

6.034 Quiz 2

15 October 2014

Name	
Email	

Circle your TA (**for 1 extra credit point**), so that we can more easily enter your score in our records and return your quiz to you promptly.

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Problem number	Maximum	Score	Grader
1	50		
2	50		
Total	100		

SRN	6		
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There are 15 pages in this quiz, including this one. As always, open book, open notes, open just about everything, including a calculator, but no computers.

Problem 1: Identification of Trees (50 points)

Part A: Identification Trees (28 points)

While walking along the Charles River in the fall, your friend points out six trees and tells you whether they are Maple or Oak trees. Eager to identify other trees yourself, you observe what appear to be their key features. In particular, you record whether each tree **Has leaves (Yes or No)**, whether it has **Orange foliage (Yes or No)**, its **Leaf shape (Pointy or Rounded)**, and its **Bark texture (Glossy, Furrowed, or Smooth)**. Your resulting training data is summarized in the table below:

Tree type	Has leaves*	Orange foliage	Leaf shape	Bark texture
Oak	Yes	Yes	Pointy	Glossy
Oak	Yes	No	Pointy	Furrowed
Oak	Yes	No	Rounded	Furrowed
Maple	Yes	Yes	Pointy	Furrowed
Maple	Yes	Yes	Pointy	Smooth
Maple	Yes	No	Pointy	Smooth

*Although some trees lose their leaves in the fall, all six of these trees still have leaves.

A1 (4 points) Based on these six training points, order the four feature tests (**Has leaves**, **Orange foliage**, **Leaf shape**, and **Bark texture**) from least to greatest disorder. (You don't need to show your calculations; you may use your intuition. If you prefer not to use your intuition, see part A2 below.) Break any ties alphabetically.

LEAST DISORDER

GREATEST DISORDER

A2 (8 points) Next, compute the disorder of each feature test. Use the table of logarithms below to express your answer as sums and products of decimals and fractions only. Your final answer should have **no logarithms** in it. Space is provided on the next page to show your work.

Test	Has leaves	Orange foliage	Leaf shape	Bark texture
Disorder				

$$-\left[\frac{1}{2}\log_2\frac{1}{2} + \frac{1}{2}\log_2\frac{1}{2}\right] = 1$$

$$-\left[\frac{2}{5}\log_2\frac{2}{5} + \frac{3}{5}\log_2\frac{3}{5}\right] \approx 0.97$$

$$-\left[\frac{1}{3}\log_2\frac{1}{3} + \frac{2}{3}\log_2\frac{2}{3}\right] \approx 0.9$$

$$-\left[\frac{1}{4}\log_2\frac{1}{4} + \frac{3}{4}\log_2\frac{3}{4}\right] \approx 0.8$$

$$-\left[\frac{1}{5}\log_2\frac{1}{5} + \frac{4}{5}\log_2\frac{4}{5}\right] \approx 0.72$$

$$-\left[\frac{1}{6}\log_2\frac{1}{6} + \frac{5}{6}\log_2\frac{5}{6}\right] \approx 0.65$$

Show your disorder calculations for partial credit. For your convenience, a copy of the training data is provided on the next page.

Has leaves

Orange foliage

Leaf shape

Bark texture

A3 (14 points)

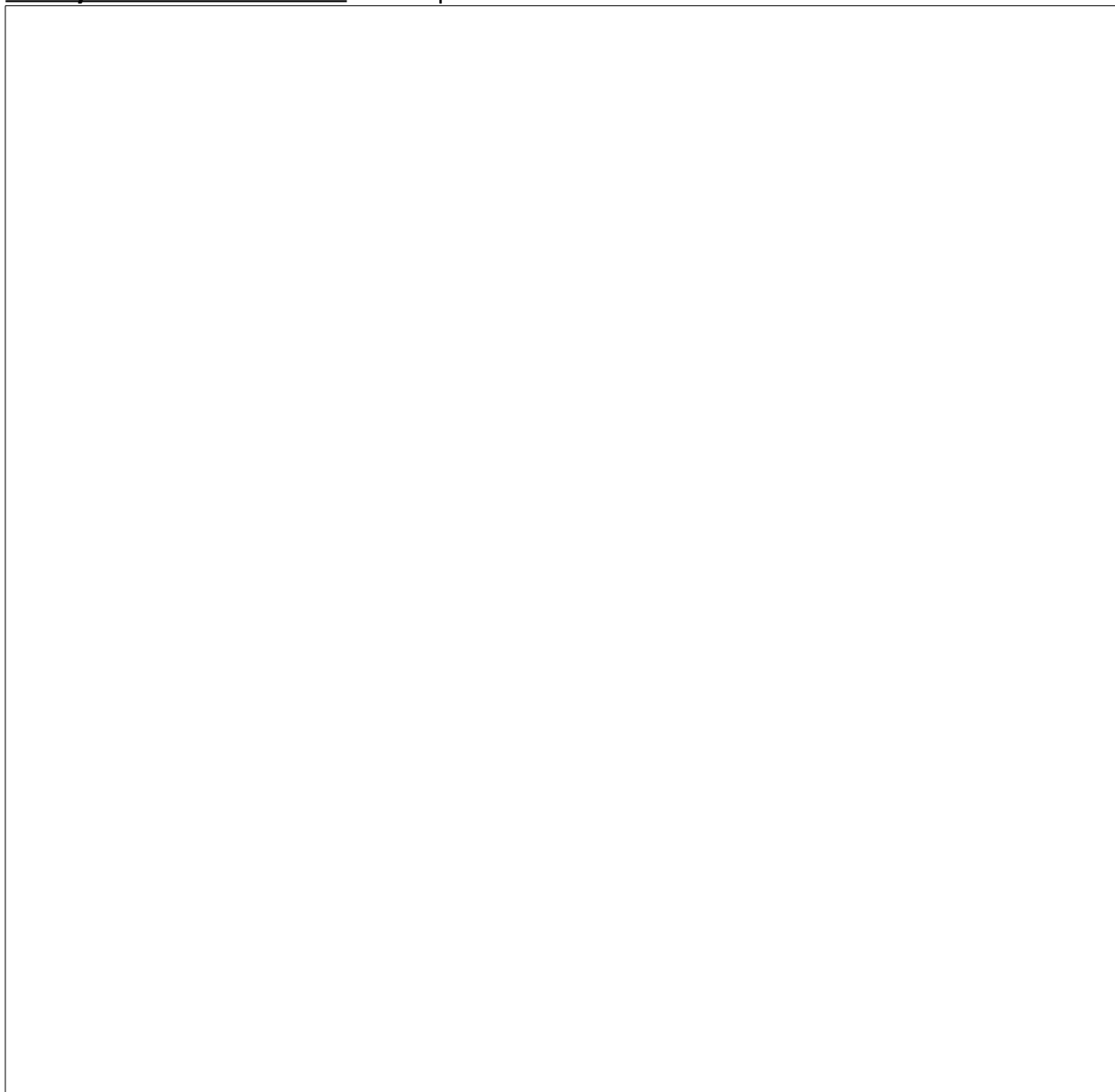
Choosing from the four feature tests (**Has leaves**, **Orange foliage**, **Leaf shape**, and **Bark texture**), construct the complete disorder-minimizing identification tree for classifying the training data as Maple or Oak.

(For your convenience, a copy of the training data is included here.)

Tree type	Has leaves*	Orange foliage	Leaf shape	Bark texture
Oak	Yes	Yes	Pointy	Glossy
Oak	Yes	No	Pointy	Furrowed
Oak	Yes	No	Rounded	Furrowed
Maple	Yes	Yes	Pointy	Furrowed
Maple	Yes	Yes	Pointy	Smooth
Maple	Yes	No	Pointy	Smooth

*Although some trees lose their leaves in the fall, all six of these trees still have leaves.

Draw your identification tree in the space below:



Additional space provided for disorder calculations, if you need it.

A4 (2 points)

How would your identification tree classify a specimen with the following features?

Has leaves	Orange foliage	Leaf shape	Bark texture
Yes	Yes	Rounded	Furrowed

Circle one:

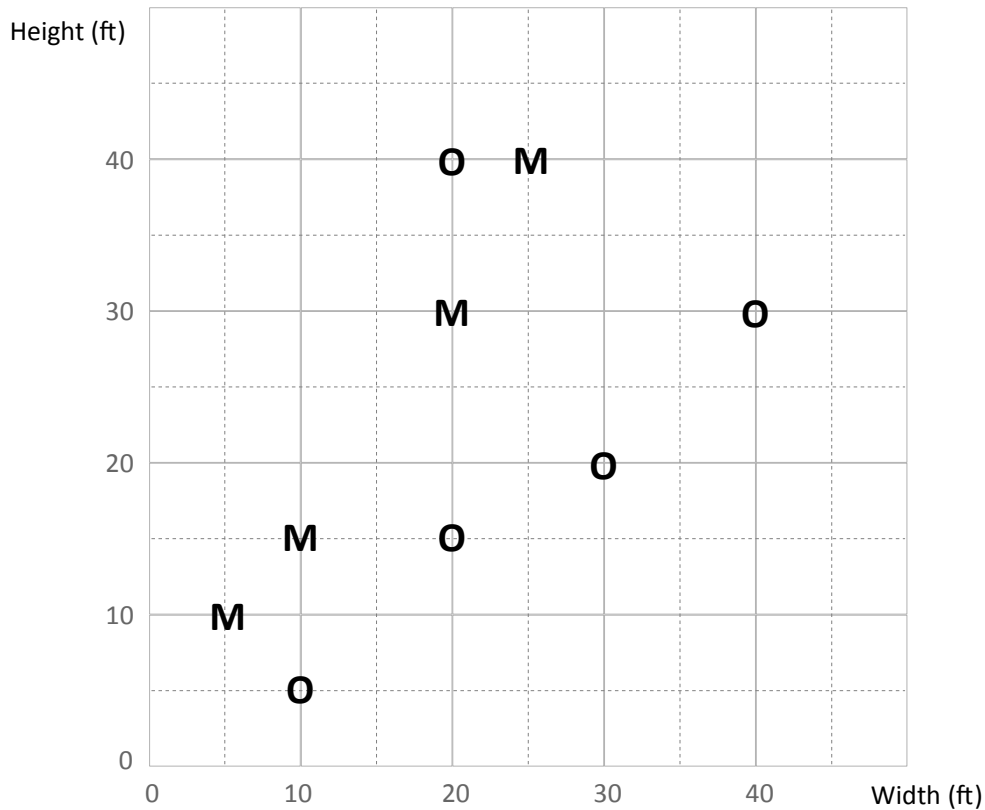
MAPLE

OAK

CAN'T TELL

Part B: Nearest neighbors (22 points)

You plan to go out and identify more trees the next day, but that night there is an early snowstorm! To your dismay, you find that a blanket of snow has obscured the leaves and bark of all the trees, so you can no longer use those as distinguishing features. Undaunted, you decide to venture out into the fresh snow and use trigonometry to measure the width and height of trees that are known to be Maple (M) or Oak (O). Your measurements are plotted on the following graph:



B1 (12 points) On the graph above, draw the decision boundaries produced by 1-Nearest Neighbors.

B2 (8 points) One of your classmates hears that you've been identifying trees. She wants to know what type of tree is knocking snow onto her second-story windowsill, so she calls you with the information that her tree is **25 ft wide** and **32 ft tall**. How would this tree be classified with each of the following classifiers? (Circle the best answer in each case.)

1-Nearest Neighbors?	MAPLE	OAK	CAN'T TELL
3-Nearest Neighbors?	MAPLE	OAK	CAN'T TELL
5-Nearest Neighbors?	MAPLE	OAK	CAN'T TELL
9-Nearest Neighbors?	MAPLE	OAK	CAN'T TELL

B3 (2 points) Finally, you want to use Nearest Neighbors to classify the pre-snowstorm data in Part A. You realize it's possible, but you must first: (Circle the **one** best answer.)

- (A) Pick just two of the features to plot.
- (B) Define a distance metric for non-numeric features.
- (C) Collect twice as many training points.
- (D) Use cross-validation to guarantee overfitting.
- (E) Devise an admissible heuristic.

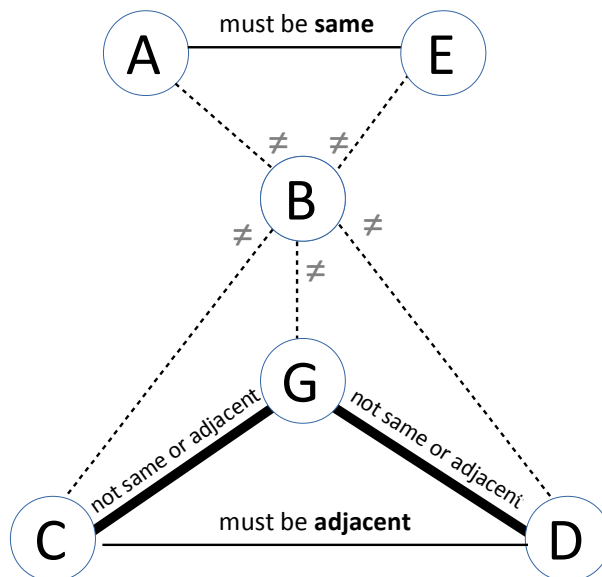
Problem 2: Dominion Domiciles (50 points)

Six powerful mages (**A**jani, **B**olas, **C**handra, **D**ack, **E**lspeth, and **G**ideon) have enlisted you to help them settle down and find homes in the multiverse. They have five neighboring worlds to choose from, arranged in a row as shown. Some worlds could be empty, and some worlds could have more than one occupant.



Naturally, mages are very particular about where they live, so your assignments must satisfy the following requirements:

1. **A**jani is **E**lspeth's mentor. They must live on the **same world**.
2. Everyone hates **B**olas. No one can live on the same world as him.
3. **C**handra wants to spy on **D**ack secretly—she must live on a world that's **adjacent to** **D**ack's world.
4. **G**ideon is a law mage. He despises the criminals **C**handra and **D**ack so much that **G**ideon **cannot live on the same world—or even on a world adjacent to** **C**handra's or **D**ack's.



(For your convenience, a graph of these constraints is shown here.)

Finally, the mages inform you that you can simplify the domains of these variables, as follows:

- **D**ack **must live on either World 1 or 4**, because he's a wanted criminal everywhere else.
- **E**lspeth **must live on World 3**, because she's stuck there and cannot leave.
- **B**olas **can't live on World 5**, because he fears its strange magic.

Thus, the initial domains of your variables are as follows:

A	1	2	3	4	5
B	1	2	3	4	
C	1	2	3	4	5
D	1			4	
E			3		
G	1	2	3	4	5

Part A. Prestidigitation (9 points)

A1 (3 points) In general (not just on this problem), when you are solving constraint satisfaction problems, which of the following strategies can require you to backtrack? (Circle **all answers** that apply.)

- (A) Depth-first search (check assignments only)
- (B) Depth-first search with forward checking
- (C) Depth-first search with forward checking and propagation through singleton domains.
- (D) Depth-first search with forward checking and propagation through reduced domains.
- (E) None of the above methods ever require backtracking.

A2 (6 points) Consider just three of the mages: **A**jani, **B**olas, and **C**handra. In what order should you assign values to them so that constraint propagation will be maximally efficient? Write their initials (**A, B, C**) in the order they should be assigned below:

Assign 1 st	Assign 2 nd	Assign 3 rd

Part B. Homelands (35 points)

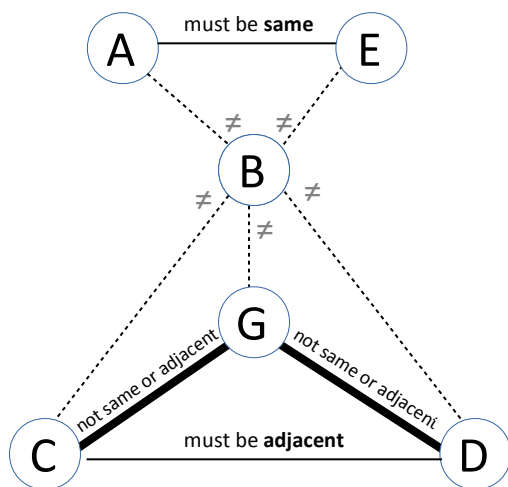
Regardless of your earlier answers, the stubborn mages insist that you assign variables in the order **A, E, D, B, G, C**. Use **depth-first search with forward checking and propagation through singleton domains (domains reduced to size 1)** to find worlds for the six mages.

- ★ On the next two pages, show your work by simultaneously
 - (1) filling out the domain worksheet and
 - (2) drawing the search tree.

☆ For your convenience, a **duplicate** copy of the domain worksheet and tree is provided on pages 12-13.

If you write on both copies, please indicate clearly which one you want us to grade.

Constraint graph for this problem



Domains for this problem

(Do not reduce these domains before starting search.)

A	1	2	3	4	5
B	1	2	3	4	
C	1	2	3	4	5
D	1			4	
E			3		
G	1	2	3	4	5

Fill out this worksheet as you draw your search tree. There may be more rows than you need.

- Every time you **assign a variable** or **remove a variable from the propagation queue**, fill out a new row in the table. (The same variable might appear in more than one row, especially if you have to backtrack.)
- In that row, indicate **which variable you assigned or de-queued**; write its **assigned** value if it has one (e.g. $X=x$), otherwise just write its **name** (X). In the second column, list the **values that were just eliminated from neighboring variables** as a result. If no values were just eliminated, write **NONE** instead.
- If your search has to backtrack after assigning or de-queuing a variable: first, **finish listing** all values eliminated from neighboring variables in the current row. Next, check the “backtrack” box in that row. Then, continue with the next assignment in the following row as usual.
- If you add several variables to your propagation queue at once, break ties by adding variables to your propagation queue **in alphabetical order**.

	Var assigned or de-queued	List all values just eliminated from neighboring variables	Back track		Var assigned or de-queued	List all values just eliminated from neighboring variables	Back track
1			<input type="checkbox"/>	8			<input type="checkbox"/>
2			<input type="checkbox"/>	9			<input type="checkbox"/>
3			<input type="checkbox"/>	10			<input type="checkbox"/>
4			<input type="checkbox"/>	11			<input type="checkbox"/>
5			<input type="checkbox"/>	12			<input type="checkbox"/>
6			<input type="checkbox"/>	13			<input type="checkbox"/>
7			<input type="checkbox"/>	14			<input type="checkbox"/>

Example row showing an assigned variable

ex	X = 3	Y ≠ 3, 4	Z ≠ 3	(example)	<input checked="" type="checkbox"/>
----	-------	----------	-------	-----------	-------------------------------------

Example row showing a de-queued (propagated) variable

ex	X	W ≠ 1, 4	(example)	<input type="checkbox"/>
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Draw your search tree on this page.

A 1 2 3 4 5

E

D

B

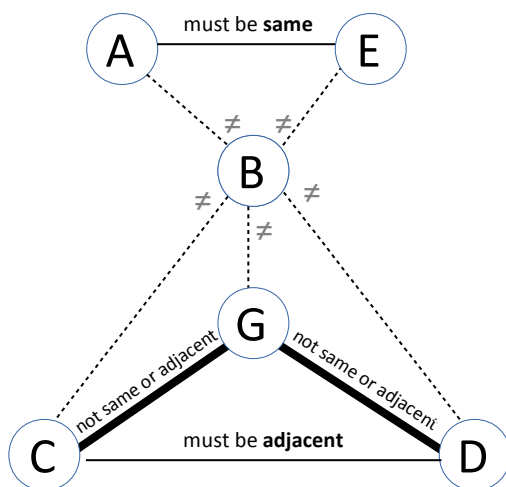
G

C

Note: This is a duplicate page provided for your convenience. Use this copy only if you want to start over. There are more questions on pages 14-15.

I want to start over; grade these pages.

Constraint graph for this problem



Domains for this problem

(Do not reduce these domains before starting search.)

A	1	2	3	4	5
B	1	2	3	4	
C	1	2	3	4	5
D	1			4	
E			3		
G	1	2	3	4	5

	Var assigned or de-queued	List all values just eliminated from neighboring variables	Back track		Var assigned or de-queued	List all values just eliminated from neighboring variables	Back track
1			<input type="checkbox"/>	8			<input type="checkbox"/>
2			<input type="checkbox"/>	9			<input type="checkbox"/>
3			<input type="checkbox"/>	10			<input type="checkbox"/>
4			<input type="checkbox"/>	11			<input type="checkbox"/>
5			<input type="checkbox"/>	12			<input type="checkbox"/>
6			<input type="checkbox"/>	13			<input type="checkbox"/>
7			<input type="checkbox"/>	14			<input type="checkbox"/>

Example row showing an assigned variable

ex	X = 3	Y ≠ 3, 4	Z ≠ 3	(example)	<input checked="" type="checkbox"/>
----	-------	----------	-------	-----------	-------------------------------------

Example row showing a de-queued (propagated) variable

ex	X	W ≠ 1, 4	(example)	<input type="checkbox"/>
----	---	----------	-----------	--------------------------

[This is a duplicate copy provided for your convenience.]
Draw your search tree on this page.

A 1 2 3 4 5

E

D

B

G

C

Part C (6 points)

C1 (3 points) Based on the results of your search in Part B, write the initials of the mages (**A, B, C, D, E, G**) in their assigned homes among the five worlds.



(If no solution exists, circle NO SOLUTION instead.)

NO SOLUTION

C2 (3 points) Based only on the tree you drew in Part B, what can you conclude about the number of solutions to this problem (i.e. consistent ways of assigning mages to worlds)?

- (A) There are **no solutions** to this problem—it's over-constrained.
- (B) There is **exactly one** solution to this problem.
- (C) There is **at least one** solution to this problem, maybe more.
- (D) There is **definitely more than one** solution to this problem.

Problem 3: Spiritual and Right-Now

Circle the **one best** answer for each of the following question. There is **no penalty for wrong answers**, so it pays to guess in the absence of knowledge.

1. Sussman is motivated by a desire to understand:

1. How English emerged from Germanic and French roots.
2. How to write more secure software.
3. How to write provably correct software.
4. How thinking works.
5. How to treat autism.

2. Sussman's explanation of propagators featured an example involving:

1. How stories change in time as they are retold.
2. Fast implementation of rule chaining.
3. Calculating the distance to a galaxy.
4. Proving a program to be correct.
5. Tweets.

3. In Sussman's propagator system, cells:

1. Pass on information distorted by a random number generator.
2. Perform complex logical operations using table lookup.
3. Achieve great speed by using multiple cores.
4. Hold information about values, rather than values.
5. Have values that reflect cultural beliefs.

4. Boyden describe how rats can be:

1. Trained to stand on two legs.
2. Respond to light without normal retinal photoreceptors.
3. Rendered vicious by cauterization of areas in the forebrain.
4. Shown to dream about movement through a familiar maze.
5. Made obese by electrical stimulation of brain areas associated with hunger.

5. Boyden described a procedure involving direct electrical stimulation of brain tissue so as to:

1. Cure chronic indigestion.
2. Suppress disturbing memories.
3. Recall childhood experiences.
4. Stop hand tremors.
5. Reduce symptoms associated with Tourette's syndrome.

6. Optogenetics has to do with:

1. Evolution of the mammalian visual system.
2. Optimization of brain circuitry by survival of the fittest.
3. Optical stimulation of genetically altered neurons.
4. Manipulation of the genetic code using lasers.
5. Poor visual acuity associated with old age.