# Review

# Final Exam Logistics

Wednesday, May 18 at 12:15PM

- 2 hours
- In the classroom
- 1 handwritten cheat sheet (front and back) with your name
- 30% of grade

# Final Exam – 30 points total

5 points

- Search (Informed and Uninformed), heuristics, Hill Climbing
- Constraint Satisfaction Problems
- Adversarial Search

# Final Exam – 30 points total

25 points

- First-Order Logic, Conversion to CNF, Resolution
- Default Reasoning:  given a KB and default rules, what can we conclude?
- Planning:  The Frame Problem, PDDL
- Uncertainty:  Joint and Conditional Probabilities, Independence, Bayes' rule, Bayes nets
- Machine Learning:
  - Naïve Bayes Classification, Laplace Smoothing
  - Perceptron, Neural Nets
  - Nearest Neighbor
  - Clustering: K-means
  - Decision Trees

# Review: First Order Logic

$\forall x\ CSMajor(x) \wedge Took(x, CS146) \Rightarrow \exists y\ Faculty(y) \wedge Advisor(y, x)$

What does this mean in English?

What's the scope of the universal quantifier $\forall x$?

$\forall x\ (CSMajor(x) \wedge Took(x, CS146) \Rightarrow \exists y\ Faculty(y) \wedge Advisor(y, x))$

What's the scope of the existential quantifier $\exists y$?

$\forall x\ (CSMajor(x) \wedge Took(x, CS146) \Rightarrow \exists\ y\ (Faculty(y) \wedge Advisor(y, x)))$

What implies what?

$\forall x\ ((CSMajor(x) \wedge Took(x, CS146)) \Rightarrow (\exists\ y\ (Faculty(y) \wedge Advisor(y, x))))$

# Review: CNF

$\forall x\ ((\text{CSMajor}(x) \wedge \text{Took}(x, \text{CS146})) \Rightarrow (\exists y\ (\text{Faculty}(y) \wedge \text{Advisor}(y, x))))$

Step 1: Replace $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$

$\forall x\ (\neg(\text{CSMajor}(x) \wedge \text{Took}(x, \text{CS146})) \vee (\exists y\ (\text{Faculty}(y) \wedge \text{Advisor}(y, x))))$

Step 2: Move ¬ inwards: replace $\neg(P \wedge Q)$ with $\neg P \vee \neg Q$

$\forall x\ ((\neg\text{CSMajor}(x) \vee \neg\text{Took}(x, \text{CS146})) \vee (\exists y\ (\text{Faculty}(y) \wedge \text{Advisor}(y, x))))$

Step 3: Standardize variables. Nothing to change.

# Review: CNF

$\forall x ((\neg CSMajor(x) \vee \neg Took(x, CS146)) \vee (\exists y (Faculty(y) \wedge Advisor(y, x))))$

Step 4: Skolemize. Each existential variable is replaced by a Skolem function of the enclosing universally quantified variable.

$\forall x ((\neg CSMajor(x) \vee \neg Took(x, CS146)) \vee (\exists y (Faculty(y) \wedge Advisor(y, x))))$

$\forall x((\neg CSMajor(x) \vee \neg Took(x, CS146)) \vee ((Faculty(F(x)) \wedge Advisor(F(x), x))))$

Step 5: Drop universal quantifiers.

$((\neg CSMajor(x) \vee \neg Took(x, CS146)) \vee ((Faculty(F(x)) \wedge Advisor(F(x), x))))$

Is this CNF?

# Review: CNF

(¬CSMajor(x) V ¬Took(x, CS146)) V (Faculty(F(x)) ∧ Advisor(F(x), x))

Step 6: Distribute V over ∧. A V (B ∧ C) is (A V B) ∧ (A V C)

(¬CSMajor(x) V ¬ Took(x, CS146)) V (Faculty(F(x)) ∧ Advisor(F(x), x))

((¬CSMajor(x) V ¬Took(x, CS146)) V (Faculty(F(x))∧(¬CSMajor(x) V ¬Took(x, CS146)) V Advisor(F(x), x))

(¬CSMajor(x) V ¬Took(x, CS146) V Faculty(F(x))∧ ¬CSMajor(x) V¬ Took(x, CS146) V Advisor(F(x), x))

# Machine Learning in Hollywood

Our goal is to predict whether a script/book will lead to a blockbuster movie.

Our training data set contains:

- 8 scripts/books – we know which ones turned out to be blockbuster movies (commercial success).
- 2 reviewers reading the scripts.

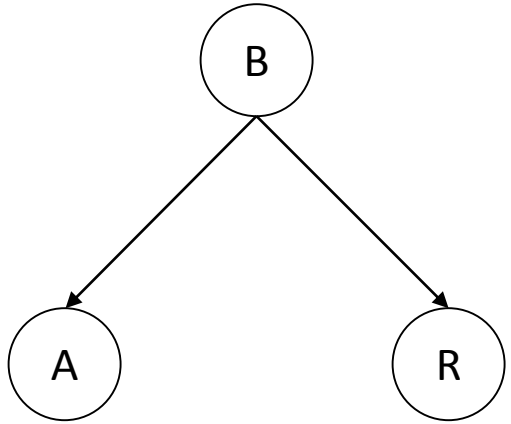
# Naïve Bayes

| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | T  | T  | T $$$$$ |
| Zootopia | T  | F  | T $$$$$ |
| San Andreas | F  | T  | T $$$$$ |
| The Pets Take Over | F  | T  | F ¢ |
| Fieldtrip to Mars | F  | F  | F ¢ |
| Forever | F  | F  | F ¢ |
| Still Here | F  | T  | F ¢ |
| A Happy Robot | F  | T  | F ¢ |

# Naïve Bayes

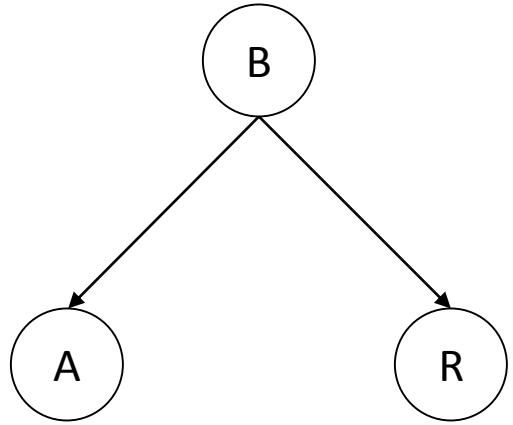
| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | T | T | T $$$$$ |
| Zootopia | T | F | T $$$$$ |
| San Andreas | F | T | T $$$$$ |
| The Pets Take Over | F | T | F ¢ |
| Fieldtrip to Mars | F | F | F ¢ |
| Forever | F | F | F ¢ |
| Still Here | F | T | F ¢ |
| A Happy Robot | F | T | F ¢ |

A: Anna likes the script
R: Ryan likes the script
B: the movie is a blockbuster



# Naïve Bayes - Learning

| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | T | T | T $$$$$ |
| Zootopia | T | F | T $$$$$ |
| San Andreas | F | T | T $$$$$ |
| The Pets Take Over | F | T | F ¢ |
| Fieldtrip to Mars | F | F | F ¢ |
| Forever | F | F | F ¢ |
| Still Here | F | T | F ¢ |
| A Happy Robot | F | T | F ¢ |




We need to learn:

P(+a|+b) = 2/3

P(+r|+b) = 2/3

P(+a|-b) = 0

P(+r|-b) = 3/5

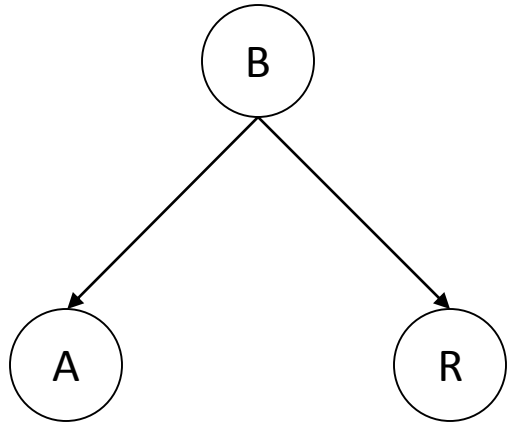
P(+b) = 3/8

# Naïve Bayes - Classification

P(+b) = 3/8

P(+a|+b) = 2/3
P(+a|-b) = 0

P(+r|+b) = 2/3
P(+r|-b) = 3/5




We have a new book that Anna likes and Ryan does not like. Should we make a movie?

P(+b|+a, -r)?

$$P(+b|+a,-r) = \frac{P(+b,+a,-r)}{P(+a,-r)} = \frac{P(+b,+a,-r)}{P(+b,+a,-r)+P(-b,+a,-r)}$$

P(+b, +a, -r) = P(+b).P(+a|+b).P(-r|+b) = …

P(-b, +a, -r) = P(-b).P(+a|-b).P(-r|-b) = 0

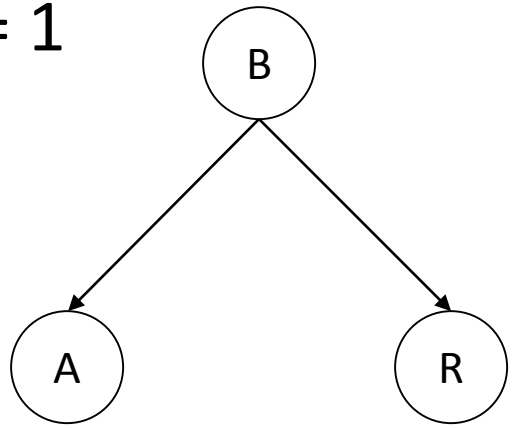
P(+b|+a, -r) = 1 and P(-b|+a, -r) = 0

What is the problem here?

# Naïve Bayes with Laplace Smoothing

| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | T | T | T $$$$$ |
| Zootopia | T | F | T $$$$$ |
| San Andreas | F | T | T $$$$$ |
| The Pets Take Over | F | T | F ¢ |
| Fieldtrip to Mars | F | F | F ¢ |
| Forever | F | F | F ¢ |
| Still Here | F | T | F ¢ |
| A Happy Robot | F | T | F ¢ |

k = 1




$$P_L(+b) = \frac{3+1}{8+2} = \frac{4}{10}$$

$$P_L(+a|+b) = \frac{2+1}{3+2} = \frac{3}{5}$$

$$P_L(+a|-b) = \frac{0+1}{5+2} = \frac{1}{7}$$

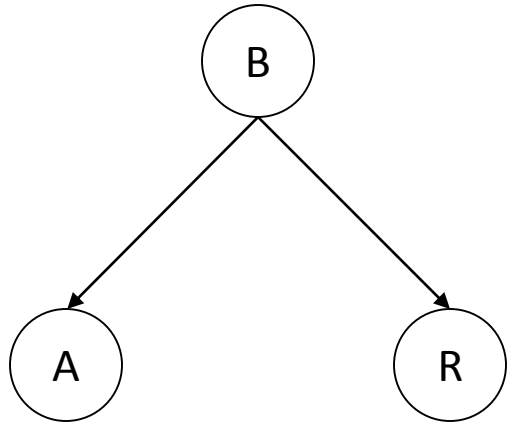
$$P_L(+r|+b) = \frac{2+1}{3+2} = \frac{3}{5}$$

$$P_L(+r|-b) = \frac{3+1}{5+2} = \frac{4}{7}$$

# Naïve Bayes Laplace Smoothing

$P_L(+b) = \frac{2}{5}$ $P_L(+a|+b) = \frac{3}{5}$ $P_L(+r|+b) = \frac{3}{5}$

$P_L(+a|-b) = \frac{1}{7}$ $P_L(+r|-b) = \frac{4}{7}$




We have a new book that Anna likes and Ryan does not like. Should we make a movie?

P(+b|+a, -r)?

$$P(+b|+a,-r) = \frac{P(+b,+a,-r)}{P(+a,-r)} = \frac{P(+b,+a,-r)}{P(+b,+a,-r)+P(-b,+a,-r)}$$

$$P(+b,+a,-r) = P(+b).P(+a|+b).P(-r|+b) = \frac{2}{5}.\frac{3}{5}.\frac{2}{5} = \frac{12}{125}$$

$$P(-b,+a,-r) = P(-b).P(+a|-b).P(-r|-b) = \frac{3}{5}.\frac{1}{7}.\frac{3}{7} = \frac{9}{245}$$

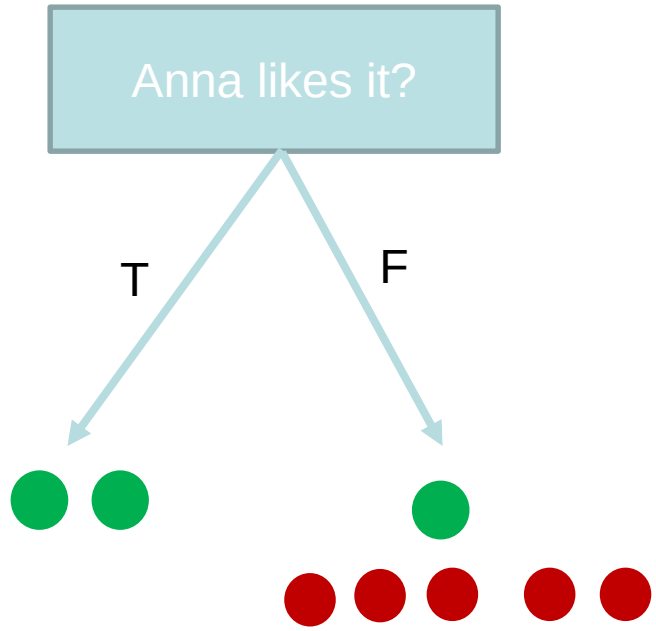
P(+b|+a, -r) = 0.72

# Decision Tree

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |

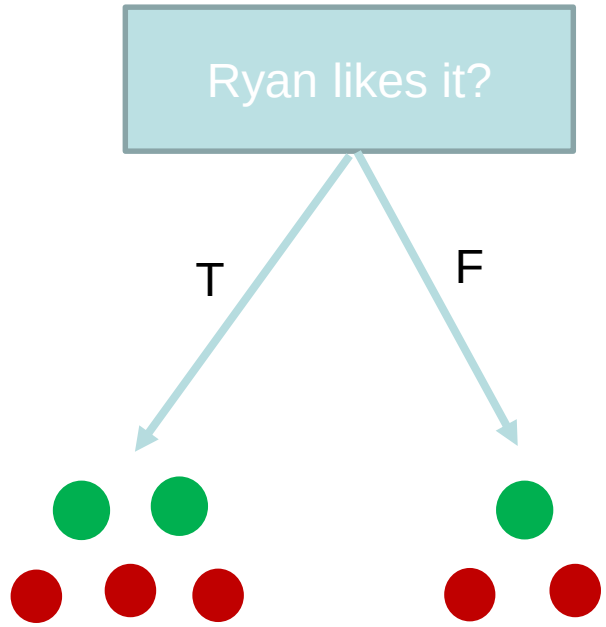
# Learning the Decision Tree

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |



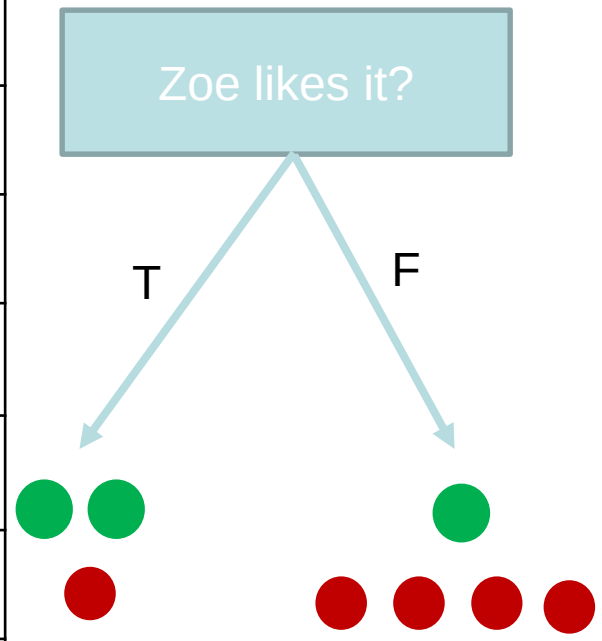
# Learning the Decision Tree

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |

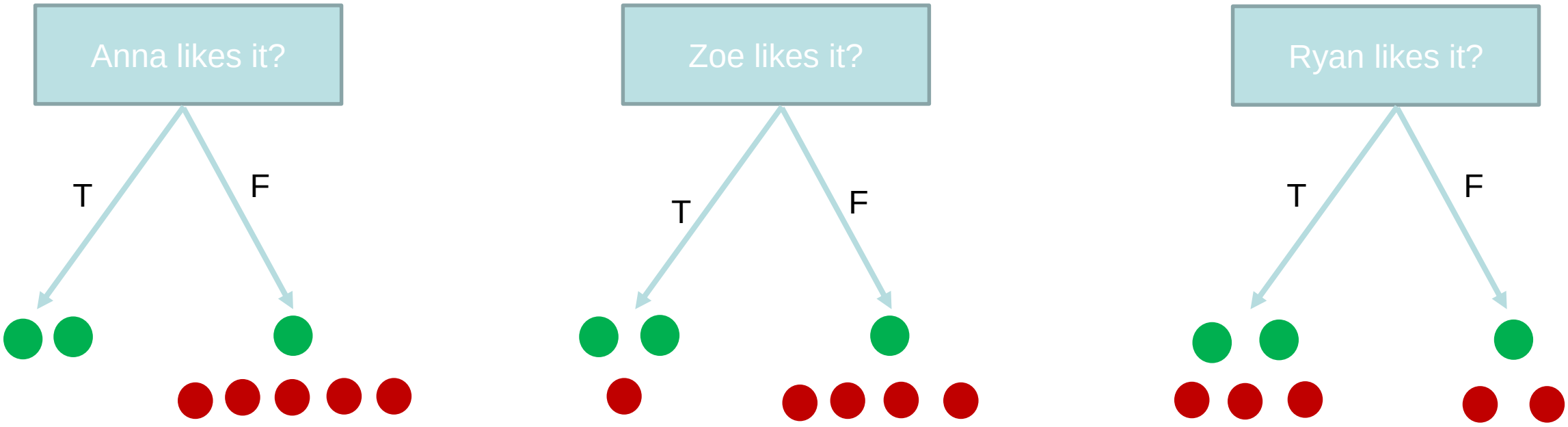


# Learning the Decision Tree

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |

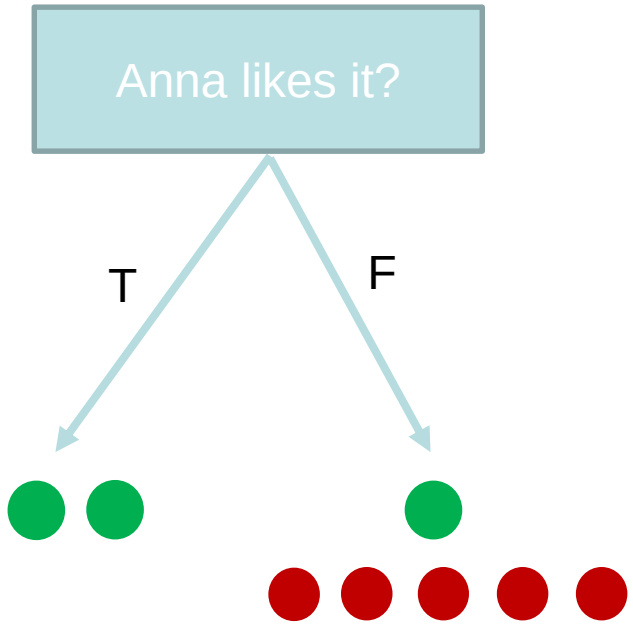


# Learning the Decision Tree




Which one is the most significant feature that will give us the best split at the root of the tree?

# Learning the Decision Tree



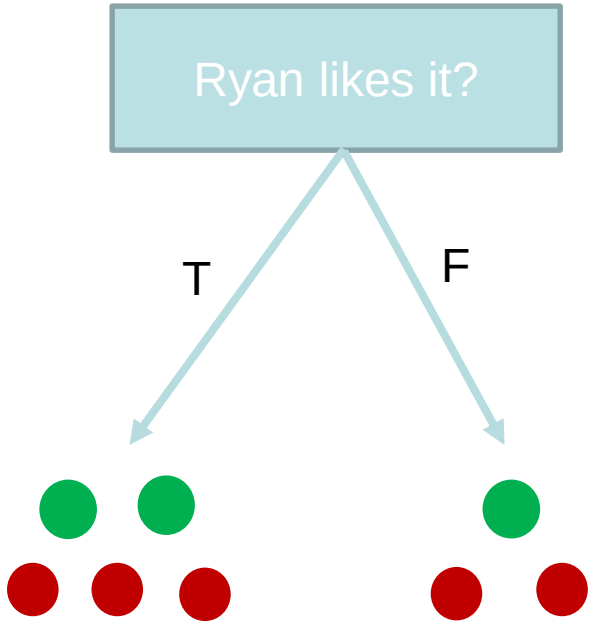

Expected entropy per example over all branches is:

$$\sum_i \frac{p_i+n_i}{p+n} H(<\frac{p_i}{p_i+n_i}, \frac{n_i}{p_i+n_i}>)$$

$$= 0 + 6/8H(<1/6, 5/6>)$$

$$= 6/8(-1/6 \log_2 1/6 - 5/6 \log_2 5/6)$$

# Learning the Decision Tree



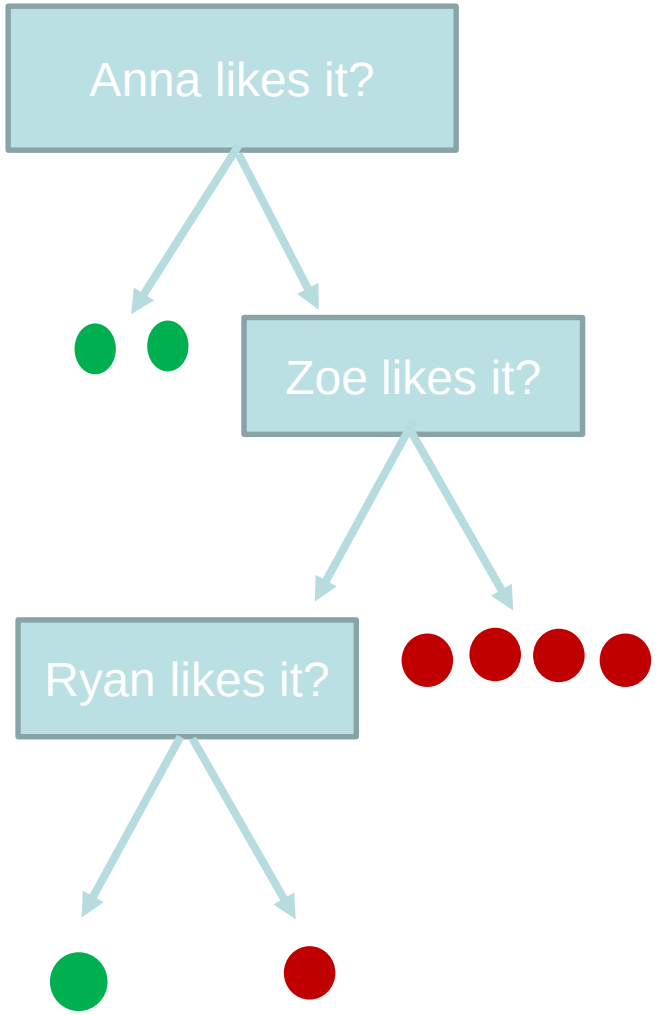

Expected entropy per example over all branches is:

$$\sum_i \frac{p_i+n_i}{p+n} H(<\frac{p_i}{p_i+n_i}, \frac{n_i}{p_i+n_i}>)$$

$$= 5/8H(<2/5, 3/5>) + 3/8\ H(<1/3, 2/3>)$$

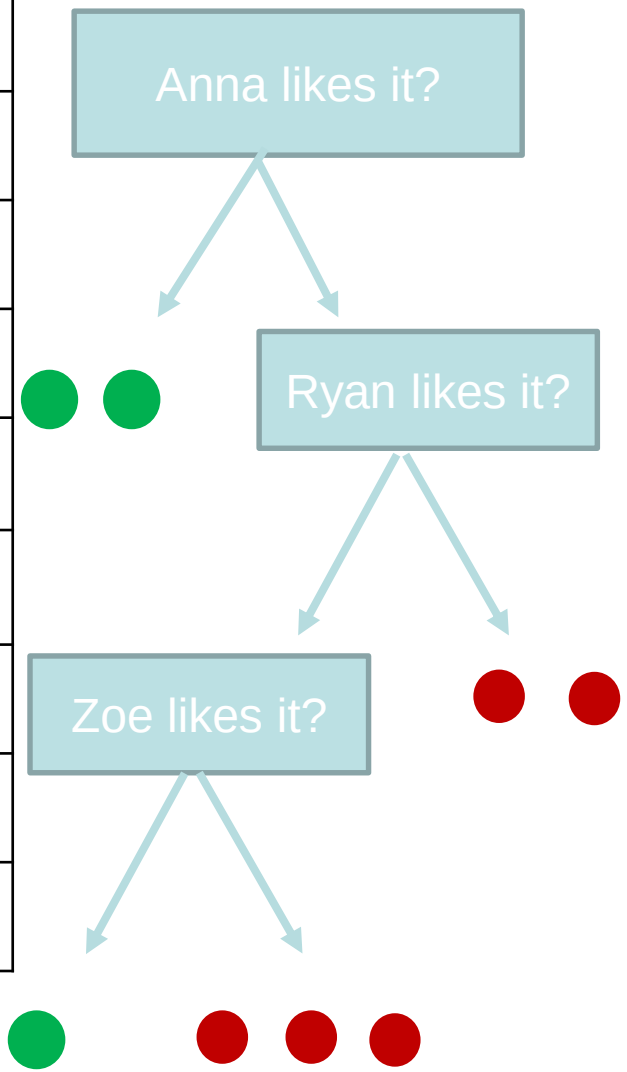
# Learning the Decision Tree

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |



# Alternate Decision Tree?

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | T | T | T | T |
| Zootopia | T | F | F | T |
| San Andreas | F | T | T | T |
| The Pets Take Over | F | T | F | F |
| Fieldtrip to Mars | F | F | T | F |
| Forever | F | F | F | F |
| Still Here | F | T | F | F |
| A Happy Robot | F | T | F | F |

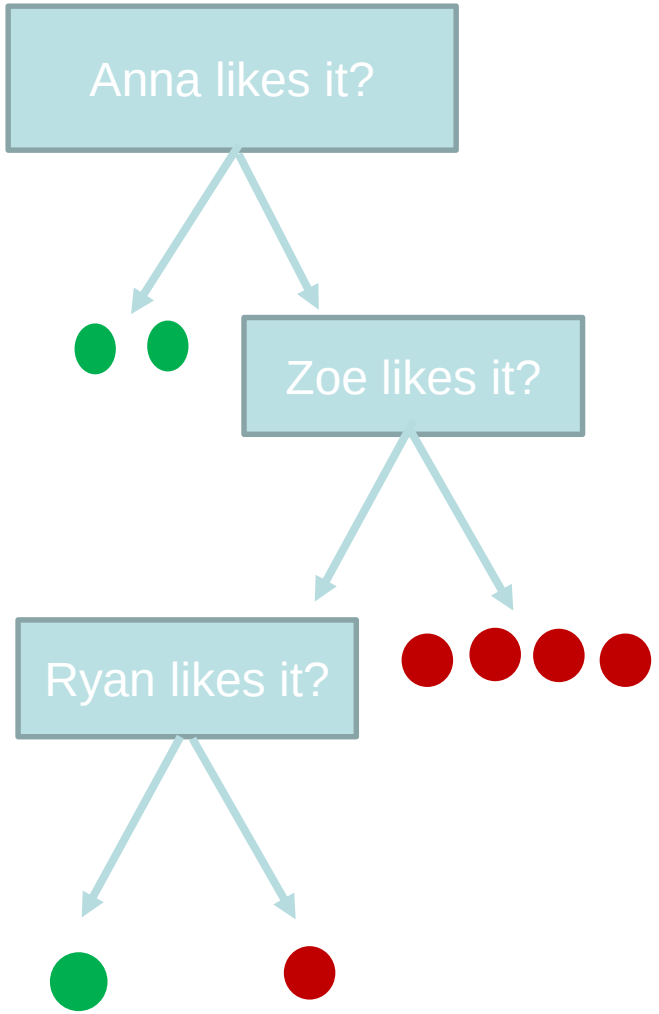


# Classifying with the Decision Tree

We have a new book that  Anna likes but Ryan and Zoe do not like.  Should we make a movie?

What about a book that neither Anna nor Zoe like?

A book that Anna does not like but Zoe and Ryan like?



# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Inside Out =

```
BIAS  : 1
Anna  : 5
Ryan  : 5
Zoe   : 5
```

$w$

```
BIAS  : 1
Anna  : 0
Ryan  : 0
Zoe   : 0
```

*f(x) .w = 1* >= 0, no weight updates

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Zootopia =

```
BIAS  : 1
Anna  : 4
Ryan  : 2
Zoe   : 1
```

$w$

```
BIAS  : 1
Anna  : 0
Ryan  : 0
Zoe   : 0
```

*f(x) .w = 1* >= 0, no weight updates

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

San Andreas =

```
BIAS  : 1
Anna  : 1
Ryan  : 4
Zoe   : 3
```

$w$

```
BIAS  : 1
Anna  : 0
Ryan  : 0
Zoe   : 0
```

*f(x) .w = 1* >= 0, no weight updates

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

The Pets…=

```
BIAS  : 1
Anna  : 1
Ryan  : 5
Zoe   : 2
```

$w$

```
BIAS  : 1
Anna  : 0
Ryan  : 0
Zoe   : 0
```

*f(x)* . *w* = 1 >= 0 should be negative

Update w (subtract f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

The Pets…=

```
BIAS  : 1
Anna  : 1
Ryan  : 5
Zoe   : 2
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

*f(x)* . *w* = 1 >= 0 should be negative

Update w (subtract f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Fieldtrip…=

```
BIAS  : 1
Anna  : 1
Ryan  : 2
Zoe   : 4
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

*f(x) . w* = -1 -10 -8 < 0 weight update

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Forever =

```
BIAS  : 1
Anna  : 2
Ryan  : 1
Zoe   : 2
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

*f(x)* . $w < 0$ no weight update

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Still Here =

```
BIAS  : 1
Anna  : 1
Ryan  : 3
Zoe   : 2
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

$f(x) \cdot w < 0$ no weight update

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Happy Robot=

```
BIAS  : 1
Anna  : 2
Ryan  : 4
Zoe   : 1
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

$f(x) \cdot w < 0$ no weight update

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Inside Out =

```
BIAS  : 1
Anna  : 5
Ryan  : 5
Zoe   : 5
```

$w$

```
BIAS  : 0
Anna  : -1
Ryan  : -5
Zoe   : -2
```

Second Iteration

$f(x) \cdot w = -5 - 25 - 10 < 0$ should be positive

update weights (add f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Inside Out =

```
BIAS  : 1
Anna  : 5
Ryan  : 5
Zoe   : 5
```

$w$

```
BIAS  : 1
Anna  : 4
Ryan  : 0
Zoe   : 3
```

Second Iteration

$f(x) \cdot w = -5 -25 -10 < 0$ should be positive

update weights (add f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Zootopia =

```
BIAS  : 1
Anna  : 4
Ryan  : 2
Zoe   : 1
```

$w$

```
BIAS  : 1
Anna  : 4
Ryan  : 0
Zoe   : 3
```

Second Iteration

*f(x)* . *w* = 1 + 16 + 3 no change

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

San Andreas =

```
BIAS  : 1
Anna  : 1
Ryan  : 4
Zoe   : 3
```

$w$

```
BIAS  : 1
Anna  : 4
Ryan  : 0
Zoe   : 3
```

Second Iteration

$f(x) \cdot w = 1 + 4 + 9$ no change

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

The Pets…=

```
BIAS  : 1
Anna  : 1
Ryan  : 5
Zoe   : 2
```

$w$

```
BIAS  : 1
Anna  : 4
Ryan  : 0
Zoe   : 3
```

Second Iteration

$f(x) \cdot w = 1 + 4 + 6 > 0$ should be negative

update weights (subtract f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

The Pets…=

```
BIAS  : 1
Anna  : 1
Ryan  : 5
Zoe   : 2
```

$w$

```
BIAS  : 0
Anna  : 3
Ryan  : -5
Zoe   : 1
```

Second Iteration

$f(x) \cdot w = 1 + 4 + 6 > 0$ should be negative

update weights (subtract f(x))

# Perceptron

| Movie | Anna | Ryan | Zoe | Blockbuster? |
|---|---|---|---|---|
| Inside Out | 5 | 5 | 5 | T |
| Zootopia | 4 | 2 | 1 | T |
| San Andreas | 1 | 4 | 3 | T |
| The Pets Take Over | 1 | 5 | 2 | F |
| Fieldtrip to Mars | 1 | 2 | 4 | F |
| Forever | 2 | 1 | 2 | F |
| Still Here | 1 | 3 | 2 | F |
| A Happy Robot | 2 | 4 | 1 | F |

Fieldtrip…=

```
BIAS  : 1
Anna  : 1
Ryan  : 2
Zoe   : 4
```

$w$

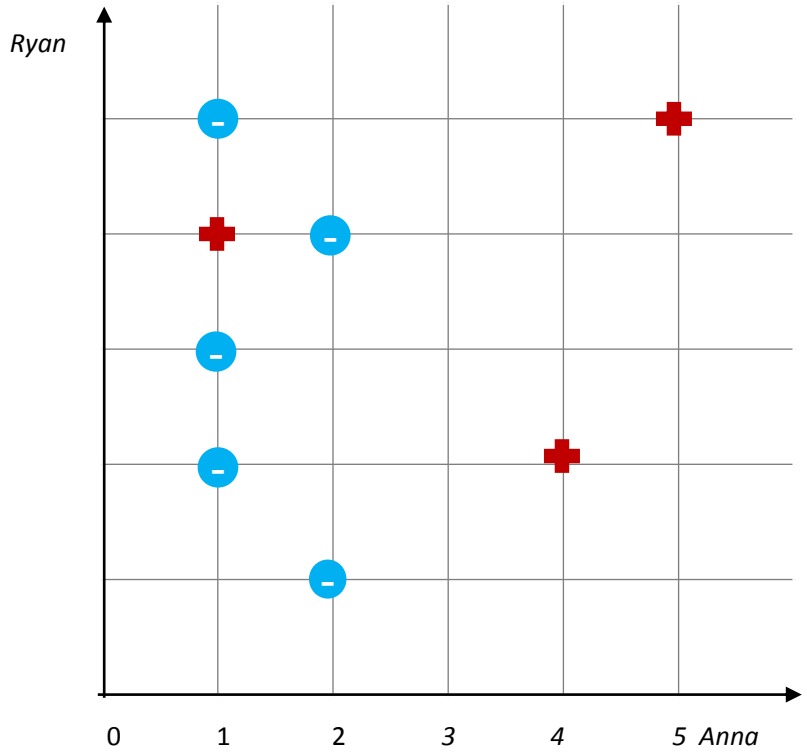
```
BIAS  : 0
Anna  : 3
Ryan  : -5
Zoe   : 1
```

Second Iteration

$f(x) \cdot w = 3 - 10 + 4$ no change …

# Nearest Neighbor

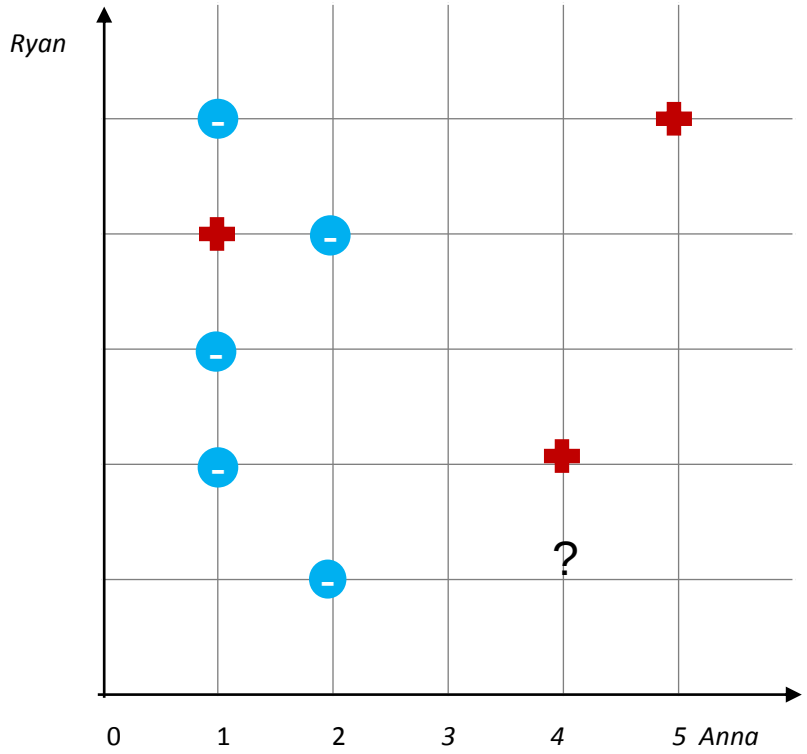
| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | 5 | 5 | T |
| Zootopia | 4 | 2 | T |
| San Andreas | 1 | 4 | T |
| The Pets Take Over | 1 | 5 | F |
| Fieldtrip to Mars | 1 | 2 | F |
| Forever | 2 | 1 | F |
| Still Here | 1 | 3 | F |
| A Happy Robot | 2 | 4 | F |




We have a new book that Anna likes (+4) and Ryan does not like (+1).
Should we make a movie? 1-NN? 3-NN?

# Nearest Neighbor

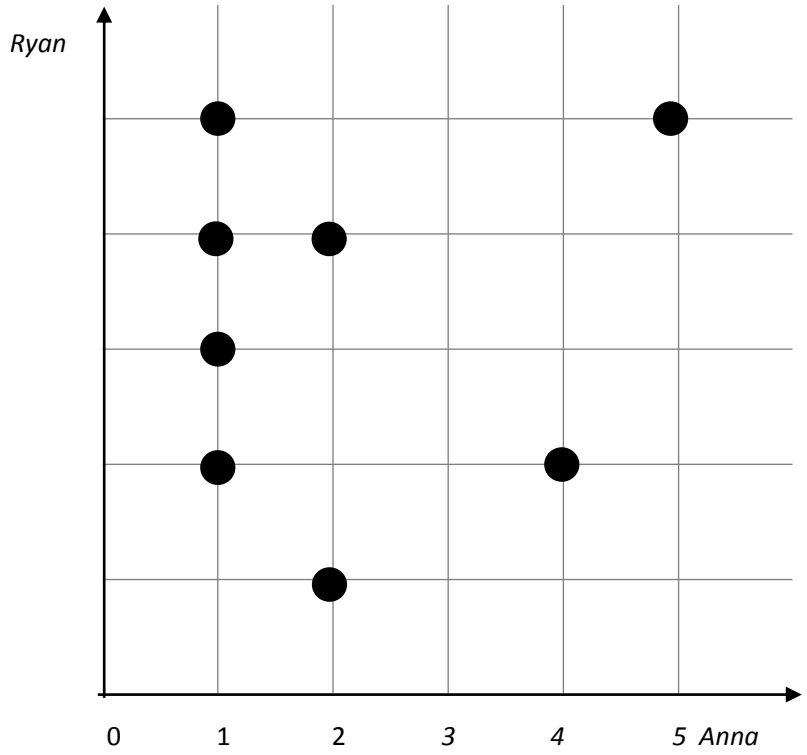
| Movie | Anna | Ryan | Blockbuster? |
|---|---|---|---|
| Inside Out | 5 | 5 | T |
| Zootopia | 4 | 2 | T |
| San Andreas | 1 | 4 | T |
| The Pets Take Over | 1 | 5 | F |
| Fieldtrip to Mars | 1 | 2 | F |
| Forever | 2 | 1 | F |
| Still Here | 1 | 3 | F |
| A Happy Robot | 2 | 4 | F |




We have a new book that Anna likes (+4) and Ryan does not like (+1).
Should we make a movie? 1-NN? Yes 3-NN? No

# Clustering

| Movie | Anna | Ryan |
|---|---|---|
| Inside Out | 5 | 5 |
| Zootopia | 4 | 2 |
| San Andreas | 1 | 4 |
| The Pets Take Over | 1 | 5 |
| Fieldtrip to Mars | 1 | 2 |
| Forever | 2 | 1 |
| Still Here | 1 | 3 |
| A Happy Robot | 2 | 4 |

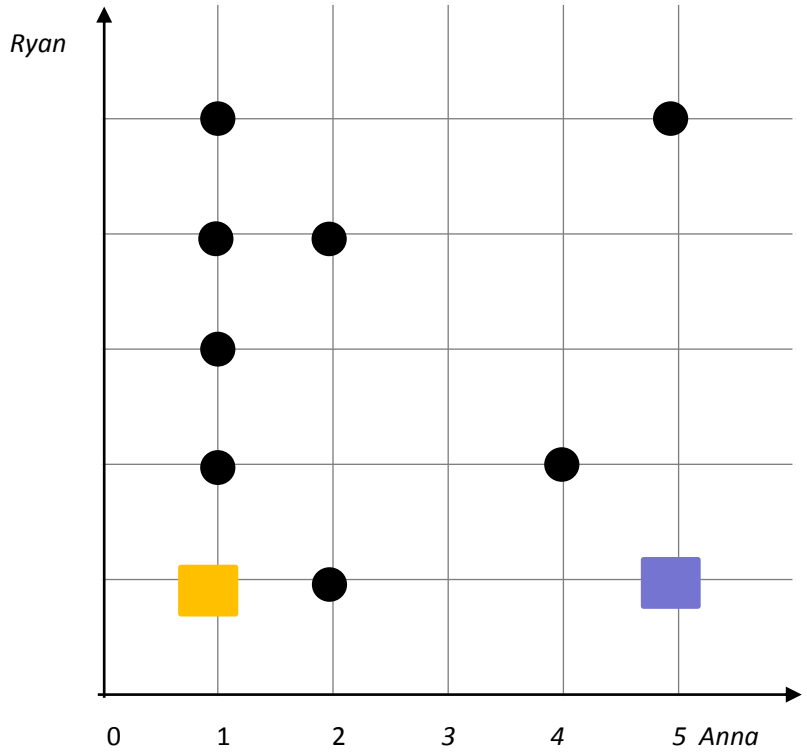



Clustering: unsupervised learning – no labels

K-means k = 2

# Clustering

| Movie | Anna | Ryan |
|---|---|---|
| Inside Out | 5 | 5 |
| Zootopia | 4 | 2 |
| San Andreas | 1 | 4 |
| The Pets Take Over | 1 | 5 |
| Fieldtrip to Mars | 1 | 2 |
| Forever | 2 | 1 |
| Still Here | 1 | 3 |
| A Happy Robot | 2 | 4 |

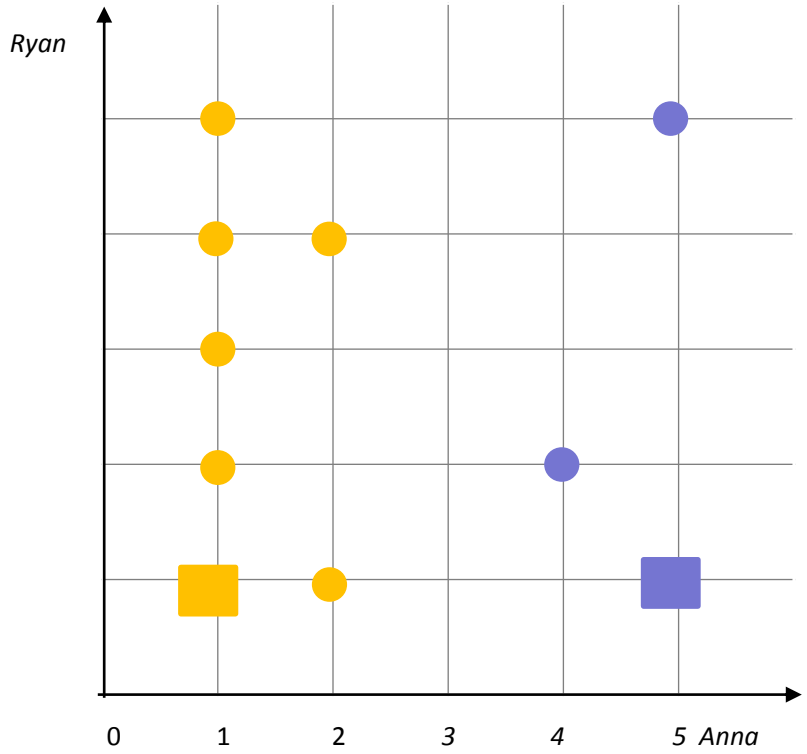



Clustering: unsupervised learning – no labels

K-means k = 2

# Clustering

| Movie | Anna | Ryan |
|---|---|---|
| Inside Out | 5 | 5 |
| Zootopia | 4 | 2 |
| San Andreas | 1 | 4 |
| The Pets Take Over | 1 | 5 |
| Fieldtrip to Mars | 1 | 2 |
| Forever | 2 | 1 |
| Still Here | 1 | 3 |
| A Happy Robot | 2 | 4 |

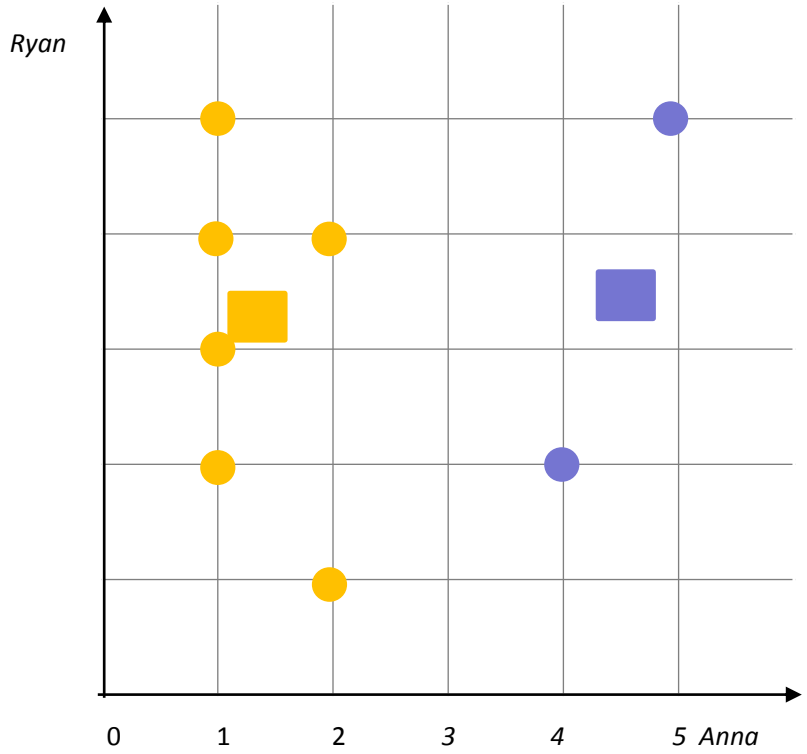



Clustering: unsupervised learning – no labels

K-means k = 2

# Clustering

| Movie | Anna | Ryan |
|---|---|---|
| Inside Out | 5 | 5 |
| Zootopia | 4 | 2 |
| San Andreas | 1 | 4 |
| The Pets Take Over | 1 | 5 |
| Fieldtrip to Mars | 1 | 2 |
| Forever | 2 | 1 |
| Still Here | 1 | 3 |
| A Happy Robot | 2 | 4 |




To calculate the new position of the means:

(1+1+1+1+2+2)/6 = 4/3 (1+2+3+4+4+5)/6 = 19/6

(4+5)/2 = 9/2 (2+5)/2 = 7?2

# PDDL

Goal(Has(Zoe, d) ∧ IsColdDrink(d) )

Action(Buy(person, store, item),

PRECOND: At(person, store) ∧ Sells(store, item) ∧ HasCreditCard(person)

EFFECT: Has(person, item))

At(person, store), Sells(store, item), HasCreditCard(person) are not included in the effects because they have not changed.

# PDDL

Goal(Has(Zoe, d) ∧ IsColdDrink(d) )

Action(Buy(person, store, item),

PRECOND: At(person, store) ∧ Sells(store, item) ∧ HasCreditCard(person)

EFFECT: Has(person, item))

Action(Go(person,from, to),

PRECOND: At(person, from)

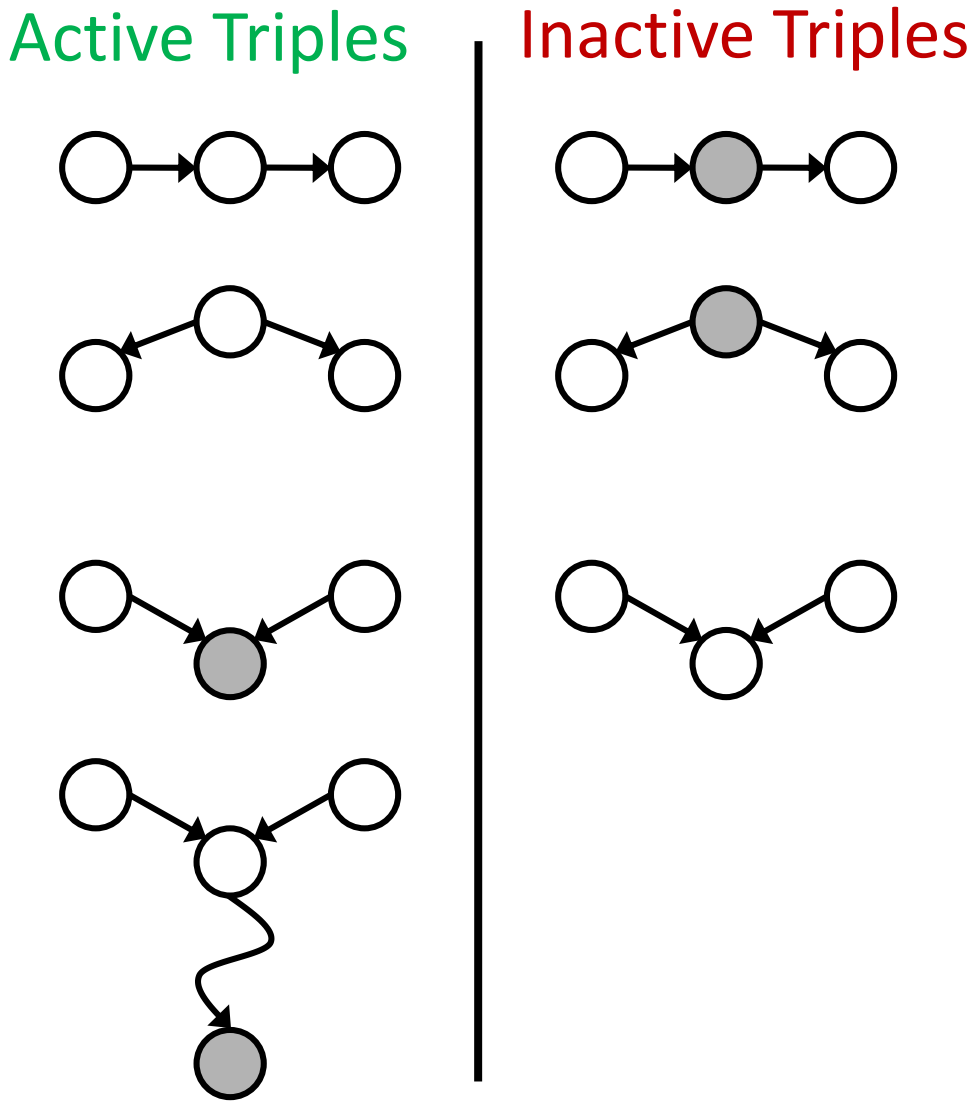
EFFECT: ¬ At(person, from) ∧ At(person, to))

Init(At(Zoe, DH) ∧ HasCreditCard(Zoe) ∧ Sells(JambaJuice, Smoothie) ∧ IsColdDrink(Smoothie) ∧ IsColdDrink(Lemonade))

Solution: [Go(Zoe, DH, JambaJuice), Buy(Zoe, Smoothie)]

# Independence

- Are X and Y conditionally independent given evidence variables Z?
  - Consider all (undirected) paths from X to Y
  - No active paths = independence!
  - X and Y "d-separated" by Z
- A path is active if each triple is active.
- All it takes to block a path is a single inactive segment



# Independence

$A \perp\!\!\!\perp D \mid B$ ?

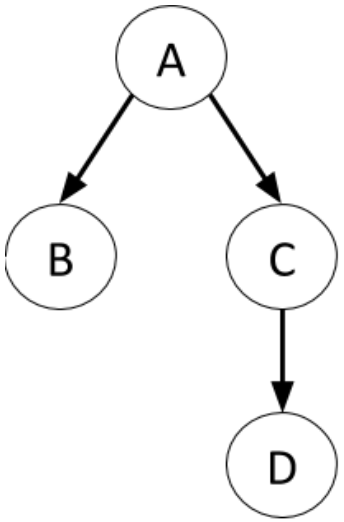
Consider all (undirected) paths from A to D:

- only one –ACD

The path includes one triplet only (ACD)

- ACD is active

Active path => No independence



# Independence

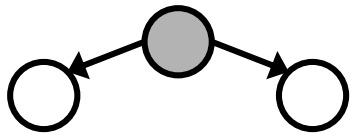
$B \perp\!\!\!\perp D \mid A$ ?

Consider all (undirected) paths from B to D:

- only one – BACD

The path includes triplets BAC and ACD

BAC is inactive

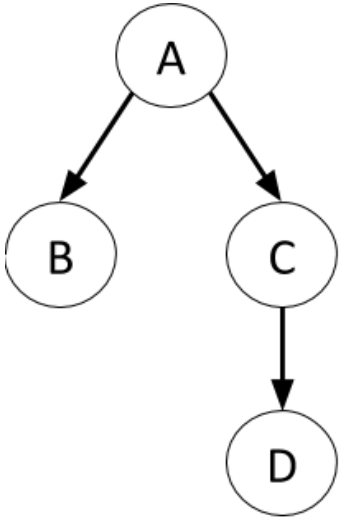


All it takes to block a path is a single inactive segment

- BACD is inactive

No active paths => independence

$B \perp\!\!\!\perp D \mid A$



# Independence

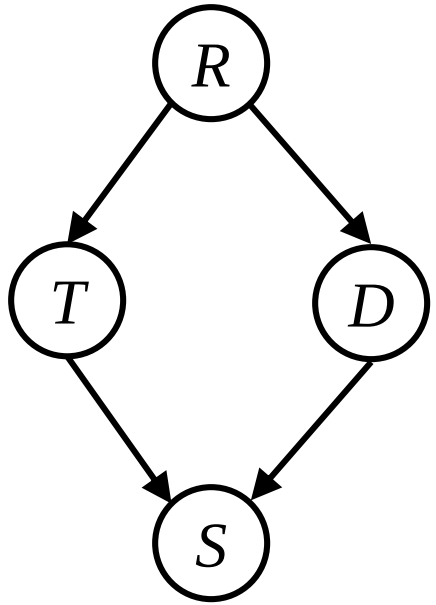
T ⫫ D?

Consider all (undirected) paths from T to D

There are two paths:  TSD and TRD

TSD inactive

TRD active =>  *No independence*



# Independence

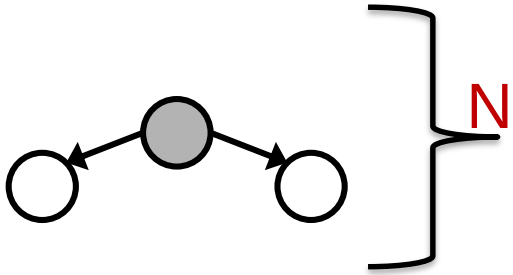
T ⫫ D | R?

Consider all (undirected) paths from T to D

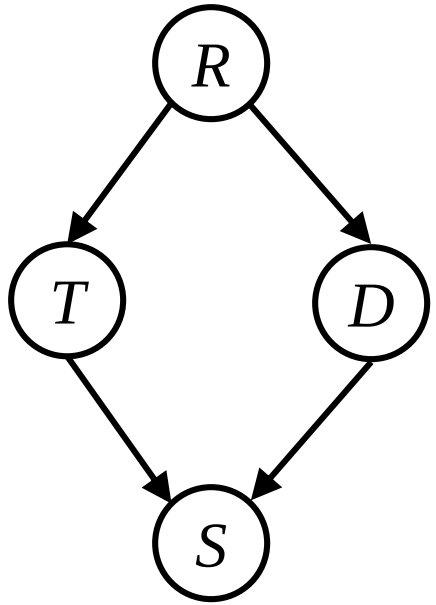
There are two paths:  TSD and TRD

TSD inactive

TRD inactive



No active paths => independence

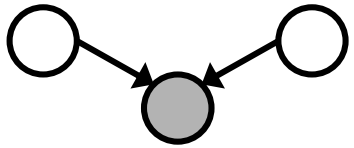


# Independence

T ⫫ D | R, S?

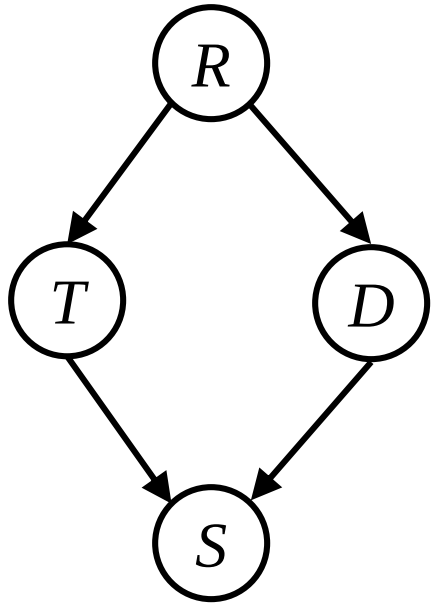
Consider all (undirected) paths from T to D

TSD and TRD

TSD active  => *No independence*

TRD inactive

One active path => No independence



# The End

- Good luck on the Final!
- Have a great summer!

- If you're interested in grading for CS 156 in the fall, please let me know.