CS 109: Introduction to Probability for Computer Scientists

Will Monroe
Summer 2017

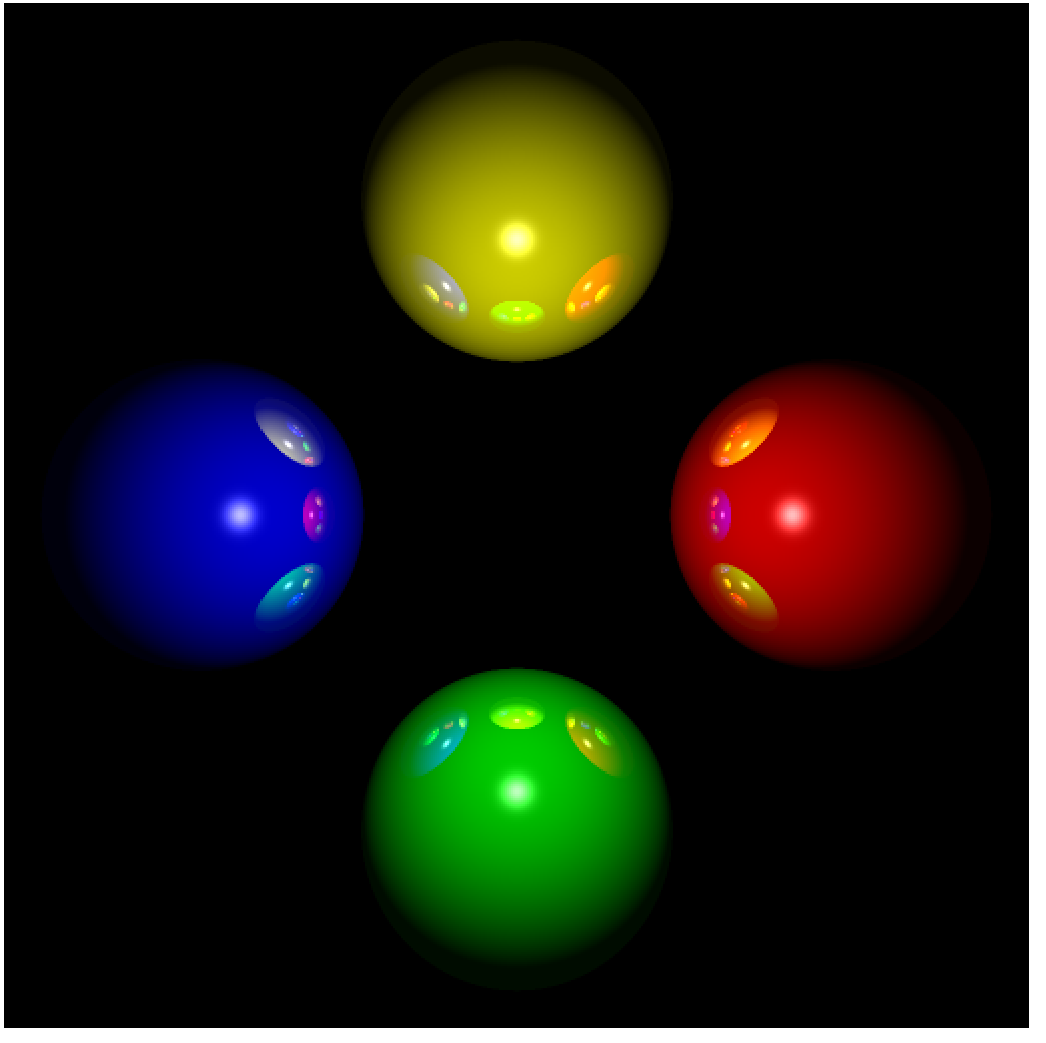
with materials by
Mehran Sahami
and Chris Piech

June 26, 2017

Who am I?

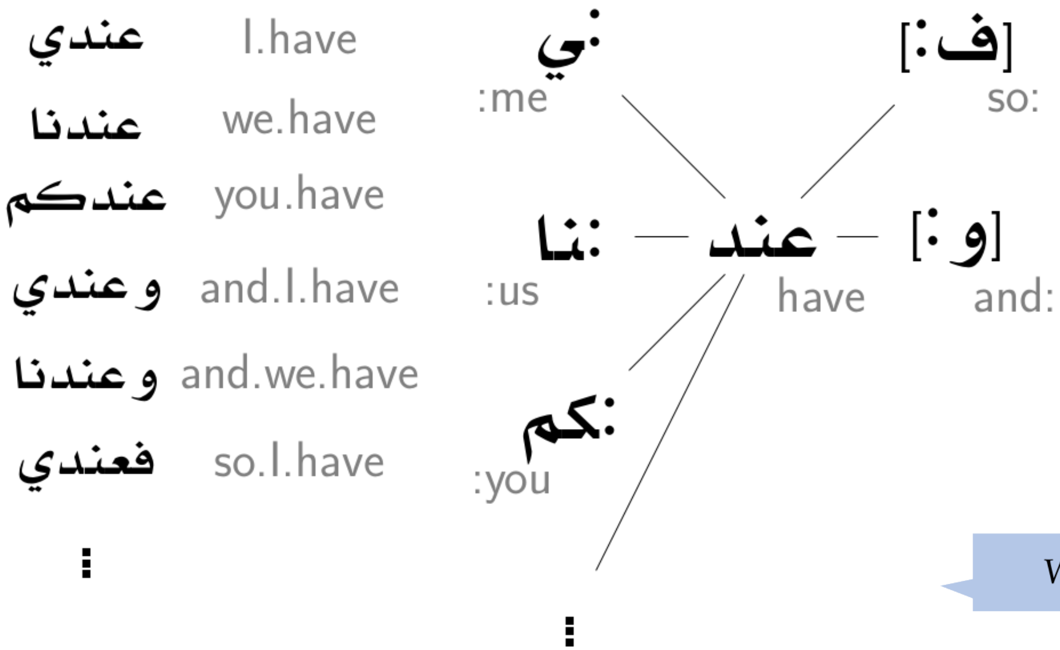
Stanford undergrad

Who am I?



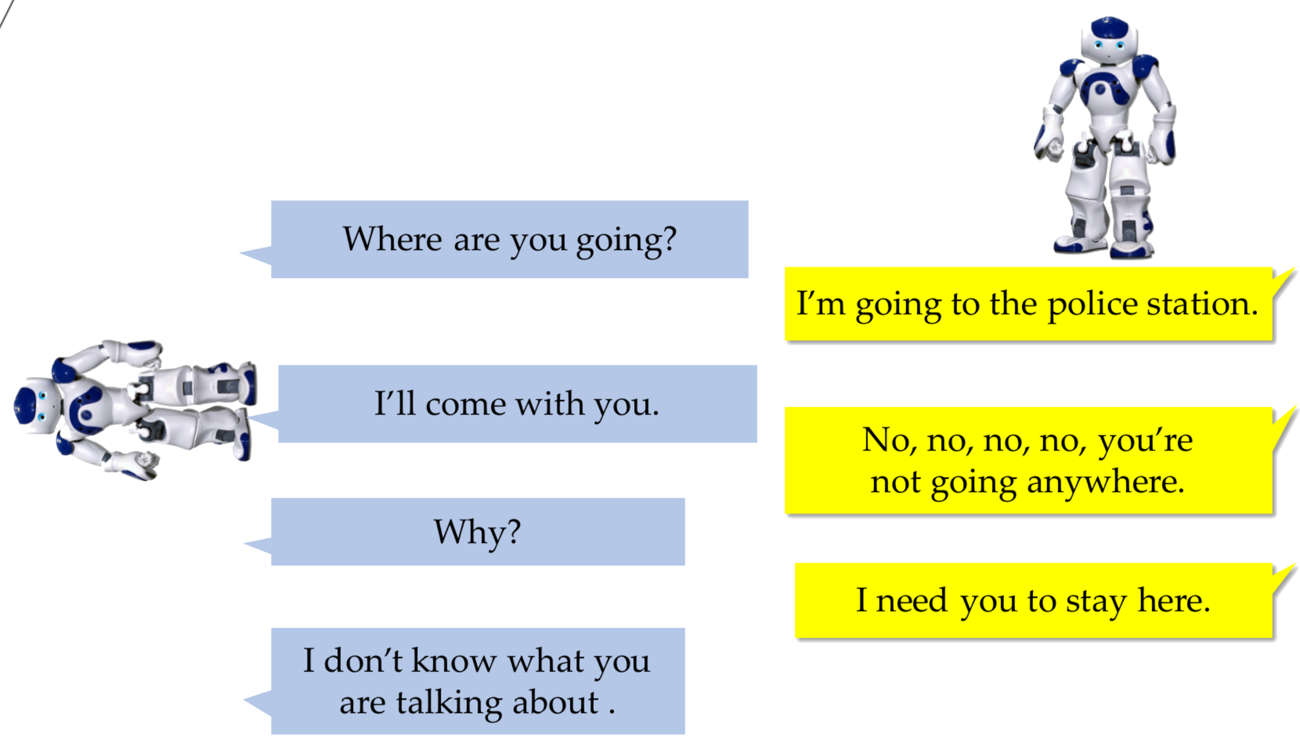
Graphics

Who am I?



Monroe et al. (2014)

Li et al. (2016)



Natural language processing

Who am I?

Call me Will!

or Mr. Monroe

~~Professor Monroe~~

~~Dr. Monroe~~

~~Master Monroe?~~

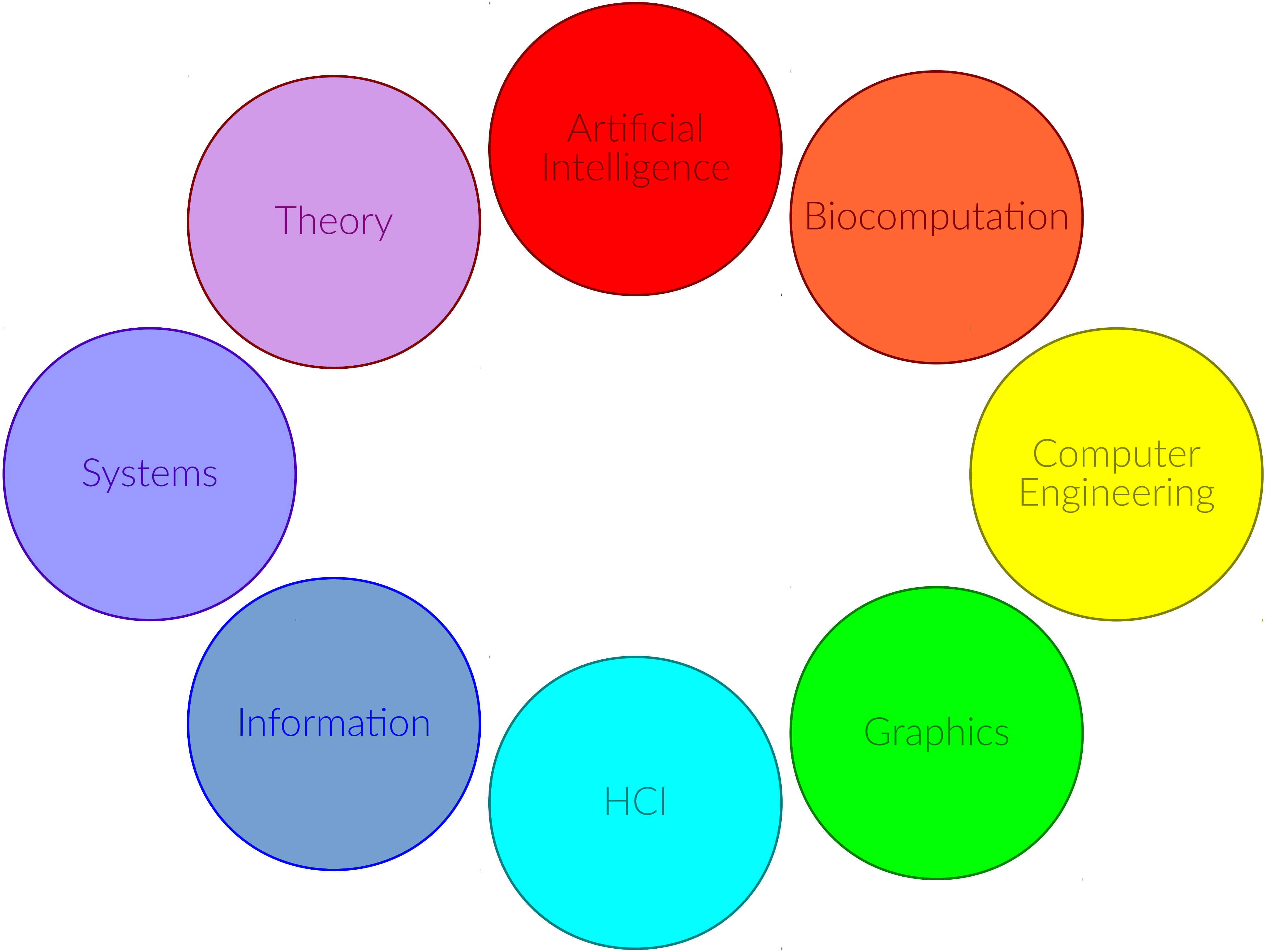
EmojiOne

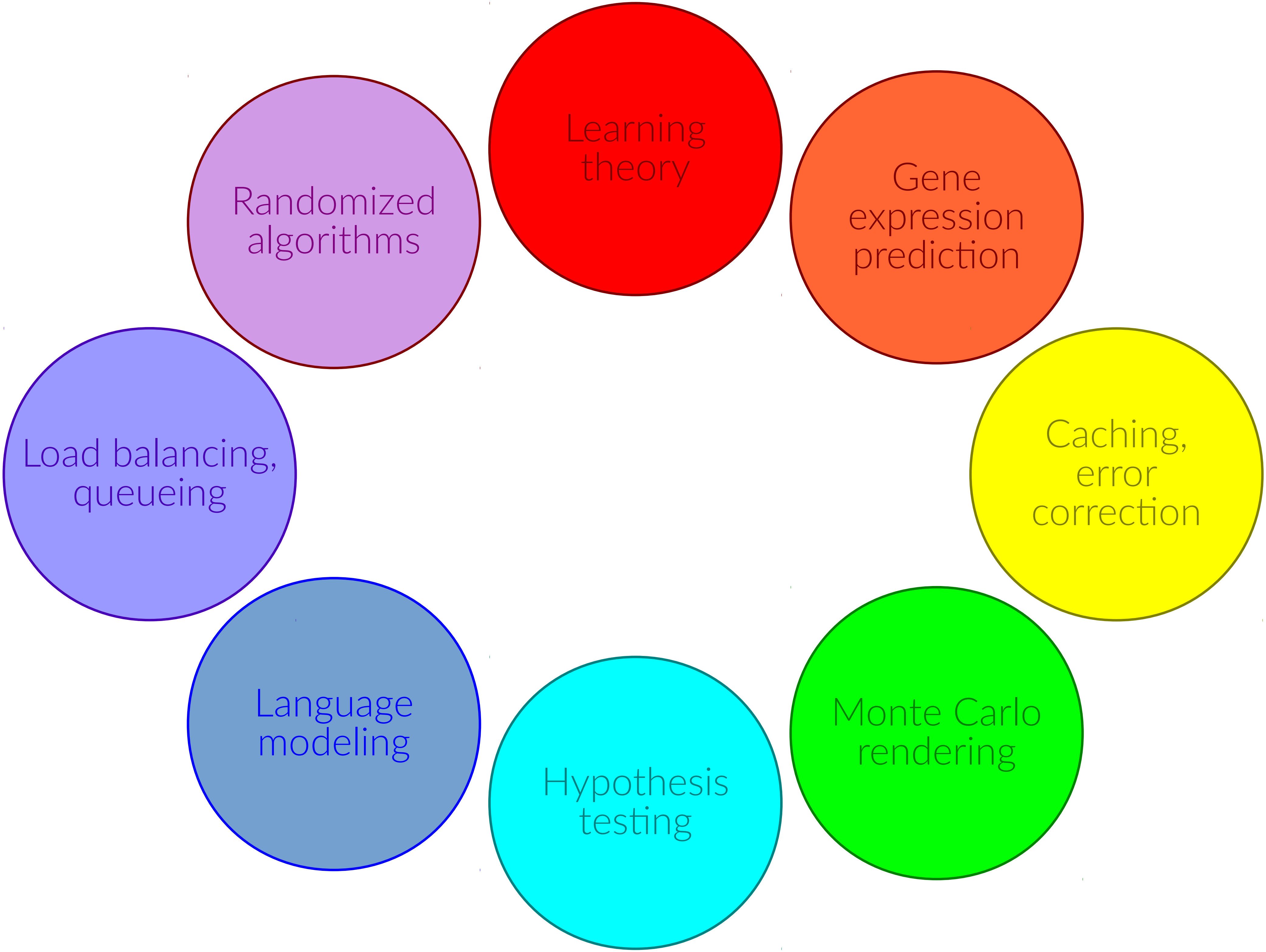
Who am I?

Reno, Nevada

Traditional probability setups

Why probability with computers?


Artificial Intelligence
Biocomputation
Computer Engineering
Graphics
HCI
Information
Systems
Theory


Learning theory
Gene expression prediction
Caching, error correction
Monte Carlo rendering
Hypothesis testing
Language modeling
Load balancing, queueing
Randomized algorithms

Quiz question

https://b.socrative.com/login/student/

Room: CS109SUMMER17

Zika testing

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0.08% of people have Zika

90% of people with Zika test positive

7% of people without Zika test positive

Someone tests positive. What's the probability they have Zika?

A) <0.5% B) 1% C) 7% D) 41% E) 90%

Zika testing

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0.08% of people have Zika

90% of people with Zika test positive

7% of people without Zika test positive

Someone tests positive. What's the probability they have Zika?

Answer: B) 1%

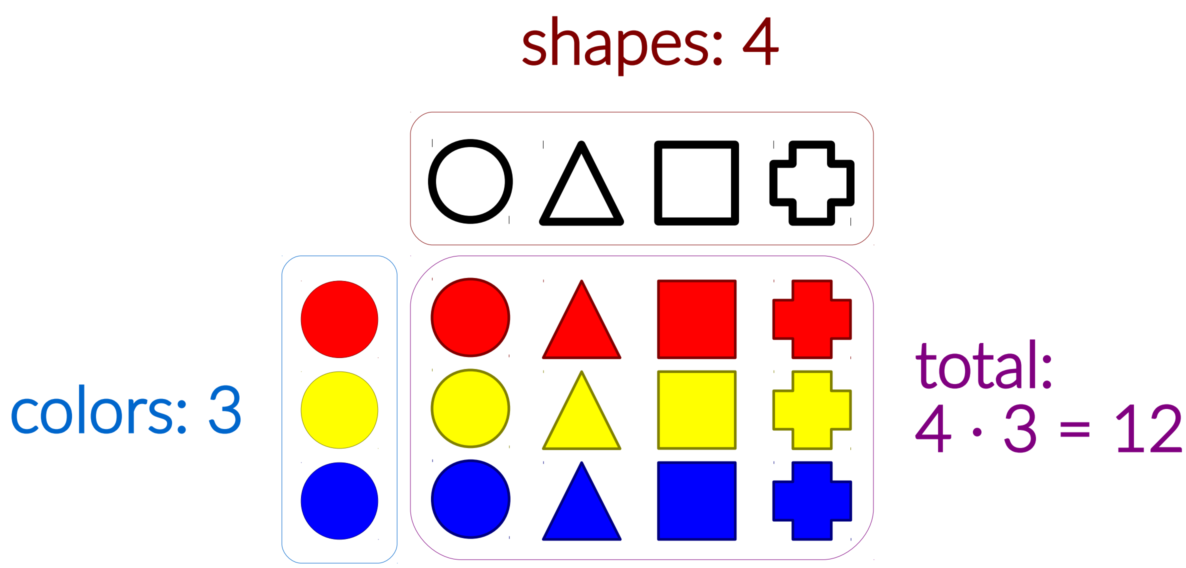

World Bank Photo Collection
~~Counting~~
Combinatorial analysis

An experiment

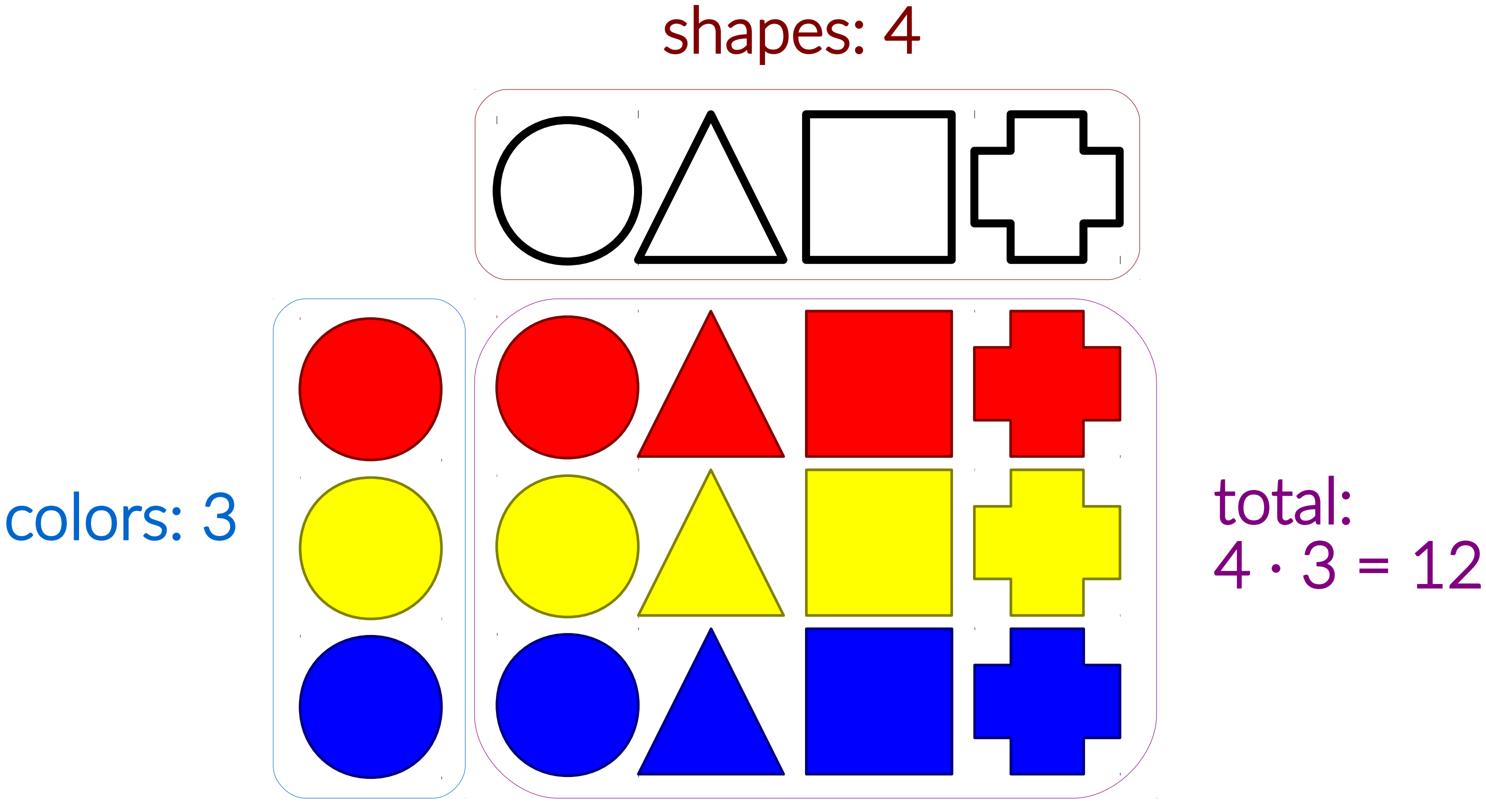
General principle of counting

An experiment consisting of two or more **separate parts** has a number of outcomes equal to the **product** of the number of outcomes of each part.

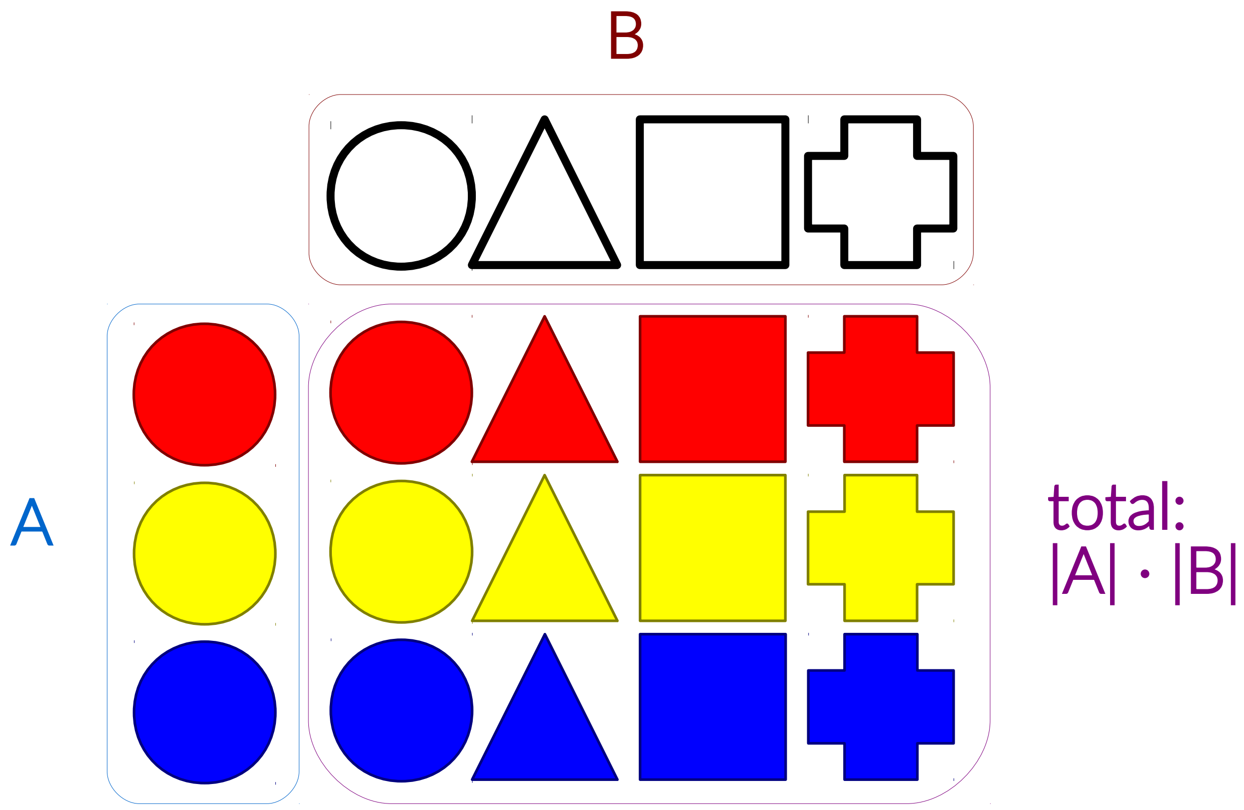
$$|A_1 \times A_2 \times \cdots \times A_n| = \prod_i |A_i|$$



General principle of counting



General principle of counting



Counting license plates

$26 \cdot 26 \cdot 26 \cdot 10 \cdot 10 \cdot 10$

$= \mathbf{17{,}576{,}000}$

$\mathbf{10} \cdot 26 \cdot 26 \cdot 26 \cdot 10 \cdot 10 \cdot 10$

$= \mathbf{175{,}760{,}000}$

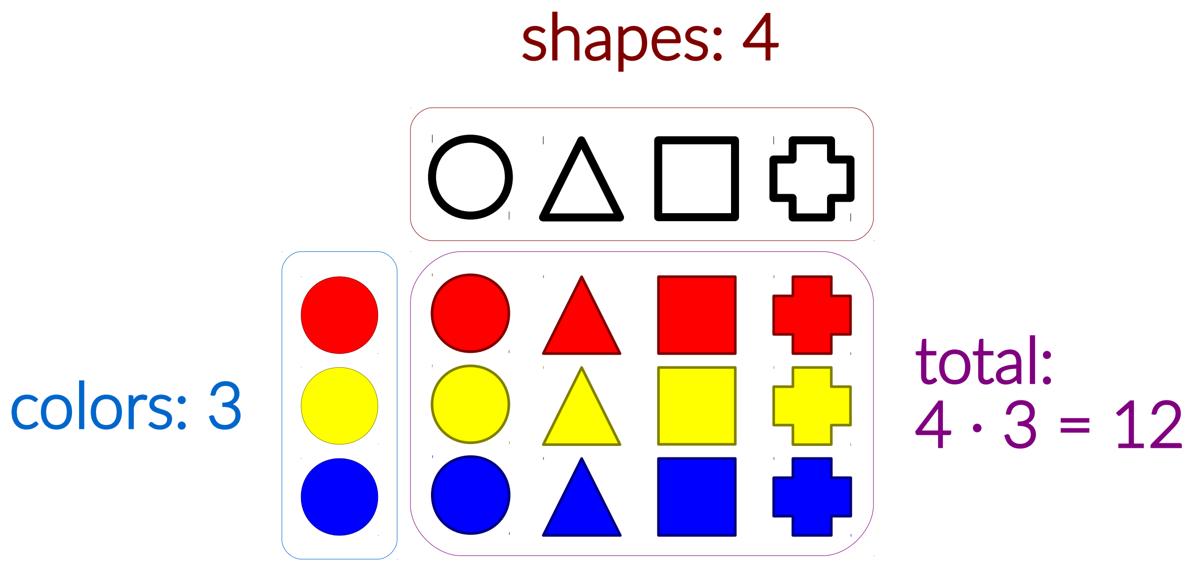
(Approximate 2017 California population: **39,800,000**)

Jerry "Woody", Happoshu

General principle of counting

An experiment consisting of two or more **separate parts** has a number of outcomes equal to the **product** of the number of outcomes of each part.

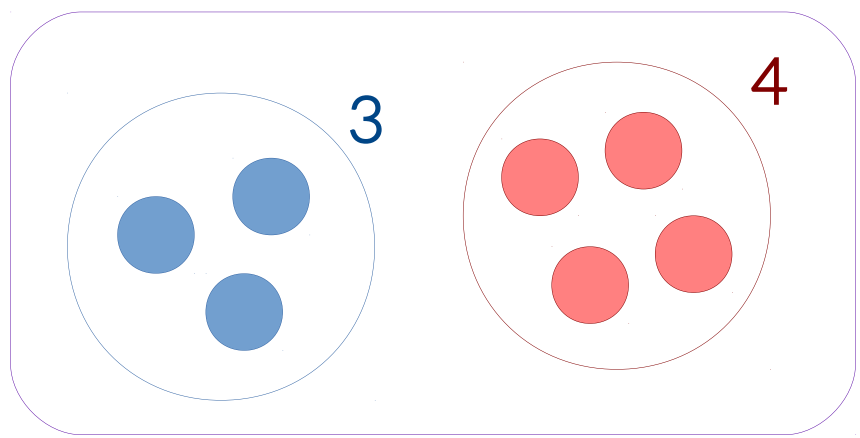
$$|A_1 \times A_2 \times \cdots \times A_n| = \prod_i |A_i|$$



Sum rule of counting

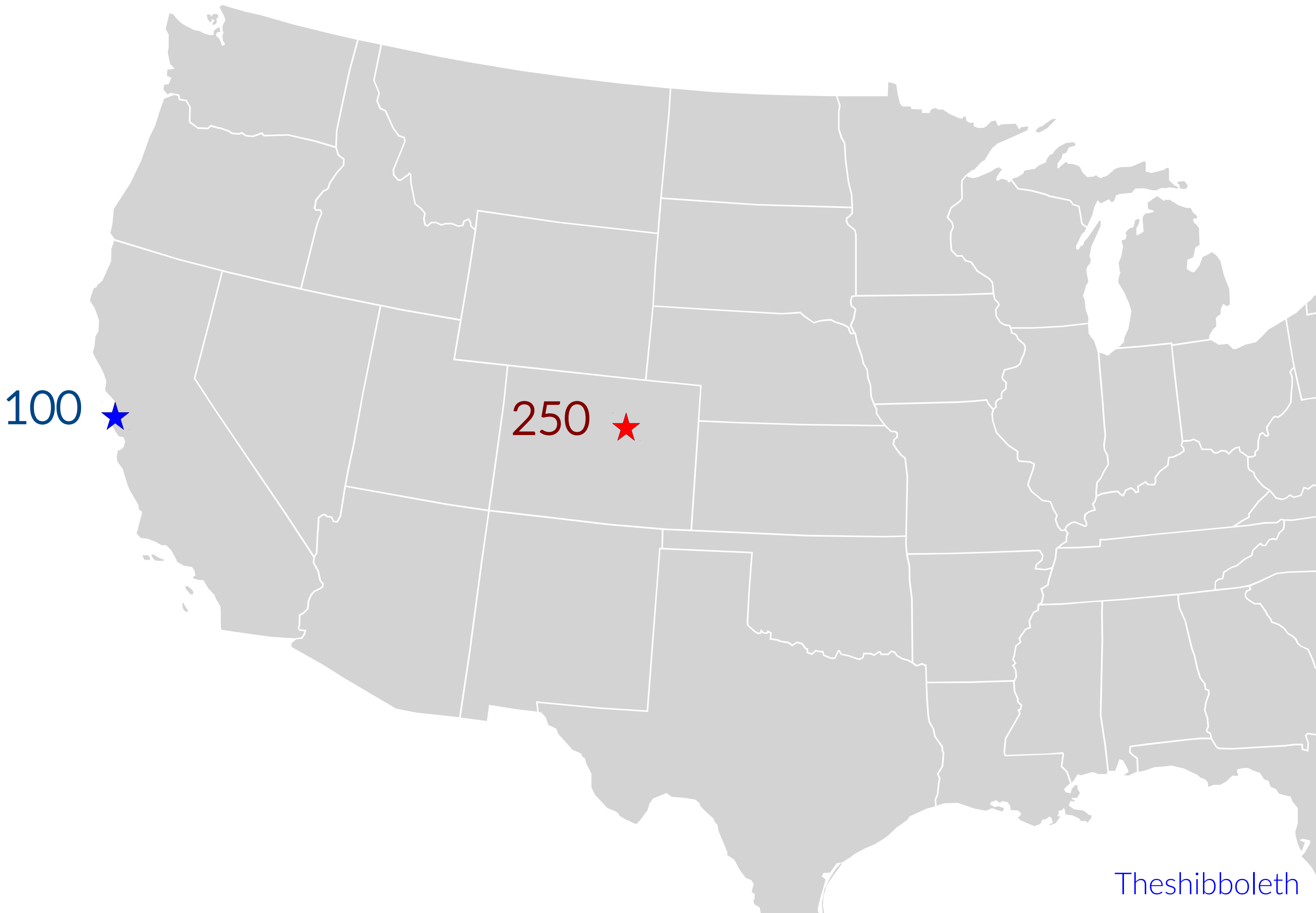
If two sets <u>don't overlap</u>, the **total number of elements** in the two sets is the **sum** of the number of elements of each set.

$$|A \cup B| = |A| + |B| \quad \text{if } A \cap B = \emptyset$$



3+4=7

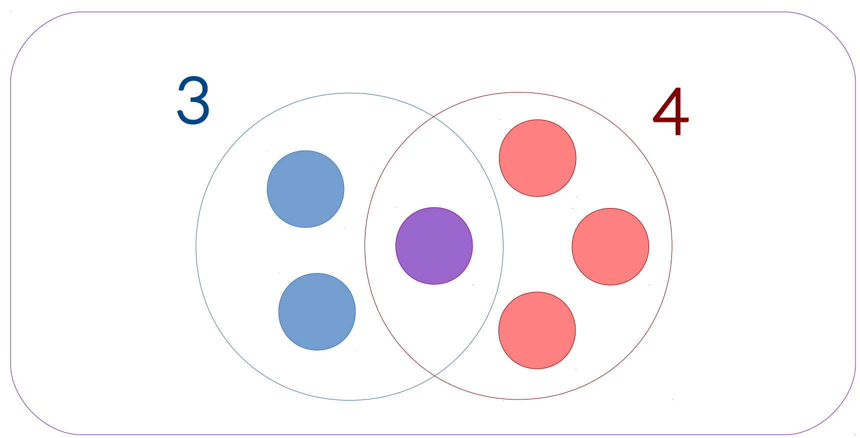
Datacenters



Principle of Inclusion/Exclusion

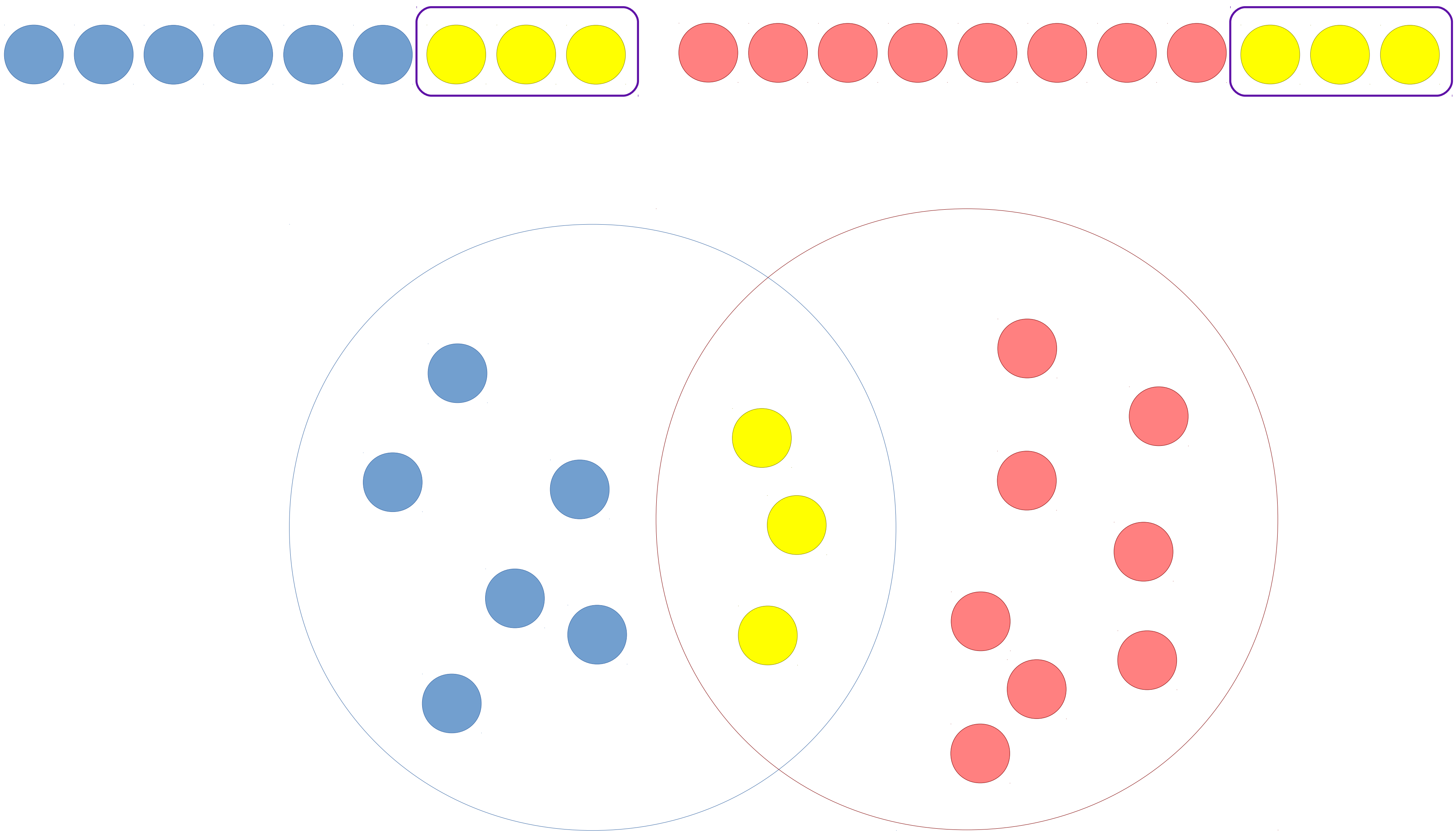
The **total number of elements** in two sets is the sum of the number of elements of each set, **minus** the number of elements in both sets.

$$|A \cup B| = |A| + |B| - |A \cap B|$$



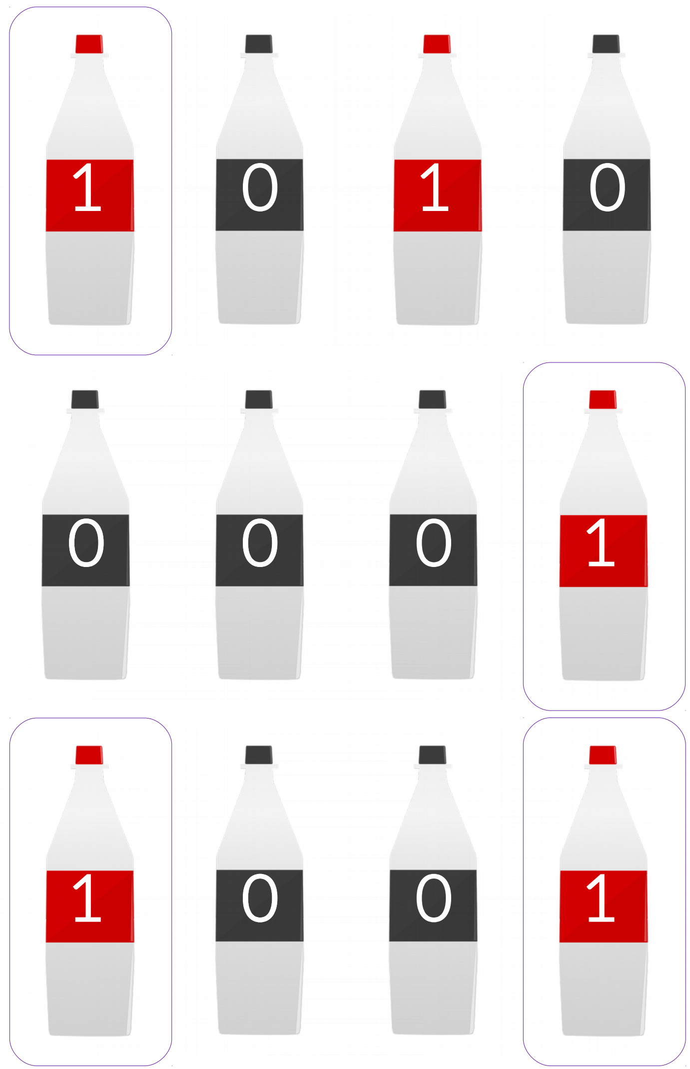
3+4-1 = 6

Inclusion/Exclusion intuition



Bit strings

How many 4-bit strings are there that **start or end with 1**?



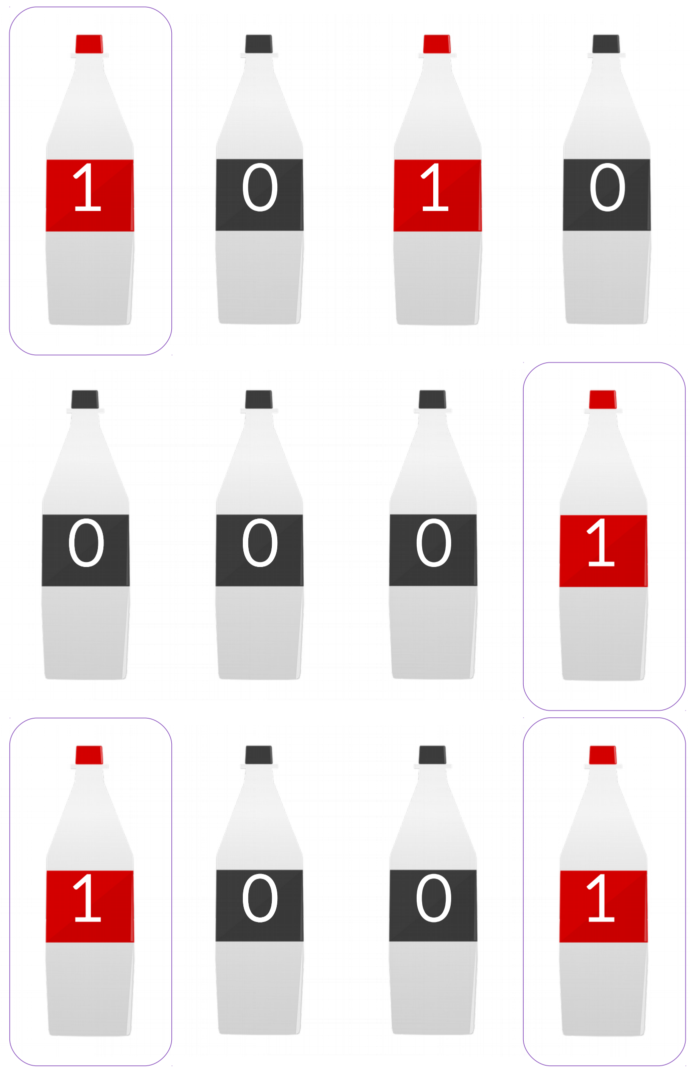
A $\qquad |A| = 2^3$

B $\qquad |B| = 2^3$

$A \cap B$ $\qquad |A \cap B| = 2^2$

Bit strings

How many 4-bit strings are there that **start or end with 1**?

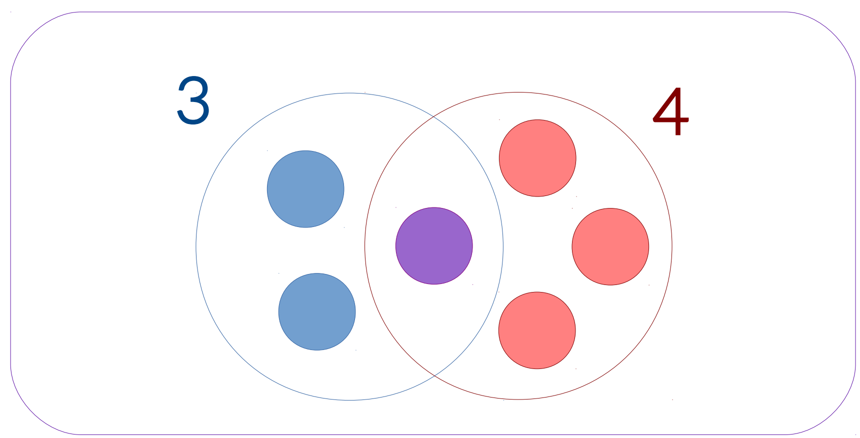


$$2^3 + 2^3 - 2^2 = 12$$

Principle of Inclusion/Exclusion

The **total number of elements** in two sets is the sum of the number of elements of each set, **minus** the number of elements in both sets.

$$|A \cup B| = |A| + |B| - |A \cap B|$$



3+4-1 = 6

Floor and ceiling

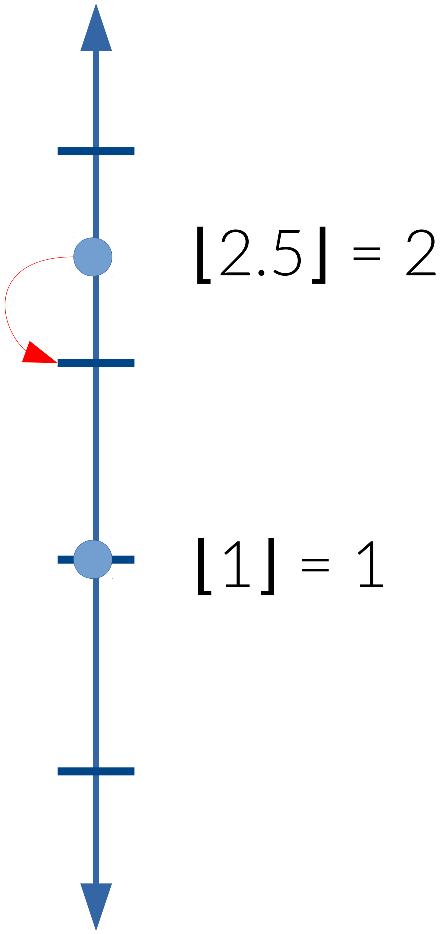
$$\lfloor x \rfloor \qquad \lceil x \rceil$$

Floor and ceiling

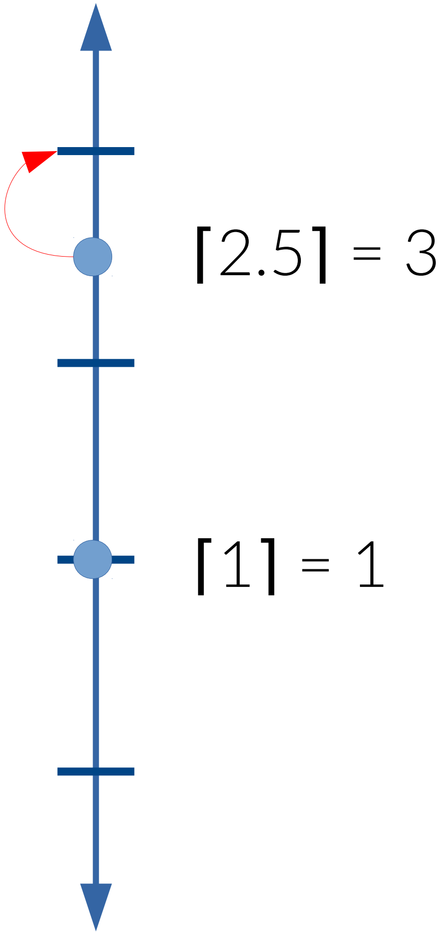
$\lfloor$  $\rfloor$

$$\lceil x \rceil$$

Floor and ceiling

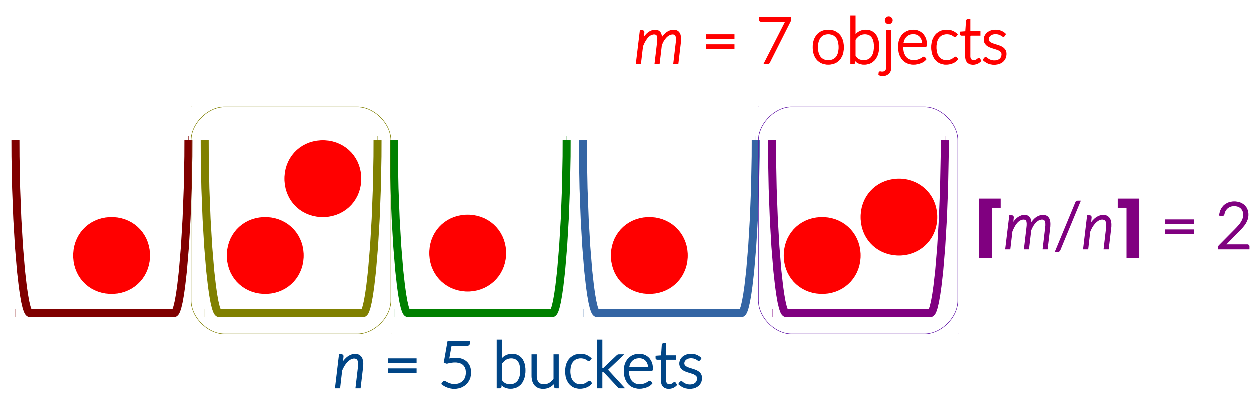


Floor and ceiling



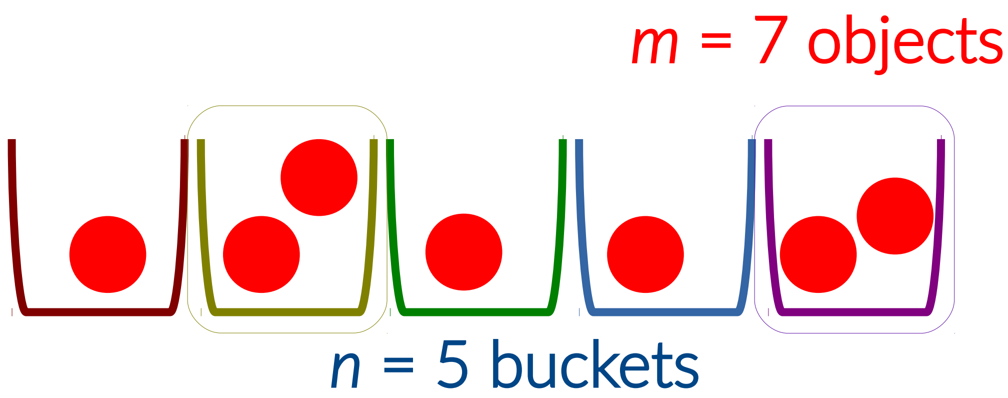
General Pigeonhole Principle

If m objects are placed in n buckets, then **at least one bucket** must contain at least $\lceil m/n \rceil$ objects.



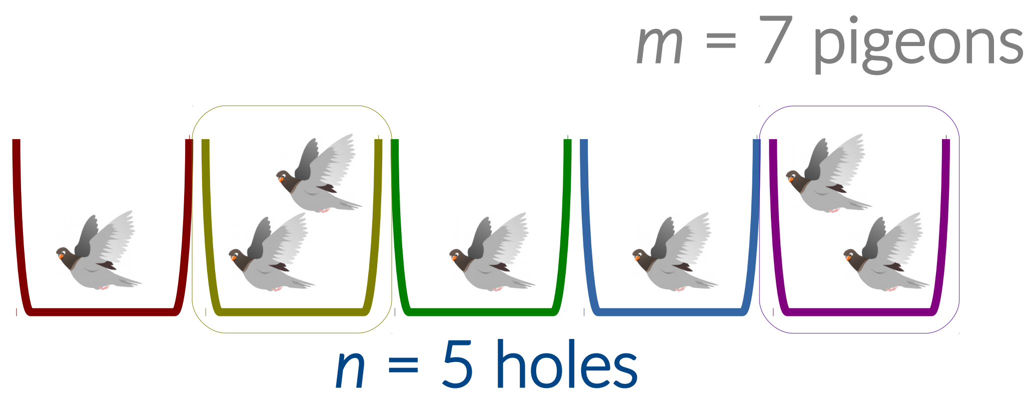
Pigeonhole Principle intuition

More objects than buckets = Some objects have to share!



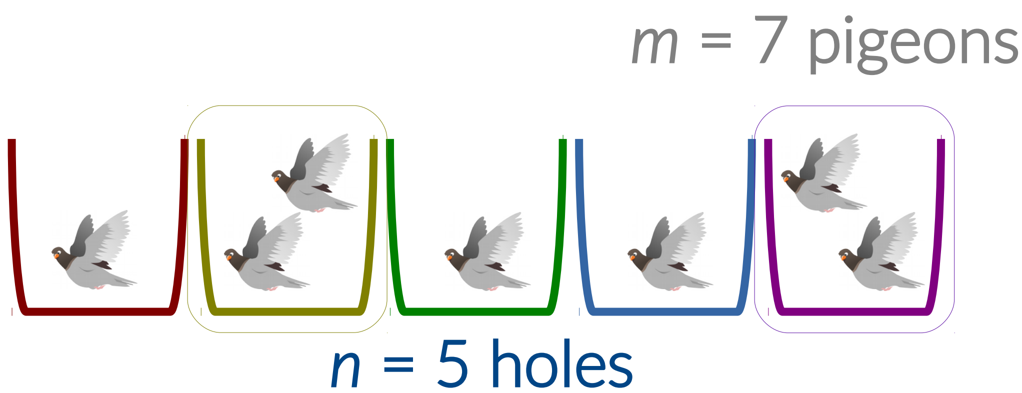
Pigeonhole Principle intuition

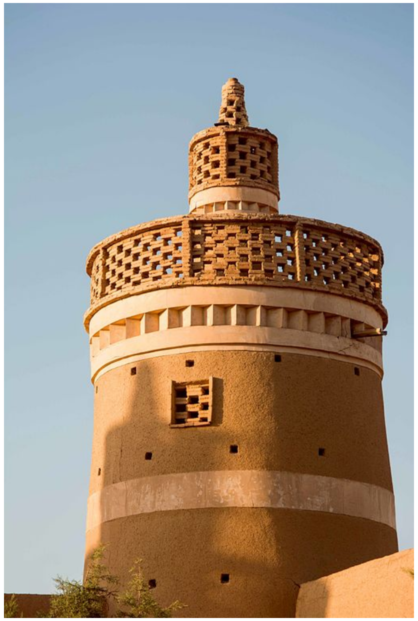
More pigeons than holes = Some pigeons have to share!



Pigeonhole Principle intuition

More pigeons than holes = Some pigeons have to share!





String hashing

m = 950 strings

n = 100 buckets

Is there a bucket with **at least 10 entries?**

A) Yes

B) No

C) Don't know

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String hashing

m = 950 strings

n = 100 buckets

Is there a bucket with **at least 9 entries?**

A) Yes

B) No

C) Don't know

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String hashing

m = 950 strings

n = 100 buckets

Is there a bucket with
at least 11 entries?

A) Yes

B) No

C) Don't know

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String hashing

m = 950 strings

n = 100 buckets

Can there be a bucket that is **empty?**

A) Yes

B) No

C) Don't know

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Break time!

Course Logistics

Course Website

https://cs109.stanford.edu/

Teaching assistants

Michela Meister

Yuling Liu

Brendan Corcoran

Prereqs

CS 106B/X

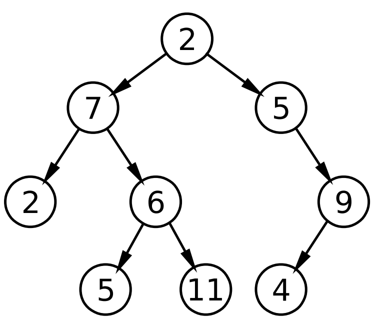
Programming
Recursion
Hash tables
Binary trees

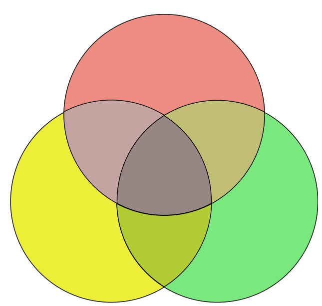
CS 103

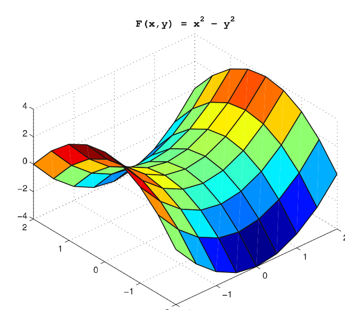
Proofs (induction)
Set theory

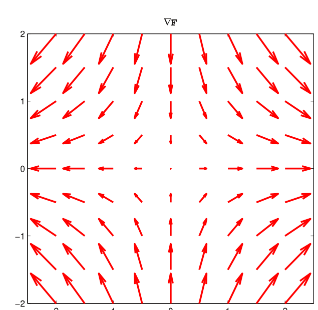
MATH 51/ CME 100

Multivariate differentiation
Multivariate integration
Basic linear algebra
(what's a vector?)









Contacting us

Office hours

Forum

cs109-sum1617-staff@lists.stanford.edu

Email

Units

Undergrads and SCPD students

$\boxed{5}$

Grad students

3,4,5

(same amount of work! ~10 hours/week for assignments)

Recorded lectures

https://mvideox.stanford.edu/

Late days

[updated July 14]

~~3~~ $\boxed{4}$

free 24-hour “extensions”

Grade components

45%	6 problem sets
20%	Midterm exam Tuesday, July 25, 7:00-9:00pm [email staff ASAP with conflicts]
30%	Final exam Saturday, August 19, 12:15-3:15pm [no alternate time!]
5%	Participation: Piazza, feedback

Honor code

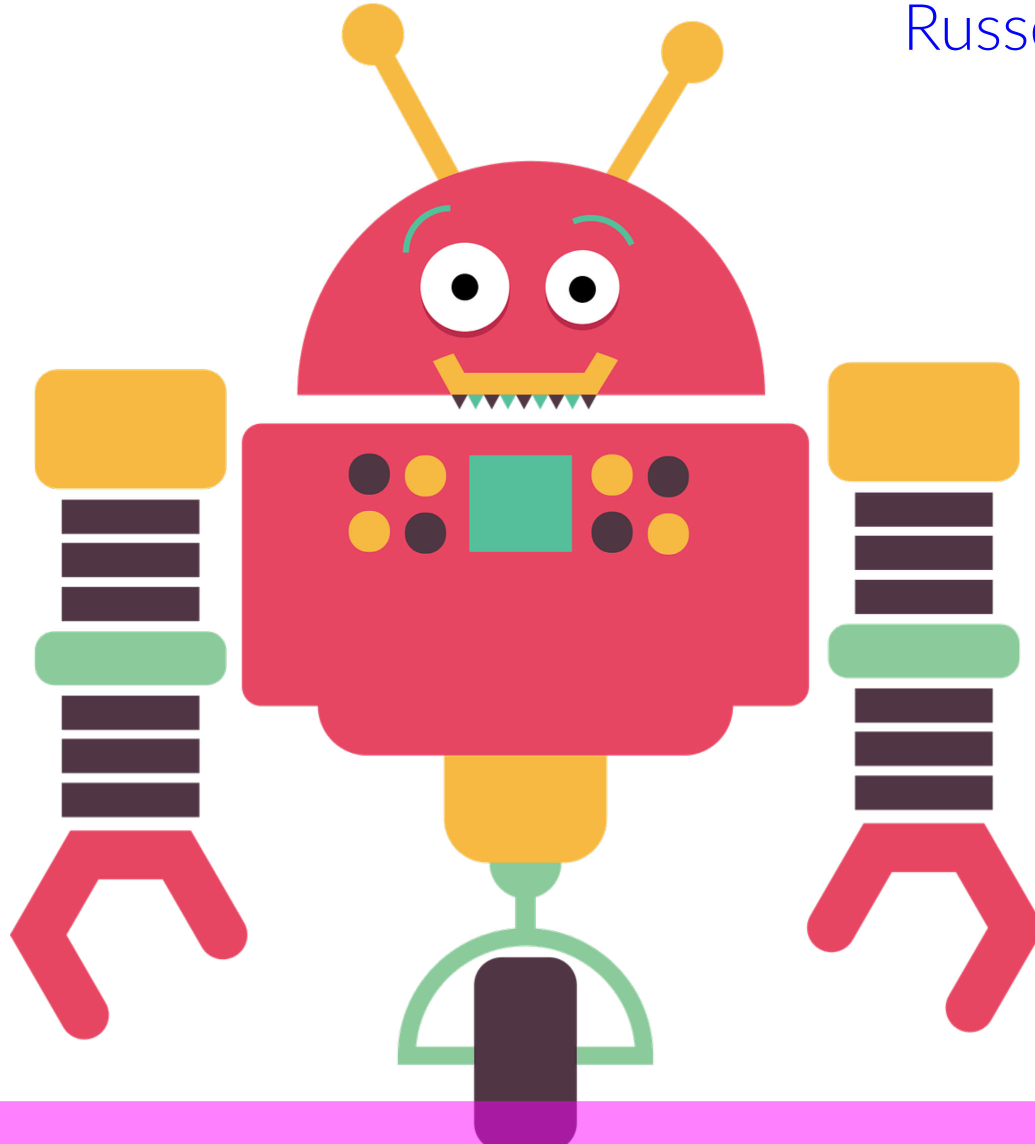
You may:

Talk with the course staff
Talk with classmates
(cite collaboration)
Look up general material online

You may not:

Copy answers:
from classmates
from former students
from the Internet
Look at previous quarters' solutions

further reading:
Russell & Norvig (2009)

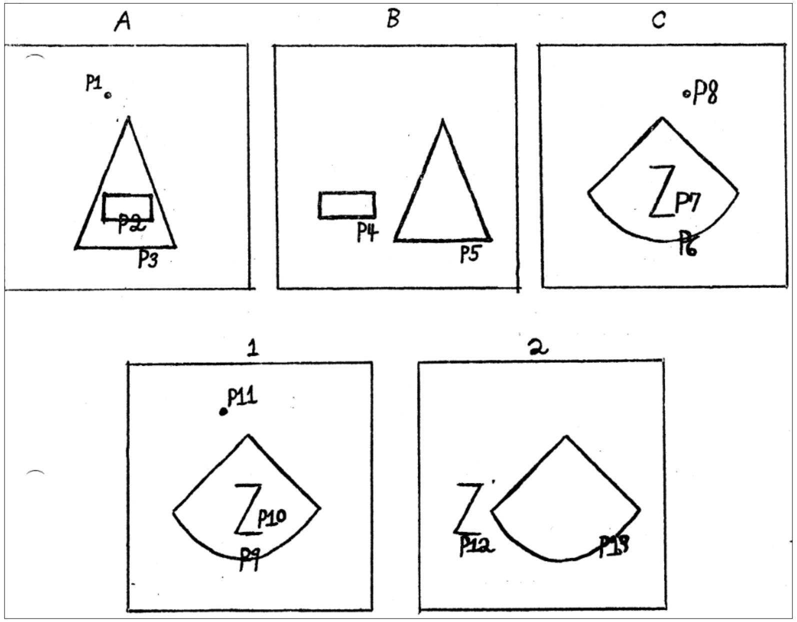


A very brief history of AI

Early AI optimism

1952

1962



Evans (1962)

Early AI optimism

"...in a visible future—the range of problems [AIs] can handle will be coextensive with the range to which the human mind has been applied."

–Herbert Simon, 1957
(quoted in Russell & Norvig, 2003)

Disillusionment (1974-1980)

"The spirit is willing but the flesh is weak"

↓

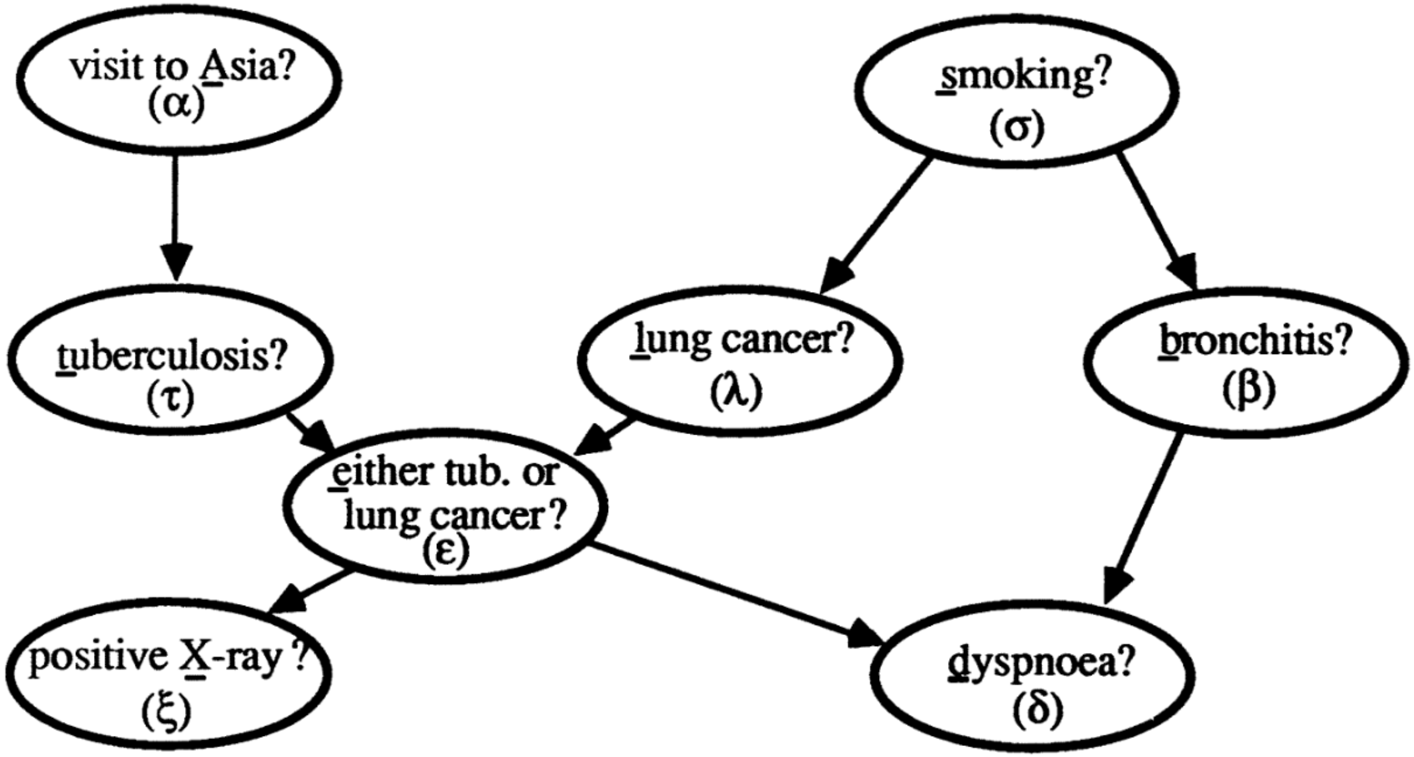
(a plausible Russian translation) "Спирт готов но мясо слабо."

↓

"The vodka is good but the meat is rotten"

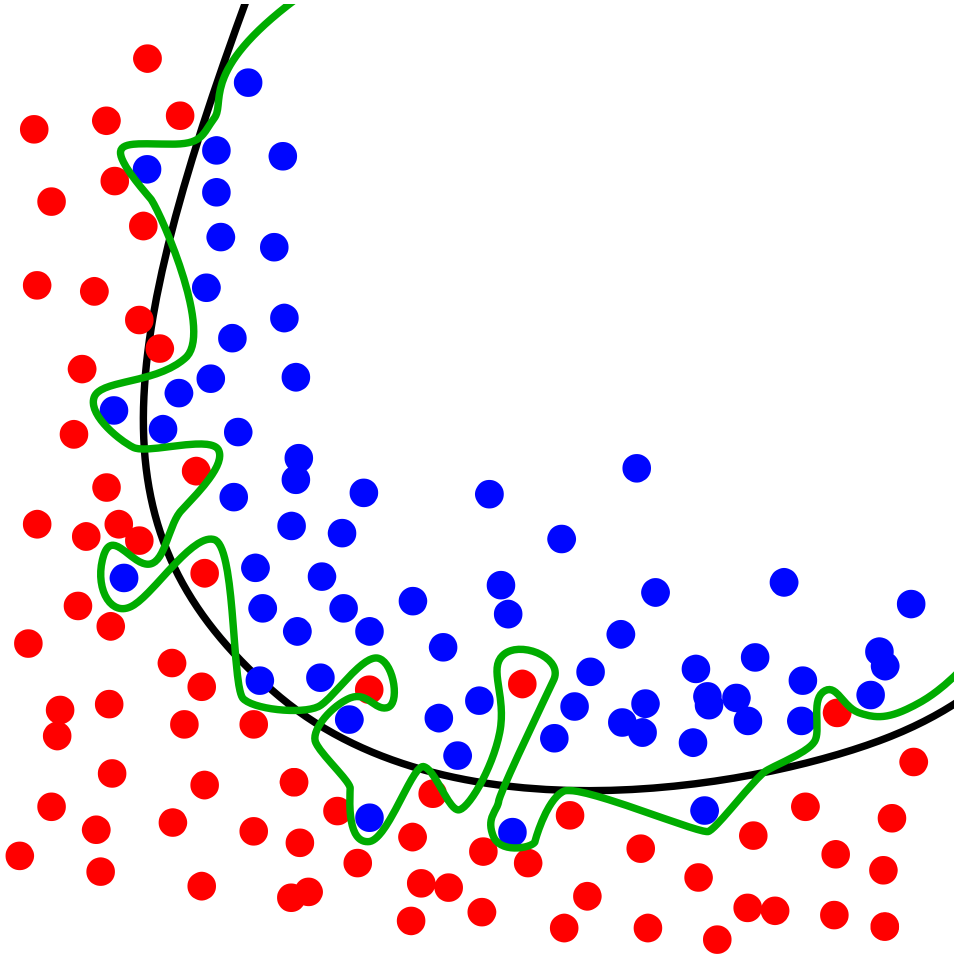

BRACE YOURSELVES
WINTER IS COMING

Expert systems (1980s)



Lauritzen & Spiegelhalter (1988)

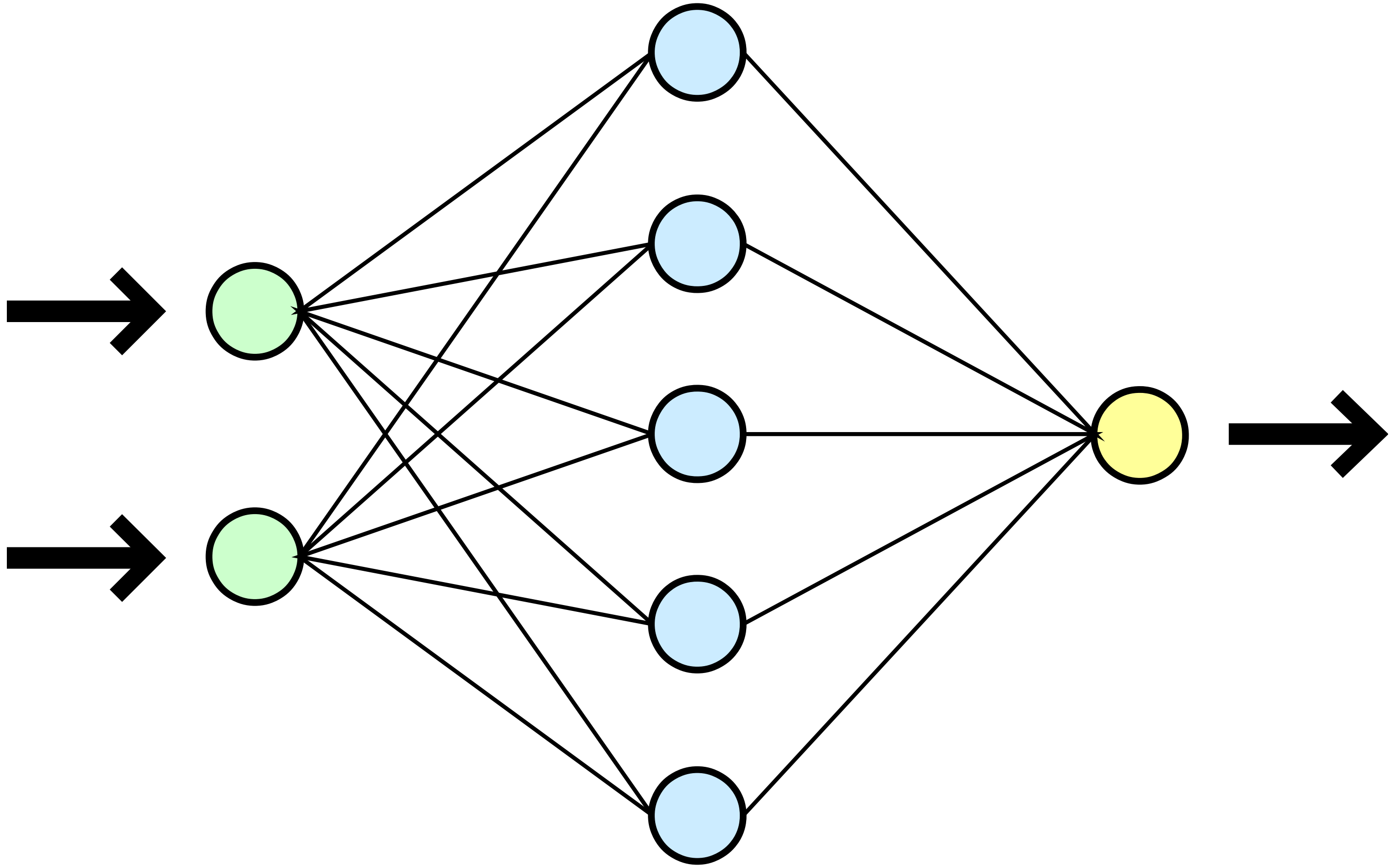
The statistical revolution (1990s)



examples → probability

picture: Ignacio Icke

Neural nets return (2000s)

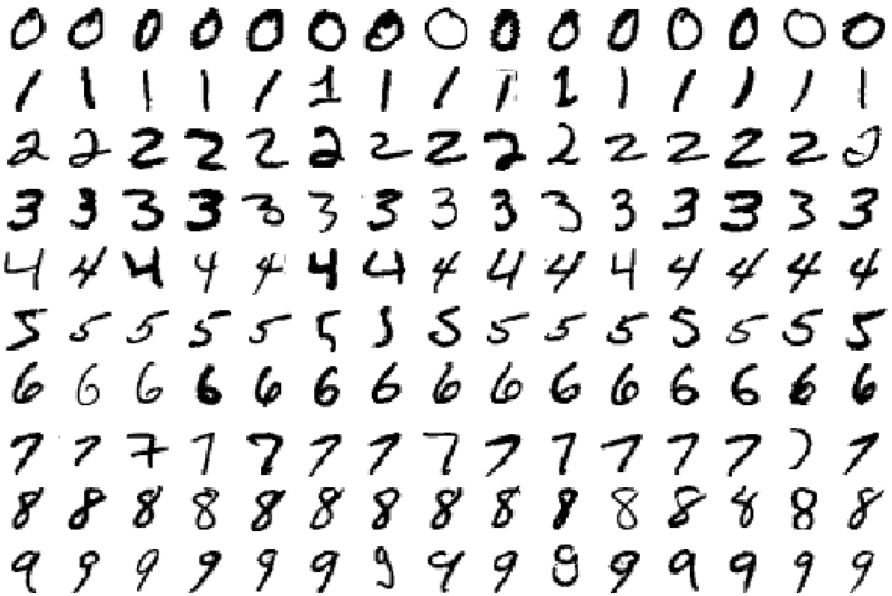


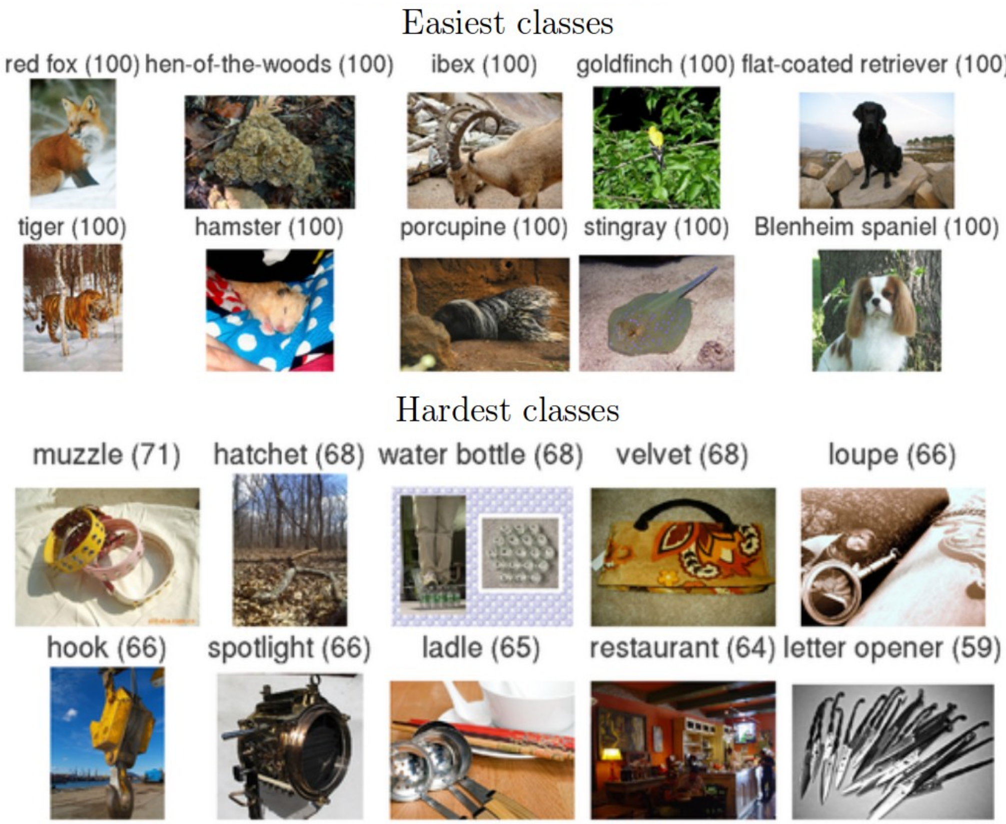
picture: Dake, Mysid

Speech recognition

who is the current president of France?

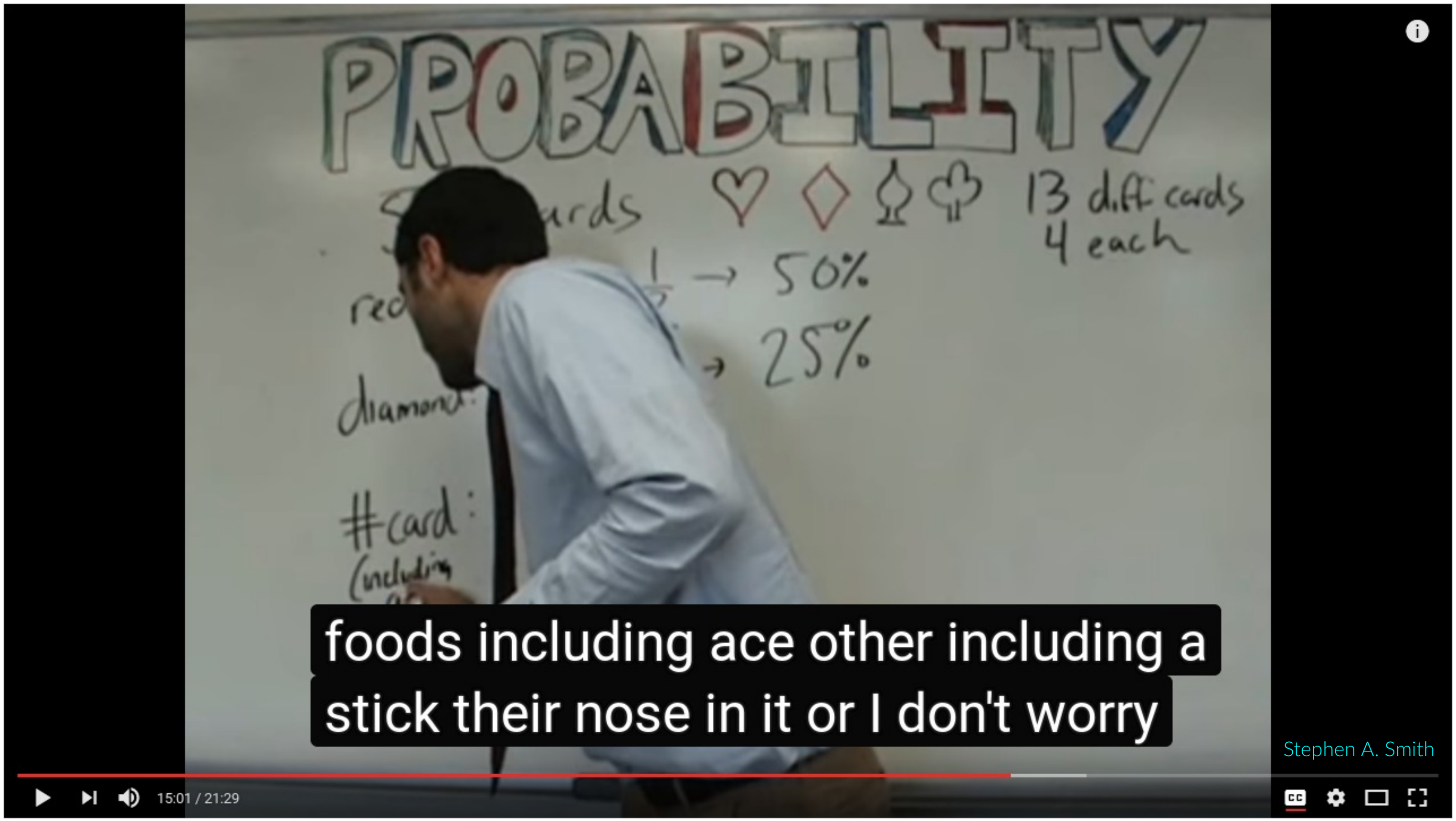
Image classification





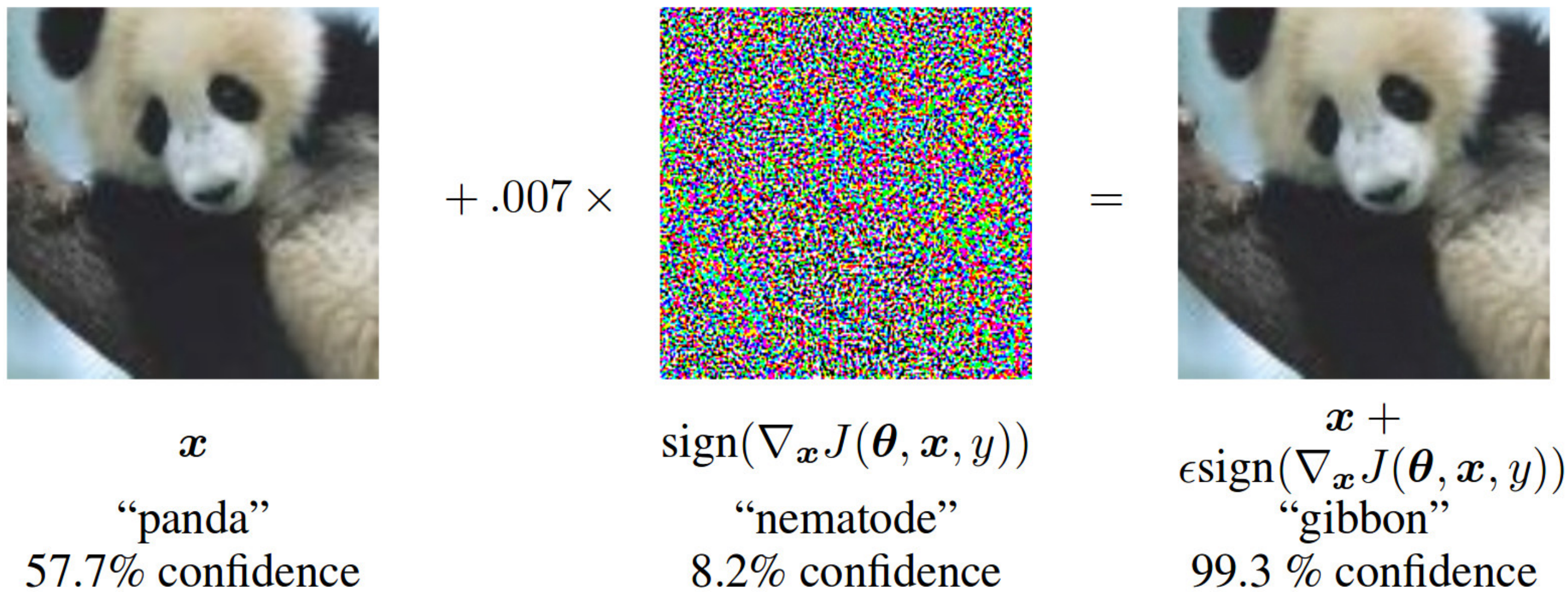
right: Russakovsky et al. (2015)

Solving speech recognition?



Teacher: ...includes— including ace.
Student: 40.
Teacher: (writing) —including—ace.
Student: Isn't it 4 out of 40...?

Solving object recognition?



Goodfellow et al. (2015)

Solving question answering?