6.034 Quiz 2

October 21, 2020

You have 24 hours from 10am, October 21, 2020 to complete the quiz. Quizzes should take on average about 1-2 hours.

This quiz is open book and open notes. You may NOT use the Internet or other people.

Updates and clarifications will be posted to a pinned Piazza post for this quiz. You may send private Piazza posts to the instructors to ask for clarification.

There will be no audio uploads.

Instructions and tear-off sheets are pages 1-6. The actual quiz is from page 7.

You can resubmit the quiz as many times as you want on Gradescope before the quiz closes.

Gradescope

When logging into Gradescope, log in with the institution (MIT), rather than creating an account.

The workflow in Gradescope will be very similar to the workflow in Quiz 1, just on a different platform. You will still download a single PDF template of the quiz (with optional tear-offs). Your quiz submission will still be a single PDF or multiple camera images, just on Gradescope. **You must now, however, designate on Gradescope which pages of your submission correspond to which questions on the quiz.**

Here are three methods of submitting the quiz:

1. Edit the PDF electronically e.g. Adobe Acrobat, Preview (OS X), Notability (OS X/iOS). These are just examples--you are free to use whatever PDF editing tool you want. Acrobat and Notability are free for MIT students.
2. Print out the PDF, write your answers, and scan/take pictures.
3. Write your answers on a blank sheet of paper, making sure to label your answers clearly. Scan/take pictures.

Tear-off sheet

We do not collect tear-off sheets, so please show your work on the quiz pages, not the tear-off sheet.

Rules and Assertions for Problem 1 (Rules) Part A

Rules:

P0	IF `'You ask` **`(?x)`** `for permission to use the car'` THEN **`'(?x)`** `says to ask` **`(?y)'`**
P1	IF **`'(?a)`** `says to ask` **`(?b)'`** THEN `'You ask` **`(?b)`** `for permission to use the car'`

Assertions:

A0: 'You ask Dad for permission to use the car'

A1: 'Boris is super annoying'

A2: 'No one is currently using the car'

Forward chaining assumptions:

- When multiple rules match, rule-ordering determines which rule fires.
- New assertions are added to the bottom of the list of assertions.
- If a particular rule matches in more than one way, the matches are considered in the top-to-bottom order of the matched assertions. Thus, if a particular rule has an antecedent that matches both A1 and A2, the match with A1 is considered first.
- Consider variables to bind in alphabetical order. Here, the two possible things to bind are Boris and Dad.

Tear-off sheet

We do not collect tear-off sheets, so please show your work on the quiz pages, not the tear-off sheet.

Rules and Assertions for Problem 1 (Rules) Part B

Rules:

P0	IF OR('**(?x)** feels bad after tricking **(?z)**', '**(?x)** had an unhappy childhood', '**(?x)** is in love with **(?y)**'), THEN '**(?x)** is not a psychopath'
P1	IF '**(?a)**'s mom was mean', THEN '**(?a)** had an unhappy childhood'
P2	IF AND('**(?x)** is in love with **(?y)**', '**(?x)** tricks **(?y)**', '**(?x)** is a professional assassin'), THEN '**(?x)** feels bad after tricking **(?y)**'
P3	IF '**(?x)** tries to poison **(?y)**', THEN '**(?x)** is in love with **(?y)**'
P4	IF OR('**(?a)** wasn't allowed to eat ice cream', '**(?a)** was sent to boarding school'), THEN '**(?a)**'s mom was mean'

Assertions:

A0: 'Eve tries to poison Villanelle'

A1: 'Villanelle tries to poison Eve'

A2: 'Villanelle grew up in an orphanage'

A3: 'Villanelle is a professional assassin'

Backward chaining assumptions:

- The backward chainer tries to find a matching assertion in the list of assertions. If no matching assertion is found, the backward chainer tries to find a rule with a matching consequent. In case no matching consequents are found, the backward chainer concludes that the hypothesis is false.
- The backward chainer never alters the list of assertions.
- Rules and antecedents are tried in the order they appear.
- Short circuiting is in effect.

Tear-off sheet

We do not collect tear-off sheets, so please show your work on the quiz pages, not the tear-off sheet.

Rules and Assertions for Problem 1 (Rules) Part C

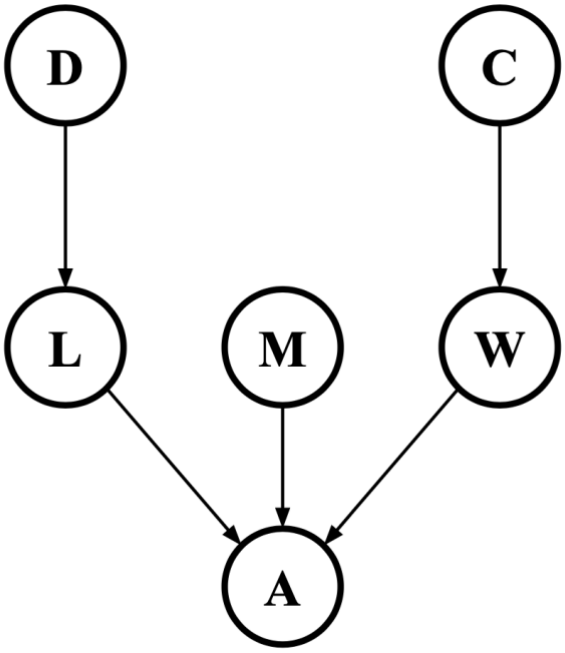
Rules:

P0	IF NOT('**(?x)** wins the popular vote'), THEN '**(?x)** loses the popular vote'
P1	IF AND(OR('**(?x)** wins the popular vote', '**(?x)** loses the popular vote'), '**(?x)** wins the electoral college')), THEN '**(?x)** wins the election'

Tear-off sheet

We do not collect tear-off sheets, so please show your work on the quiz pages, not the tear-off sheet.

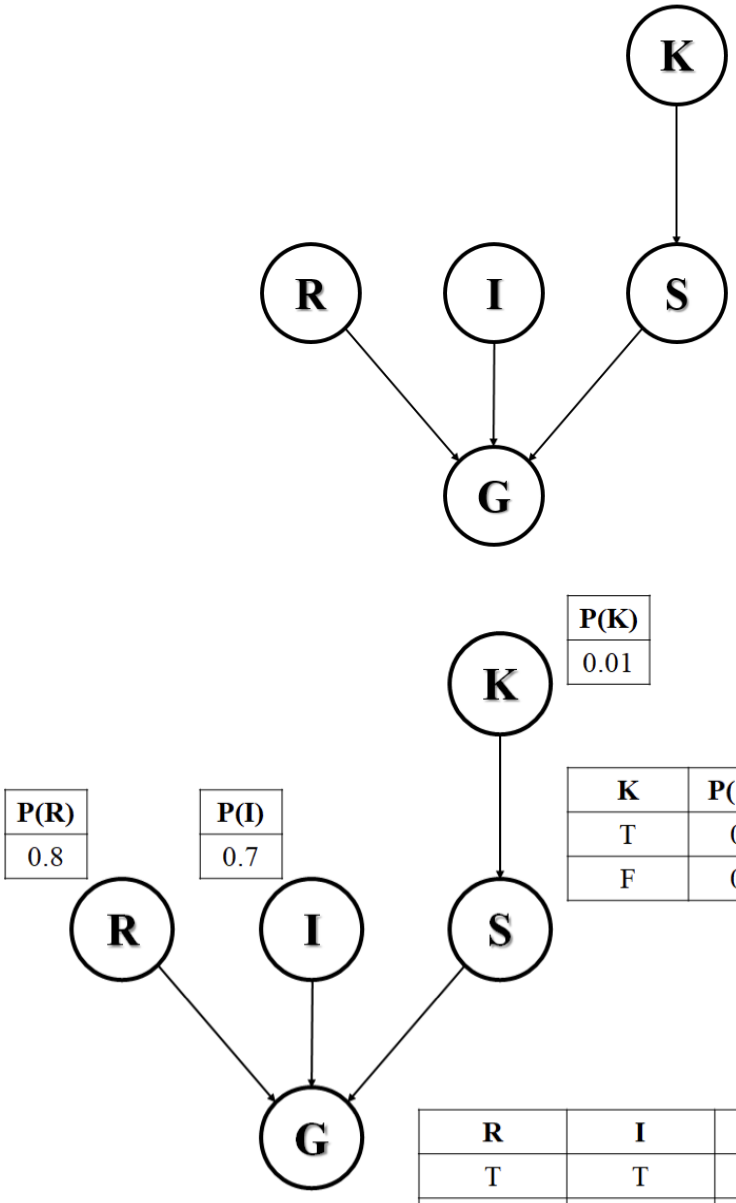
Bayes Net for Problem 2 (Bayes) Part A



Tear-off sheet

We do not collect tear-off sheets, so please show your work on the quiz pages, not the tear-off sheet.

Bayes Net for Problem 2 (Bayes) Part B



K	P(S|K)
T	0.9
F	0.6

R	I	S	P(G|I,R,S)
T	T	T	0.95
T	T	F	0.7
T	F	T	0.6
T	F	F	0.2
F	T	T	0.8
F	T	F	0.7
F	F	T	0.4
F	F	F	0.1

Quiz 2, Problem 1 Rules (50 points):

Part A: Forward Chaining (10 points)

You vehemently desire to go to the beach with your friends, but you need to get permission to use the family car. You can get permission from either your dad or your older brother, Boris. You start by asking your dad.

You have the following two rules and three assertions:

Rules:

P0	IF `'You ask` **`(?x)`** `for permission to use the car'` THEN **`'(?x)`** `says to ask` **`(?y)'`**
P1	IF **`'(?a)`** `says to ask` **`(?b)'`** THEN `'You ask` **`(?b)`** `for permission to use the car'`

Assertions:

A0: 'You ask Dad for permission to use the car'

A1: 'Boris is super annoying'

A2: 'No one is currently using the car'

Forward chaining assumptions:

- When multiple rules match, rule-ordering determines which rule fires.
- New assertions are added to the bottom of the list of assertions.
- If a particular rule matches in more than one way, the matches are considered in the top-to-bottom order of the matched assertions. Thus, if a particular rule has an antecedent that matches both A1 and A2, the match with A1 is considered first.
- Consider variables to bind in alphabetical order. Here, the two possible things to bind are Boris and Dad.

1.1 (8 points) You sense that something is wrong with the above two rules but you're not sure what. You decide to try **Forward Chaining**. Fill out the table below.

Perform Forward Chaining until you either get permission or no more rules fire.

Iter	Matched	Fired	New Assertion(s)
1			
2			
3			
4			
5			
6			
7			
8			

1.2 (2 points) Will you get permission to use the car?

YES NO

Why or why not? *Explain in* ***less than 10 words.***

Part B: Backward Chaining (17 points)

Eve is a bored, whip-smart security services operative whose job behind a desk does not fulfill her fantasies of being a spy. Villanelle is a mercurial, talented assassin who clings to the luxuries her violent job affords her. These two women, equally obsessed with each other, go head to head in a game of cat and mouse.

You are a friend of Eve, and you want to make sure that she has not fallen in love with a psychopath.

You have the following rules and assertions:

Rules:

P0	IF OR('**(?x)** feels bad after tricking **(?z)**', '**(?x)** had an unhappy childhood', '**(?x)** is in love with **(?y)**'), THEN '**(?x)** is not a psychopath'
P1	IF '**(?a)**'s mom was mean', THEN '**(?a)** had an unhappy childhood'
P2	IF AND('**(?x)** is in love with **(?y)**', '**(?x)** tricks **(?y)**', '**(?x)** is a professional assassin'), THEN '**(?x)** feels bad after tricking **(?y)**'
P3	IF '**(?x)** tries to poison **(?y)**', THEN '**(?x)** is in love with **(?y)**'
P4	IF OR('**(?a)** wasn't allowed to eat ice cream', '**(?a)** was sent to boarding school'), THEN '**(?a)**'s mom was mean'

Assertions:

A0: 'Eve tries to poison Villanelle'

A1: 'Villanelle tries to poison Eve'

A2: 'Villanelle grew up in an orphanage'

A3: 'Villanelle is a professional assassin'

Backward chaining assumptions:

- The backward chainer tries to find a matching assertion in the list of assertions. If no matching assertion is found, the backward chainer tries to find a rule with a matching consequent. In case no matching consequents are found, the backward chainer concludes that the hypothesis is false.
- The backward chainer never alters the list of assertions.
- Rules and antecedents are tried in the order they appear.
- Short circuiting is in effect.

2.1 (14 points) Using the above rules and assertions, perform backward chaining starting from the hypothesis:

```
Villanelle is not a psychopath
```

In the table below, write all of the hypotheses that the backward chaining algorithm checks, **in the order they are checked.** (The first line has been filled in for you; you may have more lines than you need.) Write an X in the backtracked column if checking that hypothesis during that step results in backtracking.

On the next page, draw the corresponding goal tree that would be created by backward chaining from this hypothesis. Feel free to abbreviate Villanelle as V and Eve as E.

Hypotheses checked in backward chaining.	**Backtracked?**
H1. `Villanelle is not a psychopath`	
H2.	
H3.	
H4.	
H5.	
H6.	
H7.	
H8.	
H9.	
H10.	
H11.	

Draw your goal tree here.

Villanelle is not a psychopath

2.2 (3 points) What is the difference between forward and backward chaining, in general?
Explain in ***less than two sentences.***

Part C: Rule Logic Manipulation (14 points)

Election logic

The US Election board wants you, a 6.034 student, to use your rule-based systems expertise to help make the electoral process less confusing.

Rules:

P0	IF NOT('**(?x)** wins the popular vote'), THEN '**(?x)** loses the popular vote'
P1	IF AND(OR('**(?x)** wins the popular vote', '**(?x)** loses the popular vote'), '**(?x)** wins the electoral college')), THEN '**(?x)** wins the election'

3.1 (2 points) Combine and simplify the two rules P0 and P1 into one rule called P2.

P2

Your simplification should not change the result of any election, so **one of your tasks is to show that P2 from above is logically consistent with P0 & P1, which we'll call rule set P01.** To be logically consistent means that each rule set always comes to the same conclusion about the truth of a hypothesis.

Ex: P4 and P56 are logically consistent with respect to A7: 'it is raining' and H7: 'the ground is wet'

```
P4  IF  'it is raining', THEN 'the ground is wet'
P5  IF  'it is raining', THEN 'water is falling from the sky'
P6  IF  'water is falling from the sky', THEN 'the ground is wet'
```

Possible sets of assertions for the task:

S0: A0: Gore wins the popular vote
A1: Gore loses the electoral college

S1: A0: Perot gets 18% of the popular vote
A1: Perot loses the electoral college

S2: A0: Bush did not win the popular vote
A1: Bush wins the electoral college

S3: A0: Obama wins the popular vote
A1: Obama wins the electoral college

Hypothesis:

H0: **(?x)** wins the election

3.2 (2 points) For both rule set P01 and rule P2, which sets of assertions make H0 true? Select all that apply.

a. S0
b. S1
c. S2
d. S3

3.3 (2 points) For both rule set P01 and rule P2, which sets of assertions make NOT(H0) true? Select all that apply.

a. S0
b. S1
c. S2
d. S3

3.4 (2 points) More generally, given a set of rules (R0, R1, … RN) and a hypothesis (J0), is it possible to have a set of assertions that makes both J0 and NOT(J0) true? Why or why not?

3.5 (6 points) The president of the Election Board is skeptical that simplifying the rules works, and she is questioning your answer to C1. You must go before the Supreme Court and justify one of your claims. You need to prove that the original rules and your rule are logically consistent with respect to one set of assertions.

- Choose one of the sets of assertions that results in H0 being true
- Perform Forward Chaining with P01
- Perform Forward Chaining with P2

3.5.1 Forward chaining using P01

Circle the set of assertions you are holding true: [S0 S1 S2 S3]

Iter	Matched	Fired	New Assertion(s)
1			
2			
3			

3.5.2 Forward chaining using P2

Circle the set of assertions you are holding true: [S0 S1 S2 S3]

Iter	Matched	Fired	New Assertion(s)
1			
2			
3			

3.5.3 Are P01 and P2 logically consistent? In other words, given a set of starting assertions, will each rule set always come to the same conclusion about the truth of H0? Why or why not?

Part D: Rule Writing (9 points)

Soft Pretzel Day at The Office!

Today is Soft Pretzel Day at the TV show The Office, and you want to show off your rule-based system skills by writing some rules about possible pretzel toppings.

Possible antecedents and consequents are of the following form:

```
'Pretzel is topped with X'
'Pretzel is topped with Y'
'Z is happy'
```

Here is an example of a rule that describes a situation:

Stanley will be happy if his pretzel has mustard on it. This rule describes the situation.

Rule:

```
P0   IF   'Pretzel is topped with mustard'
     THEN 'Stanley is happy'
```

4.1 (3 points) To be happy, the bold and brazen Michael Scott wants every available topping on his pretzel. Because he is the boss, he has more options for toppings: mustard, cinnamon sugar, cotton candy, and chocolate sauce. Using the example rule as a guide, write a rule to describe the situation where Michael Scott is happy.

4.2 (6 points) Creed is very particular. He only wants one topping. He will be happy if he gets just mustard or just cinnamon sugar, but will not be happy if he gets both toppings or neither topping. Using the example rule as a guide, write a rule to describe the situation where Creed is happy.

Quiz 2, Problem 2 Bayes (50 points):

Part A: Virtual Movie Night (27 points)

You miss hanging out with your friends in 6.034, so you decide to host a virtual movie night. Since all good movie nights involve food, you want to send each of the attendees a small care package with their favorite snacks. In order to avoid overspending by buying snacks for friends who can't make it, you come up with the idea to calculate the probability that each of your friends can **A**ttend (**A**=True). You take into account the following variables:

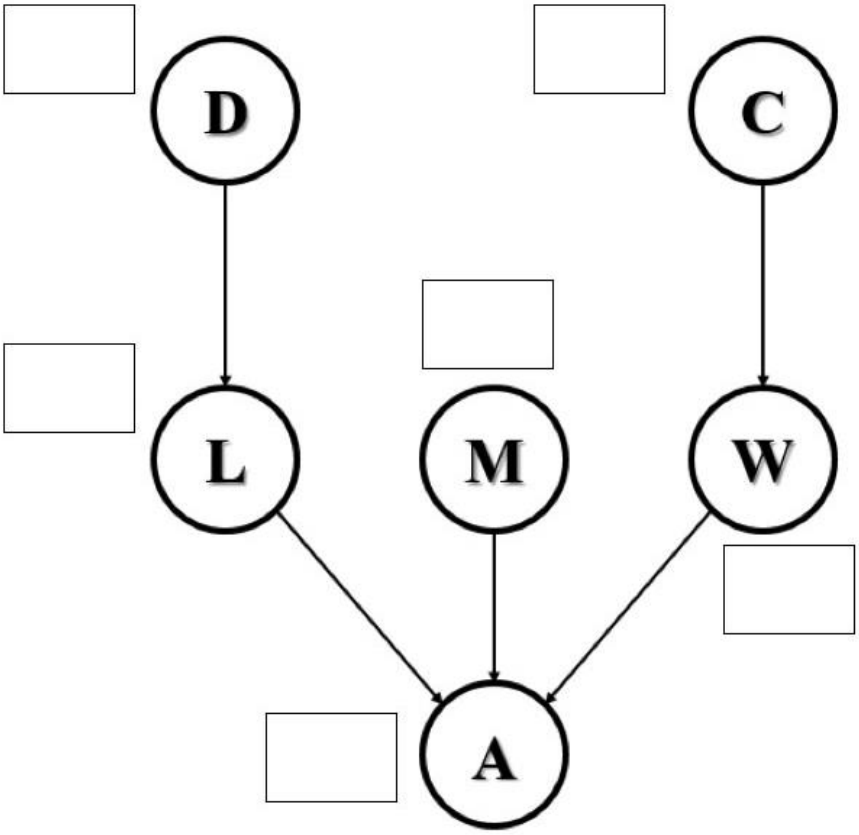
- **D:** What type of **D**ay the movie night is hosted {Weekday, Weekend}
- **M:** Your friend's favorite **M**ovie genre {Action, Comedy, Drama, Horror}
- **L:** There is a 6.034 **L**ab due the next day {True, False}
- **C:** How many other **C**lasses your friend is taking {< 3, 3, > 3}
- **W:** Your friend has a lot of **W**ork for their other classes {True, False}

Some factors will make your friends more likely to attend while others make them less likely to attend. You friends are more likely to attend if the movie night being hosted on a weekend (**D**=Weekend), if it features a scary movie (**M**=Horror), if they don't have a 6.034 lab due the next day (**L**=False), if they are taking 3 or fewer classes (**C**<=3), and if they don't have a lot of work for their other class (**W**=False).

5.1 (3 points)
Without making any assumptions about independence, how many parameters do you need in your joint probability table?

5.2 (6 points)

You realize while planning that some of the factors are dependent on the others and construct the following Bayes net:



Write in the boxes of the Bayes net provided above with the number of parameters needed to encode the conditional probability table for each node.

Write in the box provided below with how many parameters are needed in total for this Bayes net.

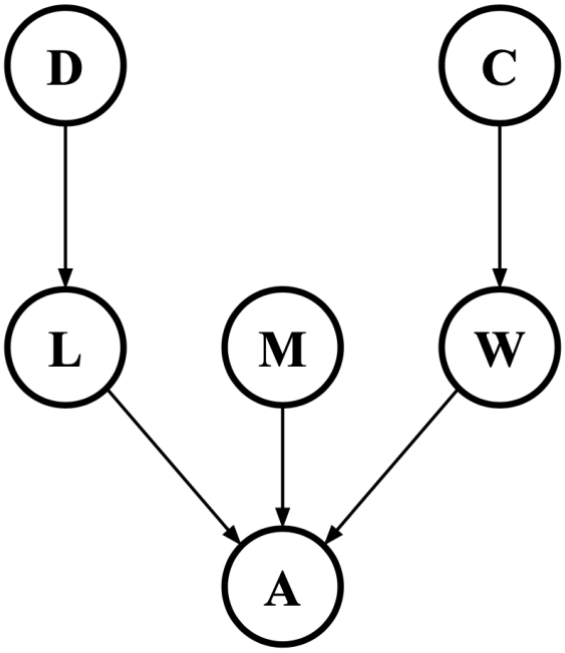
5.3 (6 points)

A friend of yours who took 6.034 last year offers to help you plan. Using the chain rule together with the information provided by the Bayes' net above, they calculate:

```
P(A,C,D,L,M,W) = P(A|C,D,L,M,W)*P(C|D,L,M,W)*P(D|L,M,W)*
                 P(L|M,W)*P(M|W)*P(W)
```

Is your friend's expansion the most efficient one for computing **`P(A,C,D,L,M,W)`** given the Bayes' Net Assumption? Explain why or why not. If your friend's expansion can be improved, how would you do so?

For problems 5.4-5.6, refer to this copy of the Bayes net. Circle one answer per question. Only select TRUE if the statement is <u>guaranteed</u> to be true.



5.4 (4 points)

TRUE FALSE `P(A|W,C)` can be described with fewer terms

For partial credit on 5.4, show your work here:

5.5 (4 points)

TRUE FALSE

```
P(W=True | A=True) = P(W=True | A=True, L=False)
```

For partial credit on 5.5, show your work here:

5.6 (4 points)

TRUE FALSE

```
P(D=Weekend | A=True) < P(D=Weekend | A=True, W=True)
```

For partial credit on 5.6, show your work here:

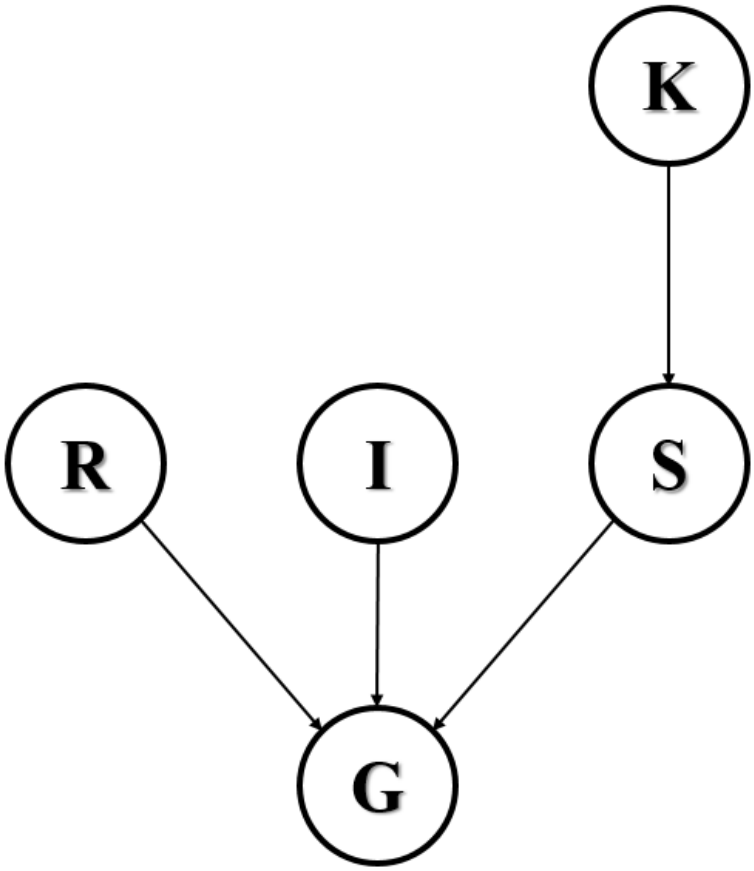
Part B: Movie Critics (23 points)

Your friends are excited for movie night, and you have decided to watch the latest film by the award-winning actress and director Kyla. After finishing the movie, you and your friends discuss what factors make a movie good or bad.

You decide that the probability of a movie being **G**ood (**G**=True) is influenced by the variables:

- **I**: the plot is **I**nteresting {True, False}
- **R**: it has a reasonable **R**untime {True, False}
- **S**: it has a **S**tellar cast {True, False}
- **K**: it features **K**yla (as the lead, of course) {True, False}

Factors that make a movie more likely to be good (**G**=True) are: an Interesting plot (**I**=True), a Reasonable runtime (**R**=True), a Stellar cast (**S**=True), and featuring Kyla (**K**=True). Based on these variables you construct the following Bayes net:



6.1 (5 points)

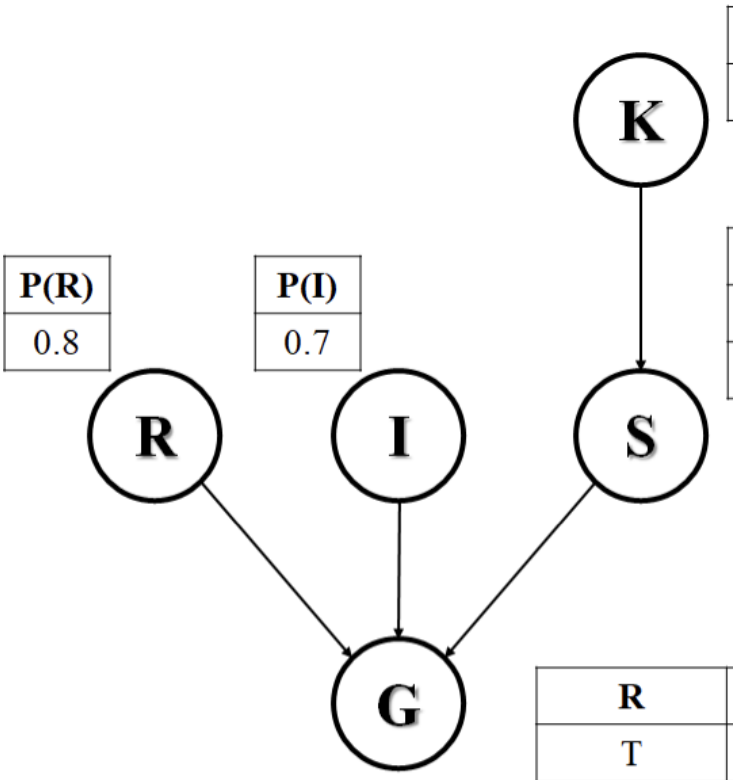
List all variables that are structurally independent of **K** based on the Bayes net above.

For partial credit on 6.1, show your work here:

6.2 (3 points)

What is the difference between structural and numerical independence?

After doing some research, you establish the probabilities shown in the Bayes net below.
Use this Bayes net to answer problems 6.3-6.5.



R	I	S	P(G|I,R,S)
T	T	T	0.95
T	T	F	0.7
T	F	T	0.6
T	F	F	0.2
F	T	T	0.8
F	T	F	0.7
F	F	T	0.4
F	F	F	0.1

6.3 (5 points)

What is the probability that a movie has a **S**tellar cast, `P(S)`?

For partial credit on 6.3, show your work here:

6.4 (5 points)

Due to quarantine restrictions, fewer movies are being made and released. However, Kyla is also a gifted voice actor and has continued to star in animated movies. The probability of a movie featuring Kyla as lead has increased to `P(K) = 0.2`. What is the new probability that a movie has a **S**tellar cast, `P(S)`?

For partial credit on 6.4, show your work here:

6.5 (5 points)

For your next movie night, you are planning to watch a movie that has an **I**nteresting plot and **S**tellar cast, but it does not feature **K**yla as the lead. What is the probability that the movie is **G**ood?

`P(G=True | I=True, S=True, K=False)`

For partial credit on 6.5, show your work here: