz 10: General Revision(Given Apr. 04. 2011)

12pt

Problem 10.1 (A* on Cartesian Grid)
You are given the following set of points (nodes) on a Cartesian grid: $A(1,1)$, $B(6,2)$, $C(8,4)$, $D(6,8)$, $E(1,7)$, $F(3,4)$, and the following set of edges between them: $(A,F,8)$, $(F,B,5)$, $(F,C,6)$, $(F,E,5)$, $(E,D,6)$, $(D,C,4)$, $(B,D,7)$. The initial node is A, the goal is C.

- Design an admissible heuristic to be used for an A* algorithm for the given problem. Give the value of the heuristic applied on every node. You **do not** have to prove that it is admissible.
- Using the heuristic stated before, write down the order of access of the nodes, when A* strategy is used.



Solution:

- The easiest-to-use heuristic is the straight-line distance (we can observe that the length of the edges is always greater or equal than the planar distance between the points). We get:

$$h(A) = \sqrt{58}$$
$$h(B) = \sqrt{26}$$
$$h(C) = \sqrt{0}$$
$$h(D) = \sqrt{20}$$
$$h(E) = \sqrt{58}$$
$$h(F) = \sqrt{5}$$

- Using this heuristic, we will visit the nodes in the following order:

$$A, F, C$$

Quiz 11: Internet Basics(Given May 02. 2011)

6pt

Problem 11.1 (Information Units)
Write down the following quantities of information in order of their size:

- 0.1 Exabytes
- 1025 Kilobytes
- 100 Gigabytes
- 5 Zettabytes
- 1 Megabyte
- 10 Petabytes

Solution:
1 Megabyte < 1025 Kilobytes < 100 Gigabytes < 10 Petabytes < 0.1 Exabytes < 5 Zettabytes.

Problem 11.2 (Internet Protocol Suite) 6pt

What is the *Internet Protocol Suite*? Define its structure as detailed as possible.

Solution: The Internet Protocol Suite is the set of communications protocols used for the Internet and other similar networks. It is structured into four layers, namely

- the Application Layer
- the Transport Layer
- the Internet Layer
- the Link Layer

An application uses a set of protocols to send its data down the layers, being further encapsulated at each level.

Quiz 12: Internet(Given May 09. 2011)

6pt

Problem 12.1 (Ports and hosts)
Please answer the following questions:

1. What is a port? Why are they needed in networking?
2. What is a hostname? What is DNS used for?

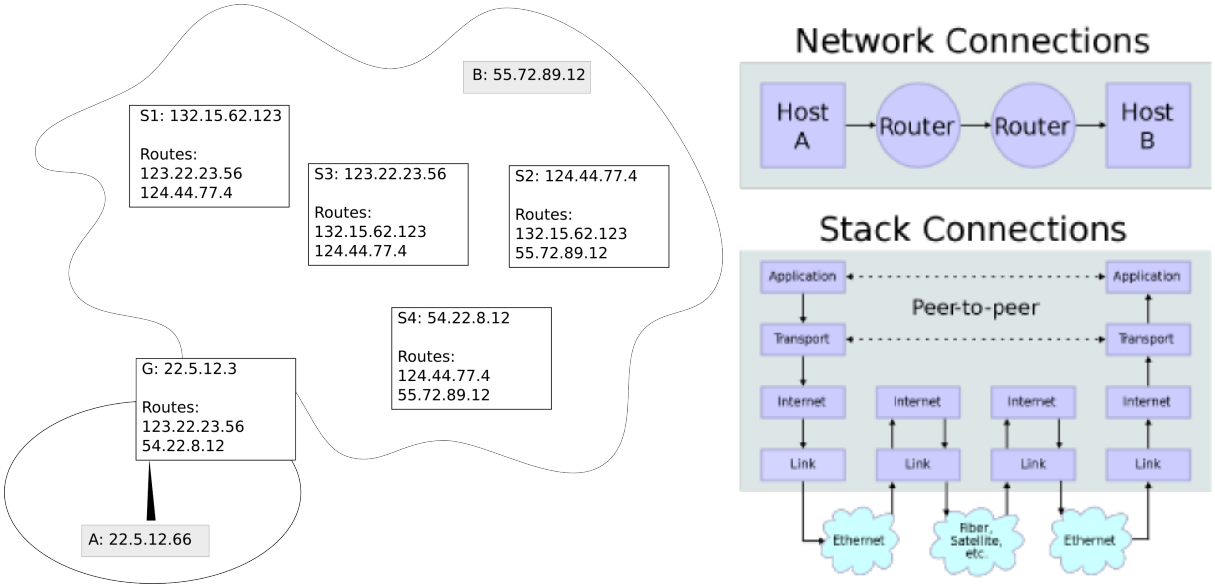
Solution:

1. A port is a number assigned to each protocol and service in the application layer. They are used to permit different connections to the same machine.
2. A hostname is a specific string which is easy to remember and which identifies the company whose site is accessed. DNS servers receive requests to translate such strings to IP addresses because connections (and routing) is only possible via IP addresses. Moreover, there might be several hostnames which resolve to the same IP address.

Problem 12.2 (Routing packets) 6pt

You are given the following network/internet configuration. You are sending a packet from A (IP 22.5.12.66) to B (IP 55.72.89.12).

1. Write **two** possible paths that a packet might go from A to B.
2. Using the model below (right), **shortly** describe which stages the packet has to go through from application layer on A to application layer on B and what happens at each layer.



Solution:

1. Path 1: A, G, S3, S2, B

   Path 2: A, G, S4, B

2. At A, the packet will go down from the application layer to the physical link, while at B it will go up from link to application layer. At each routing hop, the packet only goes up to Internet layer, where, based on the destination IP, is decided where the packet is routed.

   The Application layer generates the packet, the Transport layers adds a header (for example, packet number for oredring), the Internet layer adds the IP addresses (source, destination), ports etc., and the Link transforms it to bits and transports it through the wire.

Note: This is the long version of the explanation, written with bullet points would take less and would be faster to write.

Quiz 13: Seach Engines(Given May 16. 2011)

12pt

Problem 13.1 (Search Engine Theory)
Please answer the following questions:

1. What is a web crawler? Describe the motivation behind its creation and its exact working mechanism.
2. What types of search engines can you enumerate? Please offer a short description and one example for each case.
3. Define your own ranking formula to be used for websearch in a large database that takes into account at least two factors. Your formula does not need to be highly efficient and comparable to what the industry uses, however it should use the correct ingredients and should provide the proper behavior. State why you consider your formula to be the correct choice.

Solution:

1. A web crawler is a program that browses the WWW for the purpose of information gathering. It does so in an orderly manner, by: reading the web page, reportings its home, finding hyperlinks and following them.
2. Search engines can be:
   (a) Human-organized, categorized by experts, accurate in search results: Open Directory
   (b) Computer-created, using software spiders that crawl the web, searching large databases: Google
   (c) Hybrid, combining the above
   (d) Metasearch, directing queries to multiple search engines and cluster results: Copernic
3. The formula should be increasing, using factors such as number of hyperlinks to it, the number of important websites hyperlinking to it number of hits in the recent period etc.
