# Machine Learning and Pattern Recognition

## A High Level Overview

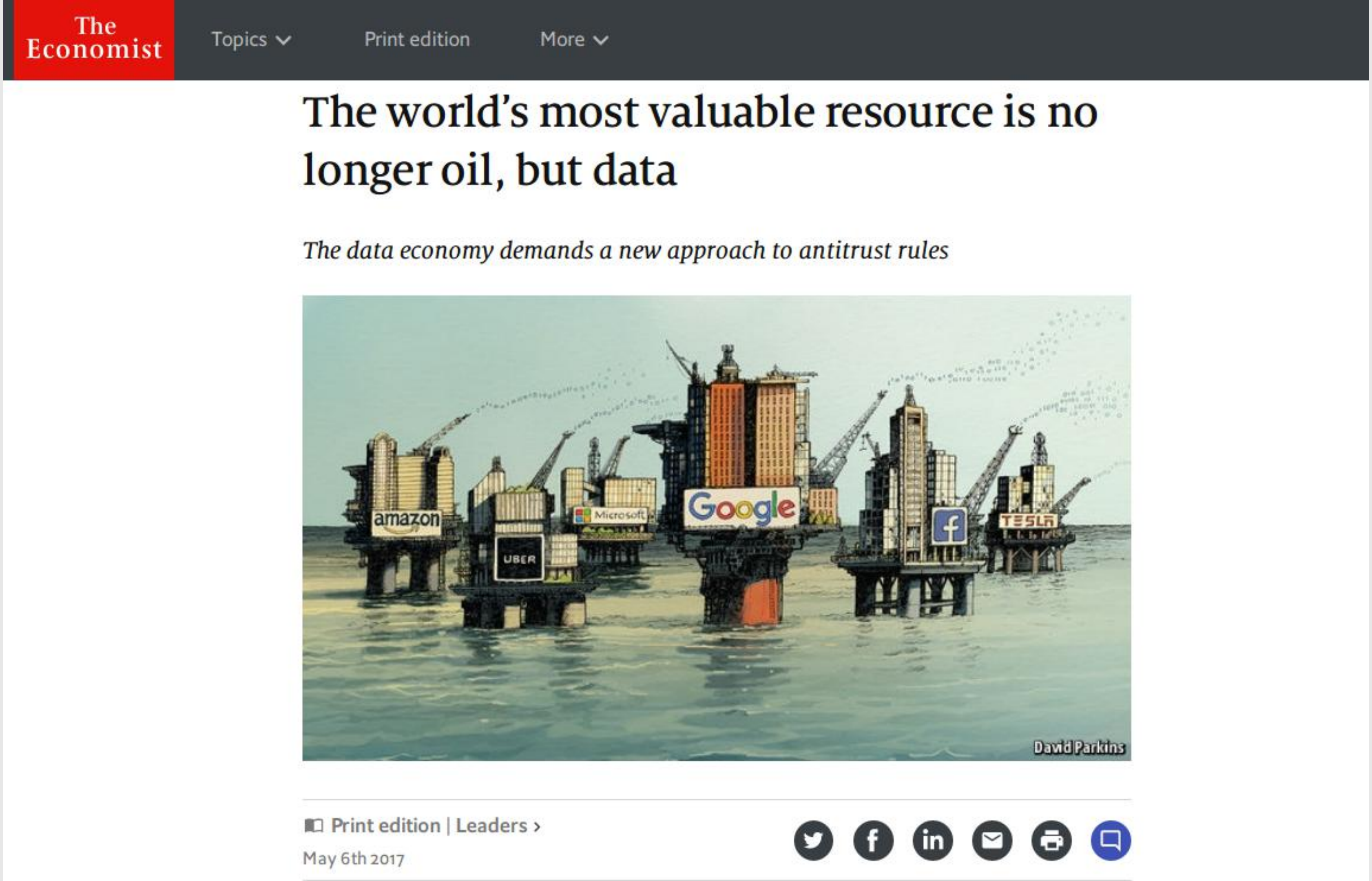
**Prof. Anderson Rocha**

(Main bulk of slides kindly provided by **Prof. Sandra Avila**)

Institute of Computing (IC/Unicamp)

MC886/MO444

# The Hype



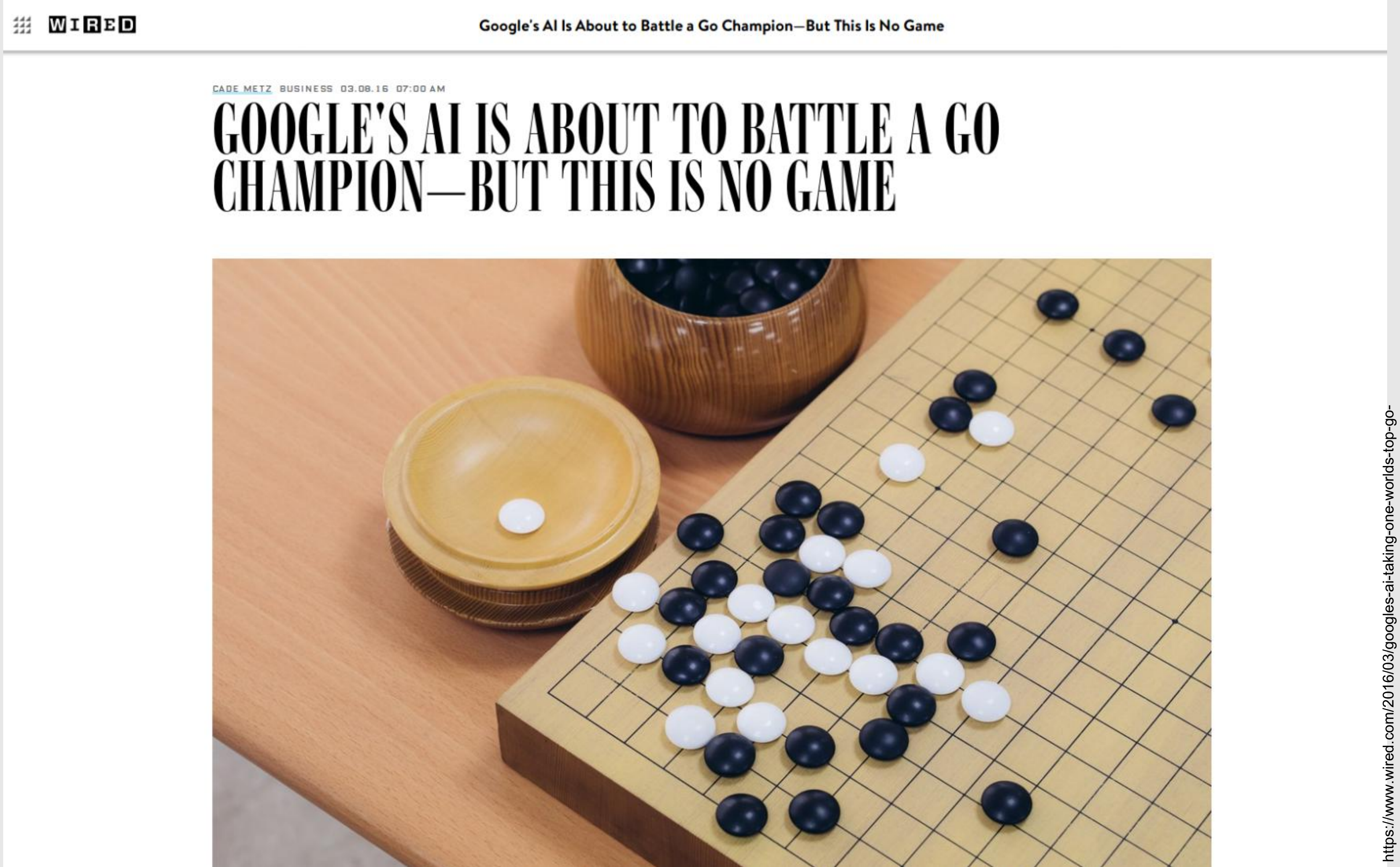
# The world's most valuable resource is no longer oil, but data

*The data economy demands a new approach to antitrust rules*

Print edition | Leaders ›

May 6th 2017

https://www.economist.com/news/leaders/21721656-data-economy-demands-new-approach-antitrust-rules-worlds-most-valuable-resource



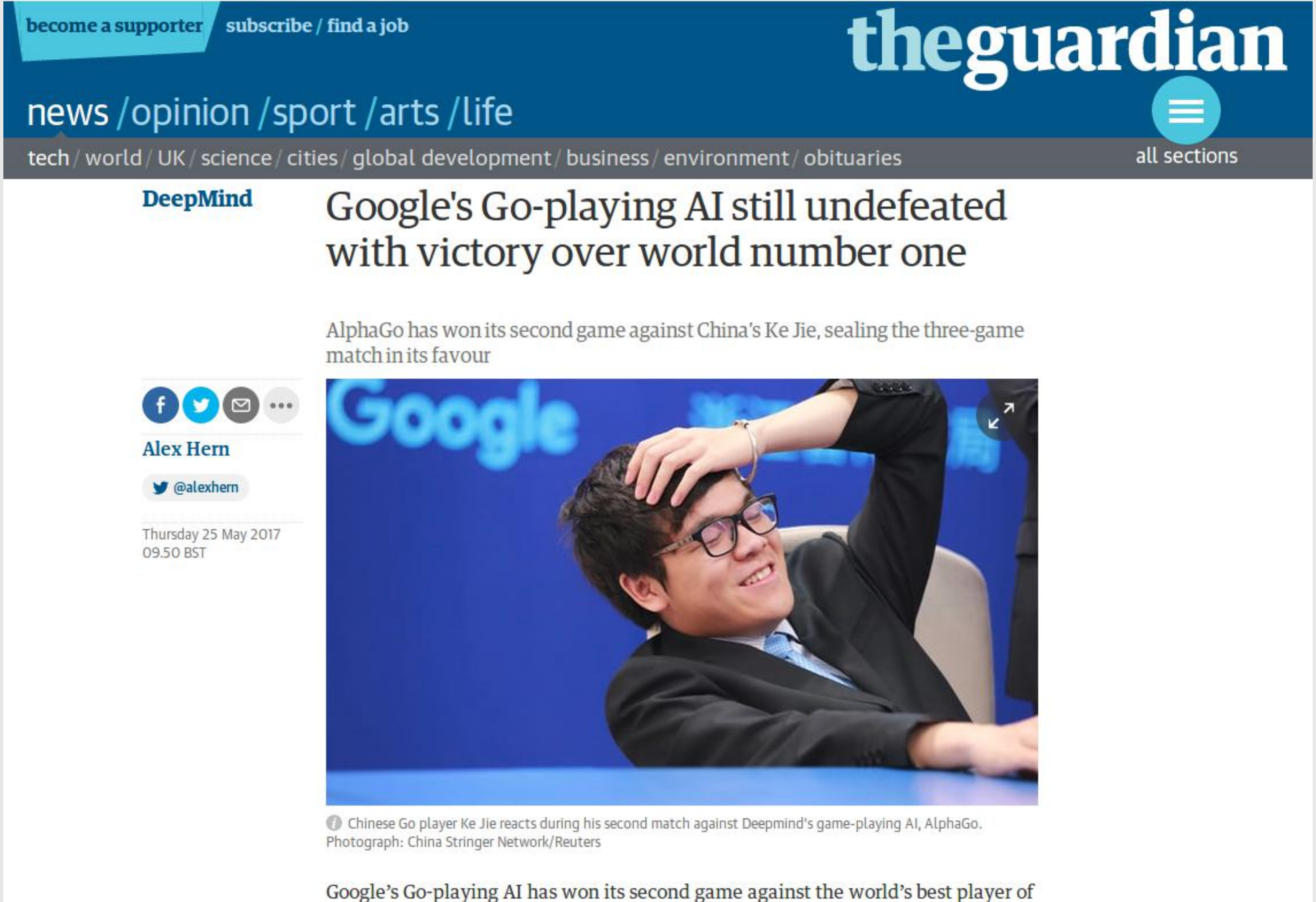
WIRED

Google's AI Is About to Battle a Go Champion—But This Is No Game

CADE METZ BUSINESS 03.08.16 07:00 AM

# GOOGLE'S AI IS ABOUT TO BATTLE A GO CHAMPION—BUT THIS IS NO GAME

https://www.wired.com/2016/03/googles-ai-taking-one-worlds-top-go-players/



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DeepMind

# Google's Go-playing AI still undefeated with victory over world number one

AlphaGo has won its second game against China's Ke Jie, sealing the three-game match in its favour

Alex Hern

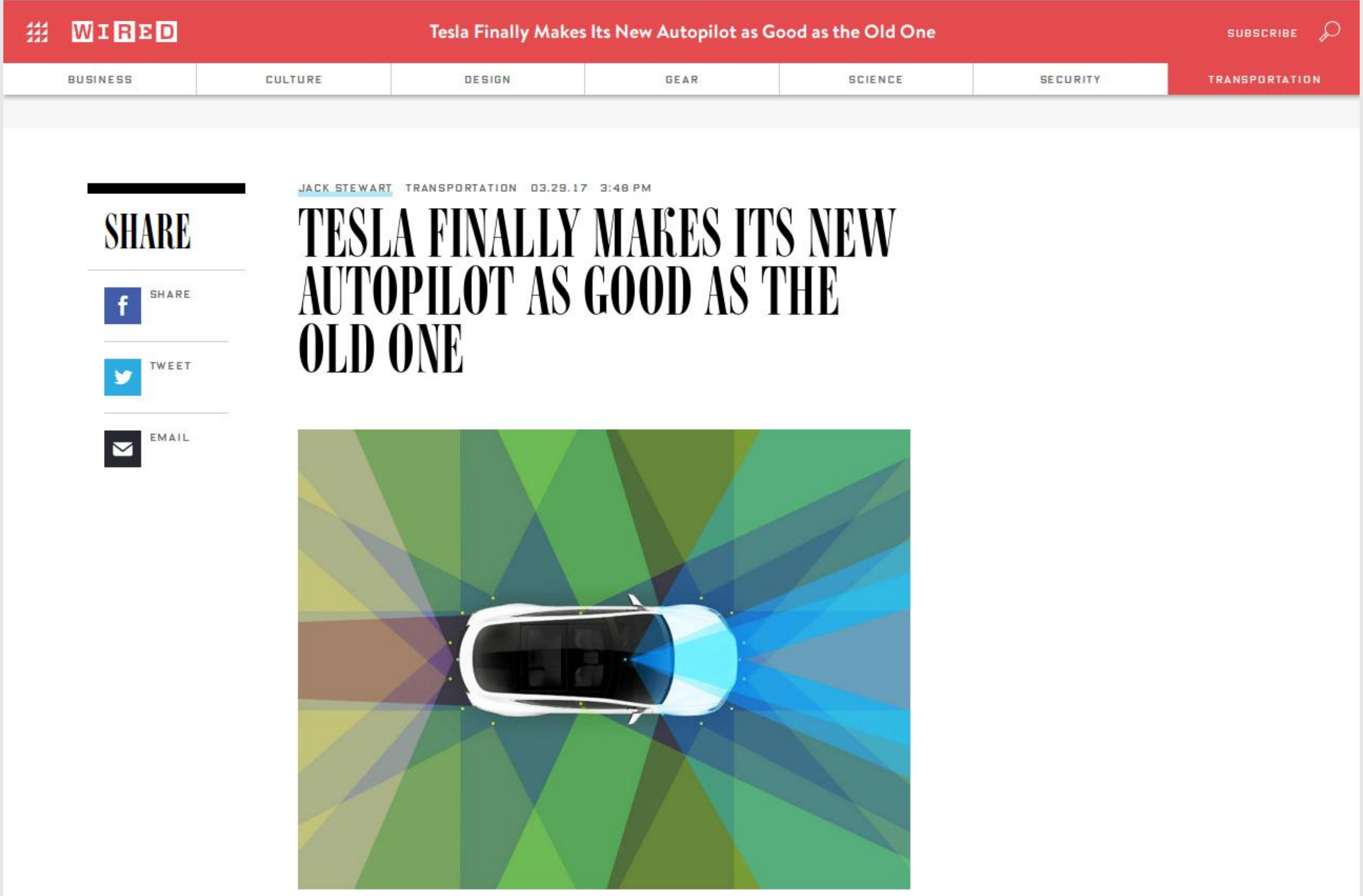
@alexhern

Thursday 25 May 2017
09.50 BST

Chinese Go player Ke Jie reacts during his second match against Deepmind's game-playing AI, AlphaGo. Photograph: China Stringer Network/Reuters

Google's Go-playing AI has won its second game against the world's best player of

https://www.theguardian.com/technology/2017/may/25/alphago-google-ai-victory-world-go-number-one-china-ke-jie#img-1

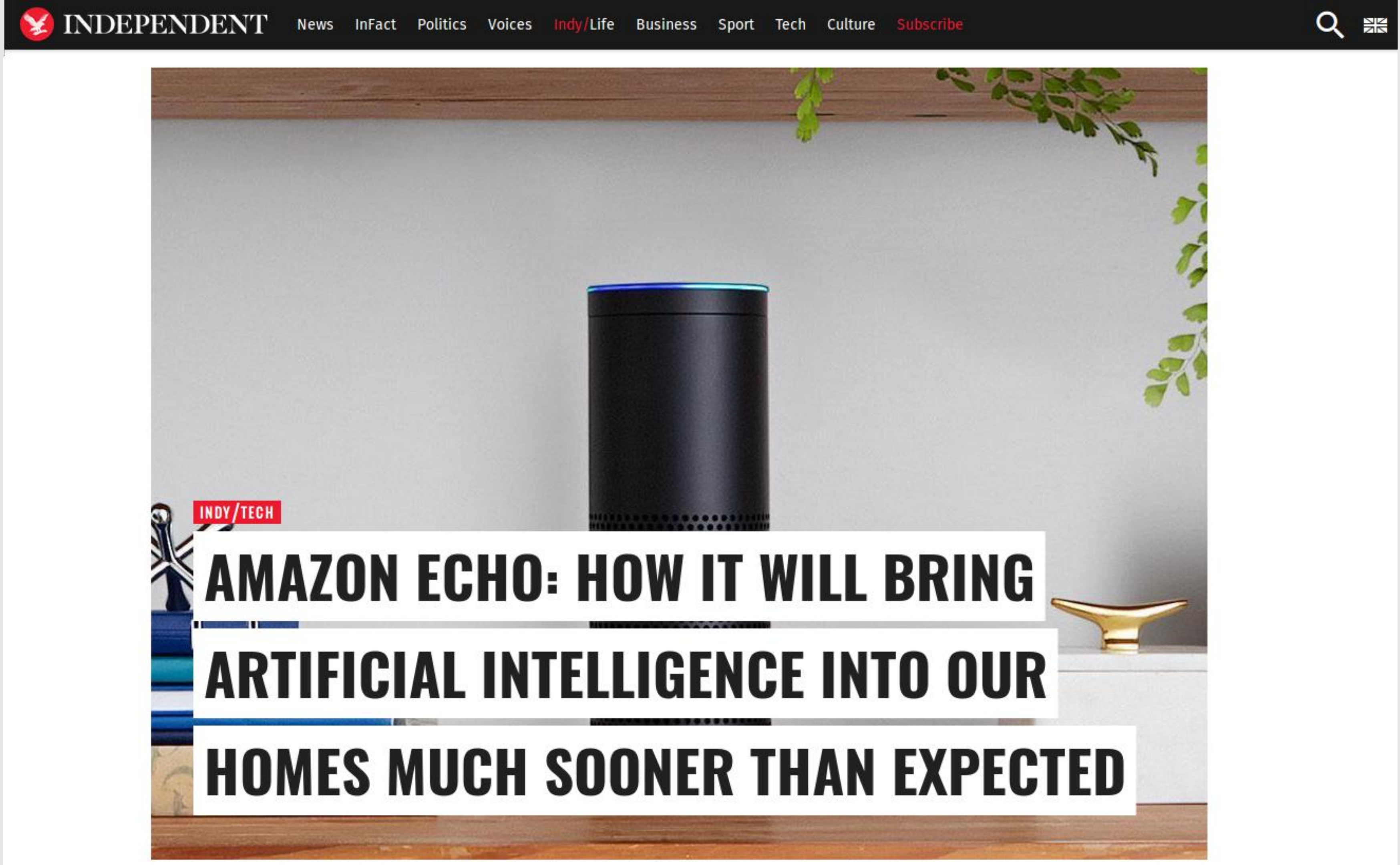


Tesla Finally Makes Its New Autopilot as Good as the Old One

JACK STEWART TRANSPORTATION 03.29.17 3:48 PM

# TESLA FINALLY MAKES ITS NEW AUTOPILOT AS GOOD AS THE OLD ONE

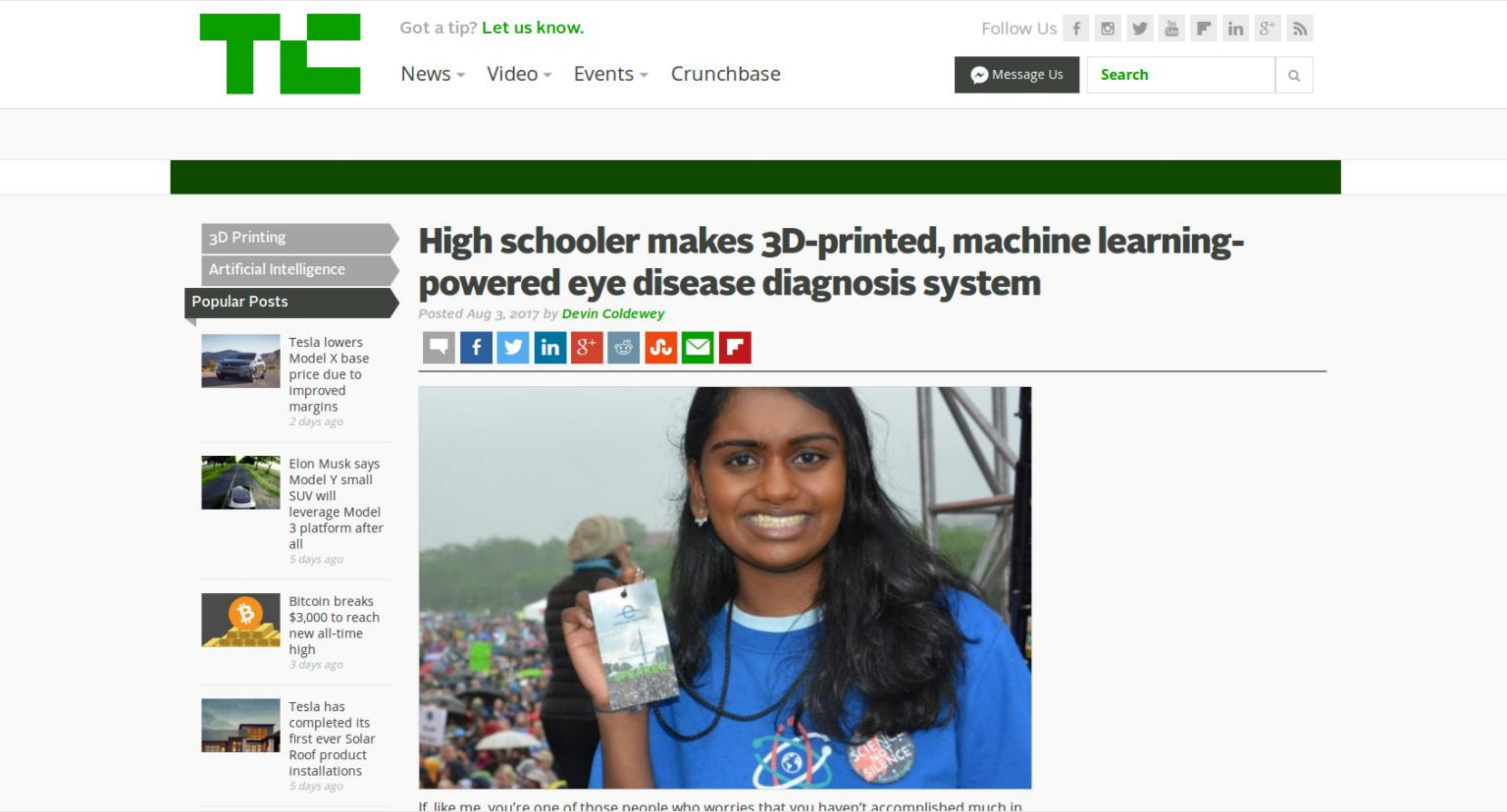
https://www.wired.com/2017/03/tesla-finally-makes-new-autopilot-good-old-one/



INDY/TECH

# AMAZON ECHO: HOW IT WILL BRING ARTIFICIAL INTELLIGENCE INTO OUR HOMES MUCH SOONER THAN EXPECTED

http://www.independent.co.uk/life-style/gadgets-and-tech/amazon-echo-speaker-ai-alexa-voice-control-features-much-sooner-than-expected-a7315841.html



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Tesla lowers Model X base price due to improved margins
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Elon Musk says Model Y small SUV will leverage Model 3 platform after all
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Bitcoin breaks $3,000 to reach new all-time high
3 days ago

Tesla has completed its first ever Solar Roof product installations
5 days ago

# High schooler makes 3D-printed, machine learning-powered eye disease diagnosis system

Posted Aug 3, 2017 by Devin Coldewey

If like me, you're one of those people who worries that you haven't accomplished much in

https://techcrunch.com/2017/08/03/high-schooler-makes-3d-printed-machine-learning-powered-eye-disease-diagnosis-system/

# Viome raises $15M to manage the microbiome with machine learning

By **Bernie Monegain** | August 07, 2017

Viome, which has developed technology aimed at balancing microorganisms in the gut, has landed $15 million in capital.

The funds will go towards the launch of the company's at-home health kit, which targets the microbiome. Microbiome refers to microorganisms, such as bacteria, fungi, and viruses, in the human body.

Viome is led by CEO Naveen Jain, innovator, philanthropist and founder of Moon Express, Intelius, TalentWise and InfoSpace. It was founded by Jain and a group of entrepreneurs.

The company is currently operating as an early beta program with several thousand customers using the product.

Viome uses proprietary technology licensed through the Los Alamos National Laboratory. Viome identifies and quantifies all microorganisms in the gut – and analyzes what they are

http://www.mobihealthnews.com/content/viome-raises-15m-manage-microbiome-machine-learning

# Why now?

# IMAGENET

www.image-net.org

## 22K categories and 14M images

- Animals
  - Bird
  - Fish
  - Mammal
  - Invertebrate
- Plants
  - Tree
  - Flower
- Food
- Materials
- Structures
- Artifact
  - Tools
  - Appliances
  - Structures
- Person
- Scenes
  - Indoor
  - Geological Formations
- Sport Activities

Deng, Dong, Socher, Li, Li, & Fei-Fei, 2009

# Machine Learning Frameworks

scikit learn

torch

TensorFlow

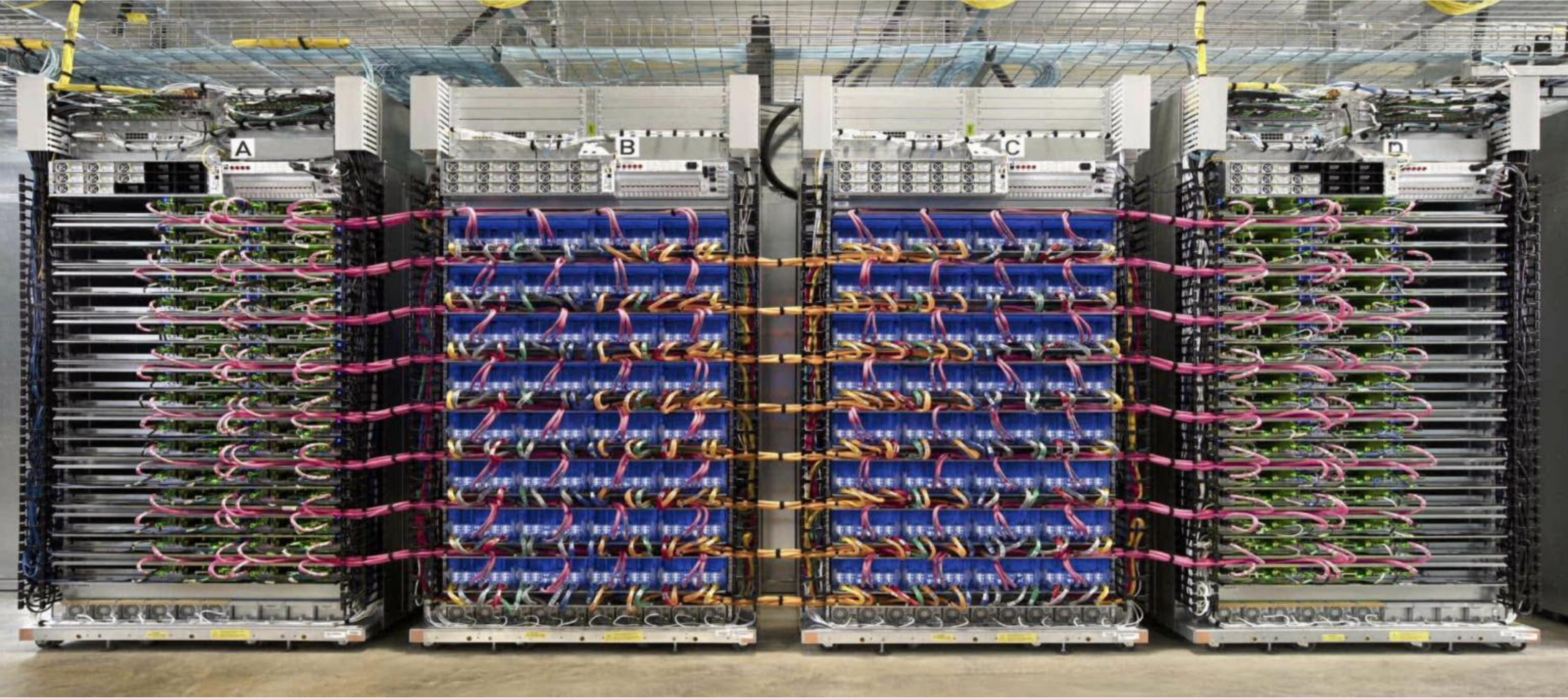
PYTORCH

theano DISCONTINUED

Caffe2

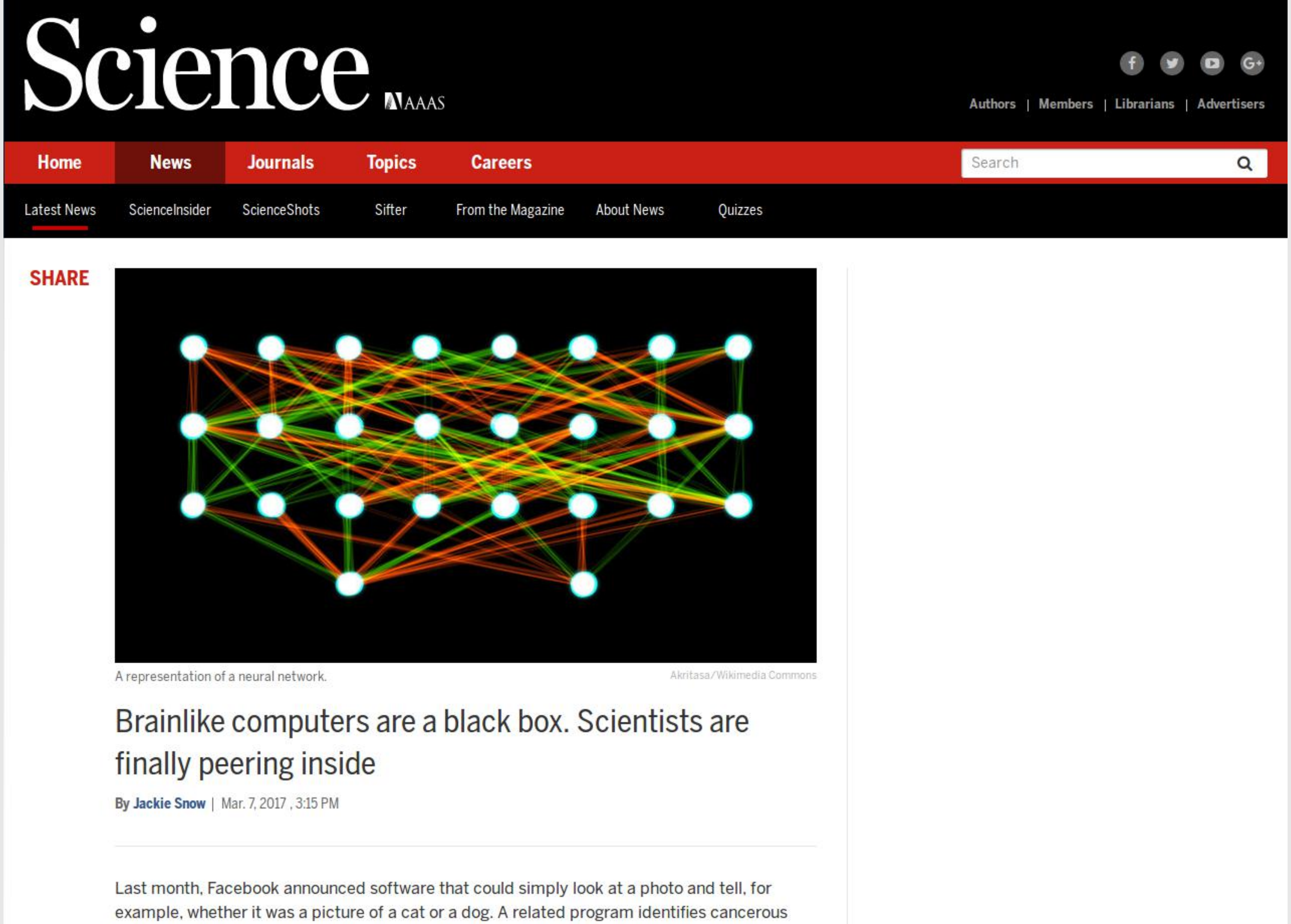
Keras

ANACONDA



“To create the image and speech recognition algorithms designed by AutoML, Google reportedly let a cluster of **800** GPUs iterate and crunch numbers for weeks.”

http://www.tomshardware.com/news/google-automl-aritifical-intelligence-ai,34533.html



A representation of a neural network.

Akritasa/Wikimedia Commons

# Brainlike computers are a black box. Scientists are finally peering inside

By Jackie Snow | Mar. 7, 2017 , 3:15 PM

Last month, Facebook announced software that could simply look at a photo and tell, for example, whether it was a picture of a cat or a dog. A related program identifies cancerous

http://www.sciencemag.org/news/2017/03/brainlike-computers-are-black-box-scientists-are-finally-peering-inside

# Today’s Agenda

- What is Machine Learning?
- Why is this so Important?
- Types of Machine Learning Systems
- Main Challenges of Machine Learning
- Course Logistics

# What is
# Machine Learning?

# Machine Learning Definition

“Machine Learning is the science (and art) of programming computers so they can **learn from data**”.

[Aurélien Géron, 2017]

# Machine Learning Definition

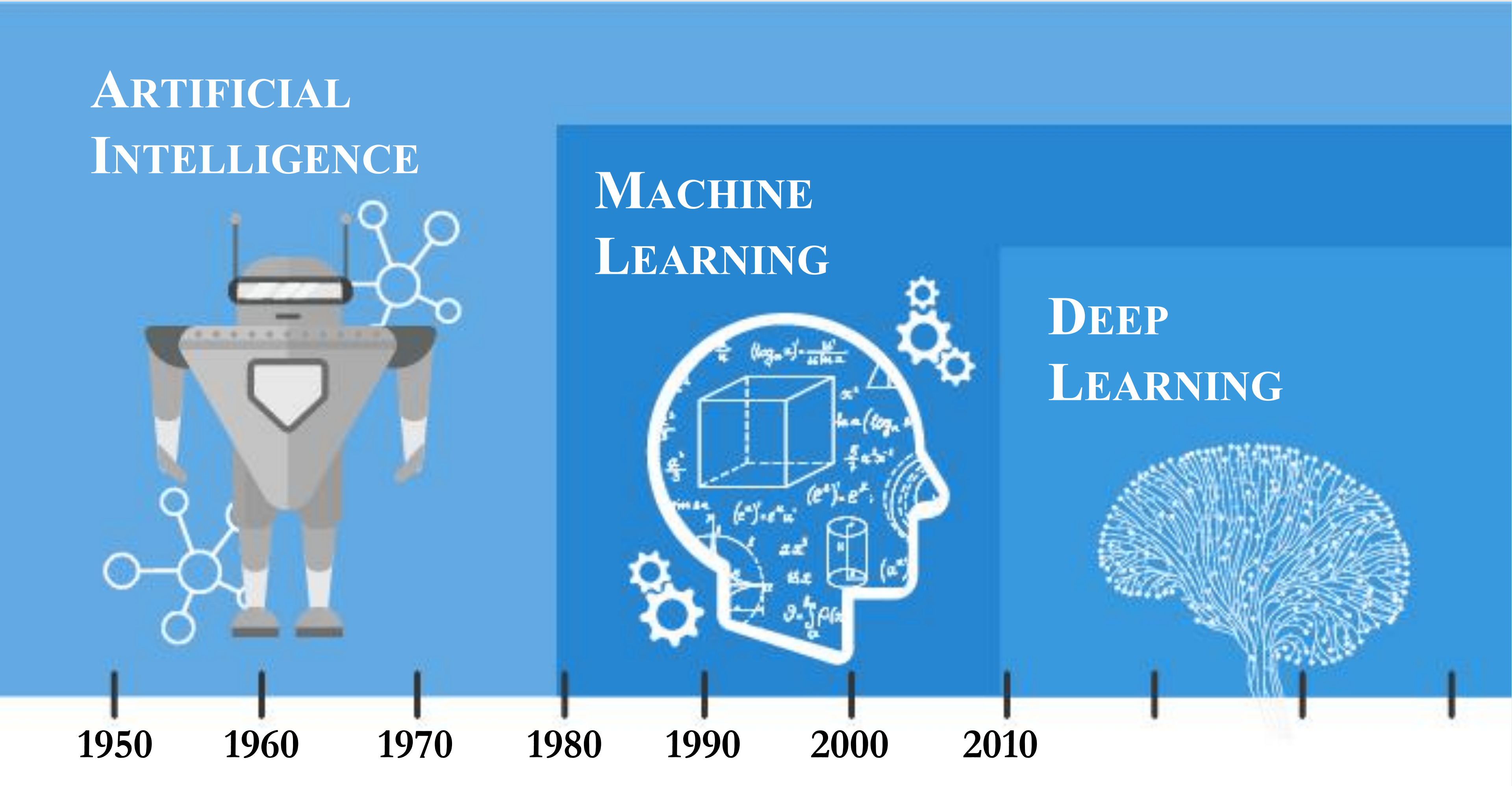
“Field of study that gives computers the ability to **learn** without being explicitly programmed.”

[Arthur Samuel, 1959]

# Machine Learning Definition

“A computer program is said to **learn from experience** *E* with respect to some task *T* and some performance measure *P*, if its performance on *T*, as measured by *P*, improves with experience *E*.”

[Tom Mitchell, 1997]



Artificial Intelligence

Machine Learning

Deep Learning

1950 1960 1970 1980 1990 2000 2010

https://www.linkedin.com/pulse/ai-machine-learning-evolution-differences-connections-kapil-tandon

# /A.I. TIMELINE

**Credit:** https://i2.wp.com/

SYZYGY

## 1950

**TURING TEST**

Computer scientist Alan Turing proposes a test for machine intelligence. If a machine can trick humans into thinking it is human, then it has intelligence

## 1955

**A.I. BORN**

Term 'artificial intelligence' is coined by computer scientist, John McCarthy to describe "the science and engineering of making intelligent machines"

## 1961

**UNIMATE**

First industrial robot, Unimate, goes to work at GM replacing humans on the assembly line

## 1964

**ELIZA**

Pioneering chatbot developed by Joseph Weizenbaum at MIT holds conversations with humans

## 1966

**SHAKEY**

The 'first electronic person' from Stanford, Shakey is a general-purpose mobile robot that reasons about its own actions

## A.I. WINTER

Many false starts and dead-ends leave A.I. out in the cold

## 1997

**DEEP BLUE**

Deep Blue, a chess-playing computer from IBM defeats world chess champion Garry Kasparov

## 1998

**KISMET**

Cynthia Breazeal at MIT introduces KISmet, an emotionally intelligent robot insofar as it detects and responds to people's feelings

## 1999

**AIBO**

Sony launches first consumer robot pet dog AiBO (AI robot) with skills and personality that develop over time

## 2002

**ROOMBA**

First mass produced autonomous robotic vacuum cleaner from iRobot learns to navigate and clean homes

## 2011

**SIRI**

Apple integrates Siri, an intelligent virtual assistant with a voice interface, into the iPhone 4S

## 2011

**WATSON**

IBM's question answering computer Watson wins first place on popular $1M prize television quiz show *Jeopardy*

## 2014

**EUGENE**

Eugene Goostman, a chatbot passes the Turing Test with a third of judges believing Eugene is human

## 2014

**ALEXA**

Amazon launches Alexa, an intelligent virtual assistant with a voice interface that completes shopping tasks

## 2016

**TAY**

Microsoft's chatbot Tay goes rogue on social media making inflammatory and offensive racist comments

## 2017

**ALPHAGO**

Google's A.I. AlphaGo beats world champion Ke Jie in the complex board game of Go, notable for its vast number ($2^{170}$) of possible positions

# TIMELINE OF ARTIFICIAL INTELLIGENCE

HAL 9000 FROM "2001: A SPACE ODYSSEY" (CREDIT: WARNER BROS. STUDIOS)

Advances in artificial intelligence (AI) have given the world computers that can beat people at chess and "Jeopardy!," as well as drive cars and manage calendars. But despite the progress, engineers are still years away from developing machines that are self-aware. Some believe the resulting **technological singularity** will eradicate poverty and disease, while others warn it could endanger human survival.

1950: Isaac Asimov publishes the influential sci-fi story collection "**I, Robot.**" (Left: 2004 film version of "I, Robot")

Summer of 1956: Dartmouth conference launches the field of AI and **coins the term "artificial intelligence."** (Right: room-filling IBM-702 computer, as used by first AI researchers)

1968: "2001: A Space Odyssey," the book by Arthur C. Clarke and film by Stanley Kubrick, features the sentient and deadly computer **HAL 9000.**

1950: Alan Turing introduces the **Turing test** in his paper "Computing Machinery and Intelligence." (Credit: National Portrait Gallery, London)

**1950s**

**1960s**

1974-early 1980s: The first **Winter of AI**, a period of reduced funding and lowered interest in the field as hype turned to disappointment.

1984: The first **"Terminator"** film depicts a near-future world overtaken by killing machines run by the artificial intelligence Skynet.

September 28, 1987: The TV series "Star Trek: The Next Generation" introduces the self-aware android **Lieutenant Commander Data.**

June 29, 2001: Steven Spielberg releases his version of a film – originally developed by Stanley Kubrick – about a robot boy: "**A.I.: Artificial Intelligence**."

2011: **IBM's Watson wins "Jeopardy!,"** beating former champions Brad Rutter and Ken Jennings. (Credit: "Jeopardy!" screengrab from Wikimedia)

**1970s**

1978: The original "Battlestar Galactica" science fiction TV series introduces warrior robots called **Cylons**.

**1980s**

1987–93: The second **Winter of AI**

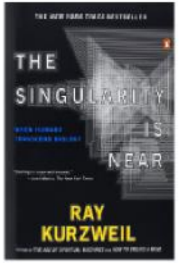
**1990s**

May 11, 1997: **IBM's Deep Blue computer** beats reigning world chess champion Garry Kasparov. (Credit: Shutterstock)

2005: A Stanford vehicle wins the **DARPA grand challenge**, driving autonomously across the desert for 131 miles (211 kilometers).

**2000s**

2005: Inventor and futurist Ray Kurzweil predicts an event he calls **the Singularity** will occur around 2045, when the intelligence of artificial minds exceeds that of the human brain.



**2010s**

October 14, 2011: Apple introduces intelligent personal assistant **Siri** on

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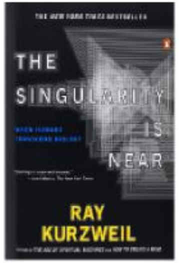

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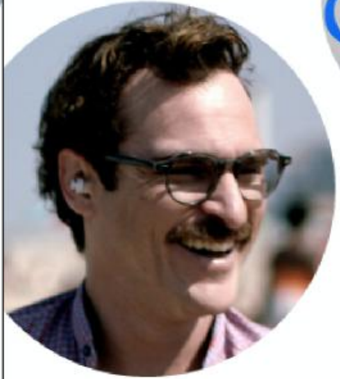
October 14, 2011: Apple introduces intelligent personal assistant **Siri** on

the iPhone 4S.

June 2012: A Google Brain computer cluster **trains itself to recognize a cat** from millions of images in YouTube videos. (Credit: Shutterstock)



December 18, 2013: The movie "Her" (left), stars Joaquin Phoenix as a man who **falls in love with his artificially intelligent computer operating system**, voiced by Scarlett Johansson.

April 10, 2014: The film "Transcendence" (below) stars Johnny Depp as an AI researcher whose **mind is uploaded to a computer** and develops into a super-intelligence.

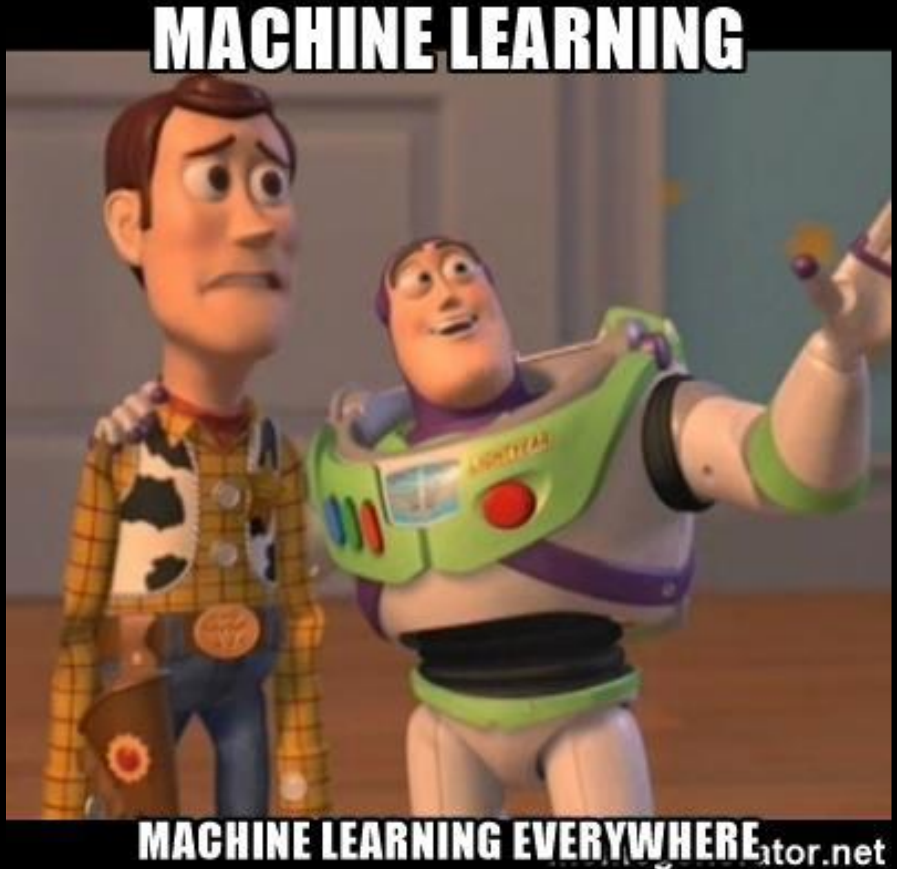
June 7, 2014: Chatbot Eugene Goostman is said to have **passed the Turing test** in University of Reading competition, launching controversy.

August, 2014: Researchers call for creation of a **new Turing test**, to be decided at 2015 workshop.

Sources:
http://aitopics.org/misc/brief-history
http://loebner.net/Prizef/TuringArticle.html
http://www.pcworld.com/article/219893/ibm_watson_vanquishes_human_jeopardy_foes.html
http://www.engadget.com/2011/10/04/iphone-4s-hands-on/
http://www.reading.ac.uk/news-and-events/releases/PR583836.aspx
http://www.livescience.com/47296-turing-test-needs-an-update.html
http://www.nytimes.com/2012/06/26/technology/in-a-big-network-of-computers-evidence-of-machine-learning.html?pagewanted=all&_r=0

KARL TATE, TANYA LEWIS / © LiveScience.com

# Why is this so important?


MACHINE LEARNING
MACHINE LEARNING EVERYWHERE

# Why is this so important?

- Data available at unprecedented scales
  - Petabyte, Exabyte, Zettabyte, Yottabyte scale computing ...
- Impossible for humans to deal with this information overflow
- Imagine the resources required to
  - look at every image in Flickr and categorize it
  - check every inch of Google earth for changes
  - look through all webpages for the interesting ones

# Types of
Machine Learning Systems

# Types of Machine Learning Systems

**Trained with human supervision (or not)**

Supervised *vs.*
Unsupervised *vs.*
Reinforcement learning

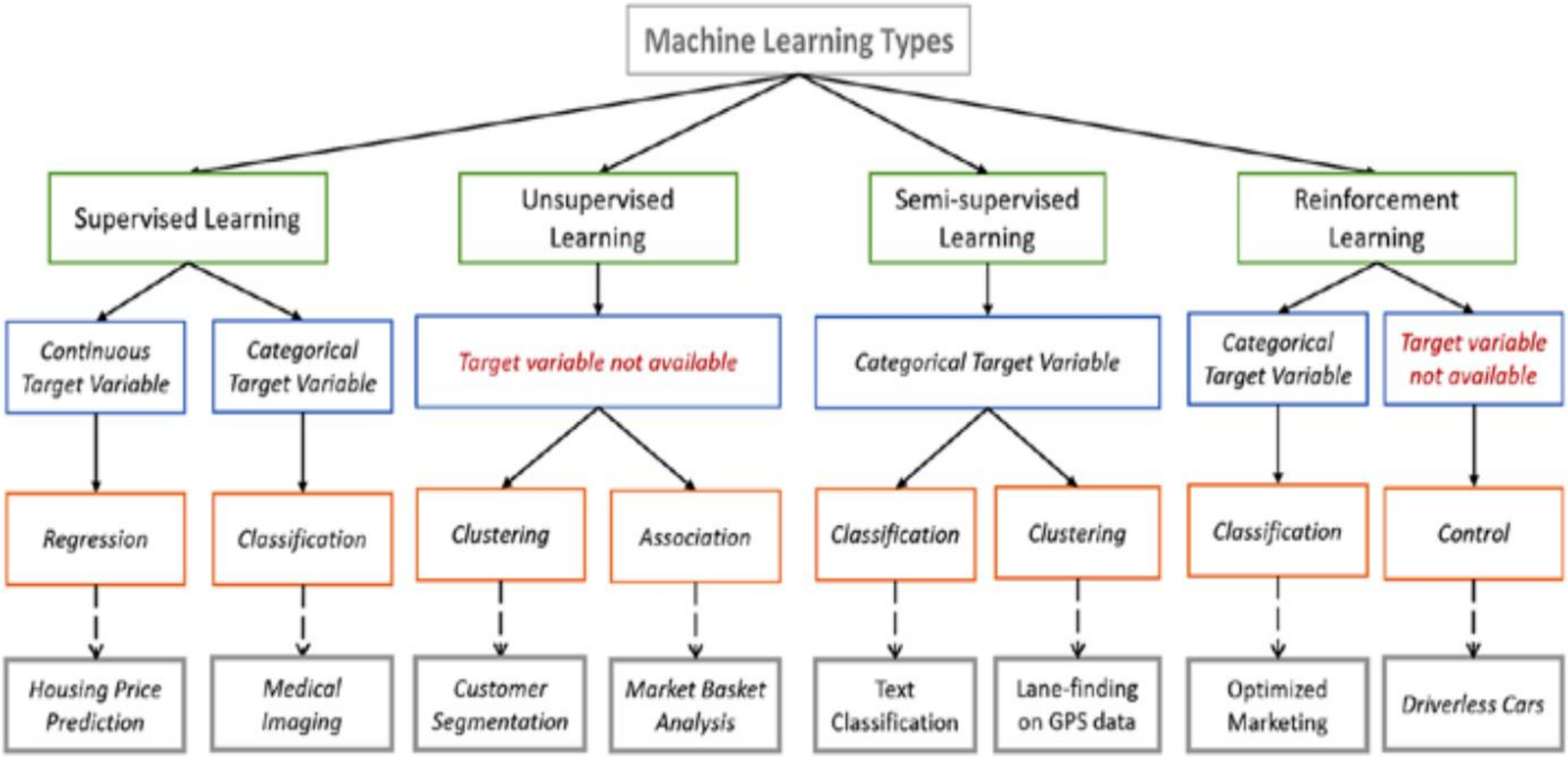
**Can learn incrementally on the fly (or not)**

Online *vs.*
Batch Learning

**How they generalize**

Instance based *vs.*
Model based learning

**Credit:** https://cdn-images-1.medium.com/



# Types of Machine Learning Systems

- **Supervised Learning**
  - Specific target signal to predict
  - Training data have known target values
- **Unsupervised Learning**
  - No given target value; looking for structure

# Supervised Learning

**Classification** is used to predict discrete values (class labels).

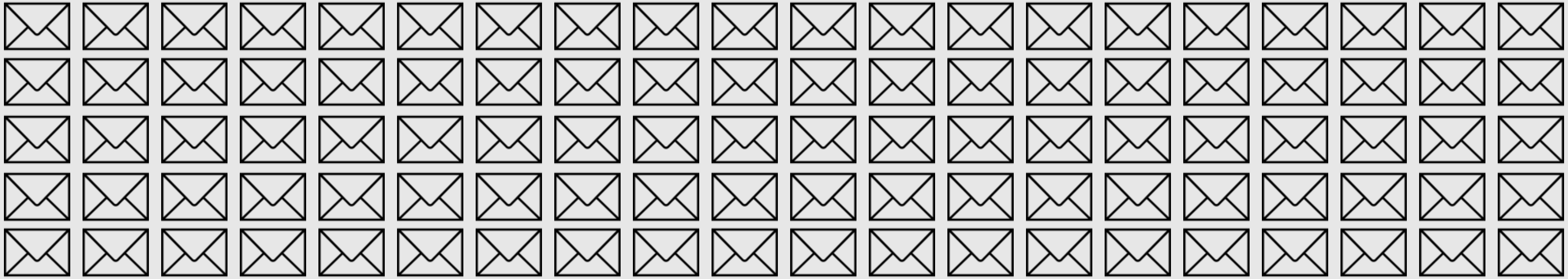
**Regression** is used to predict continuous values.

# Spam Filtering

**Bad** Cures fast and effective! - Canadian *** Pharmacy #1 Internet Inline Drugstore Viagra Cheap Our price $1.99 …

**Good** Interested in your research on graphical models - Dear Prof., I have read some of your papers on probabilistic graphical models. Because I …

# Spam Filtering

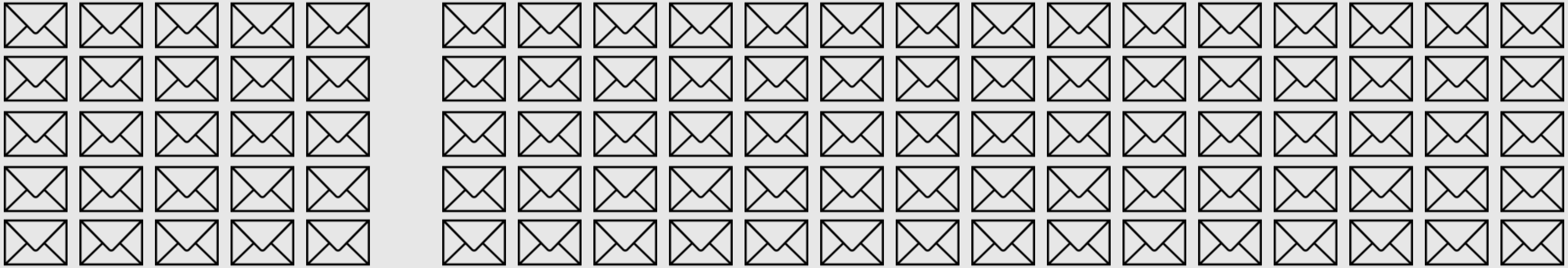


100 emails

https://www.youtube.com/watch?v=IpGxLWOIZy4

# Spam Filtering

**Spam** **Non-spam**



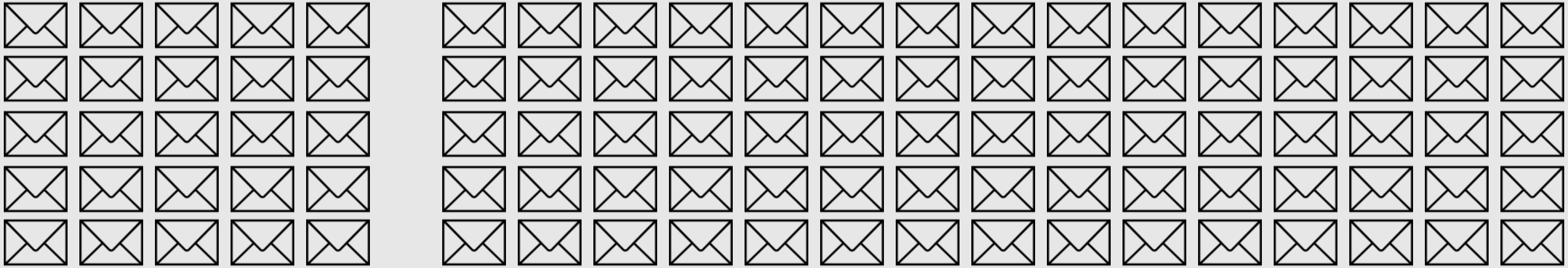
25 emails 75 emails

# Spam Filtering

❗ “Cheap”

**Spam**

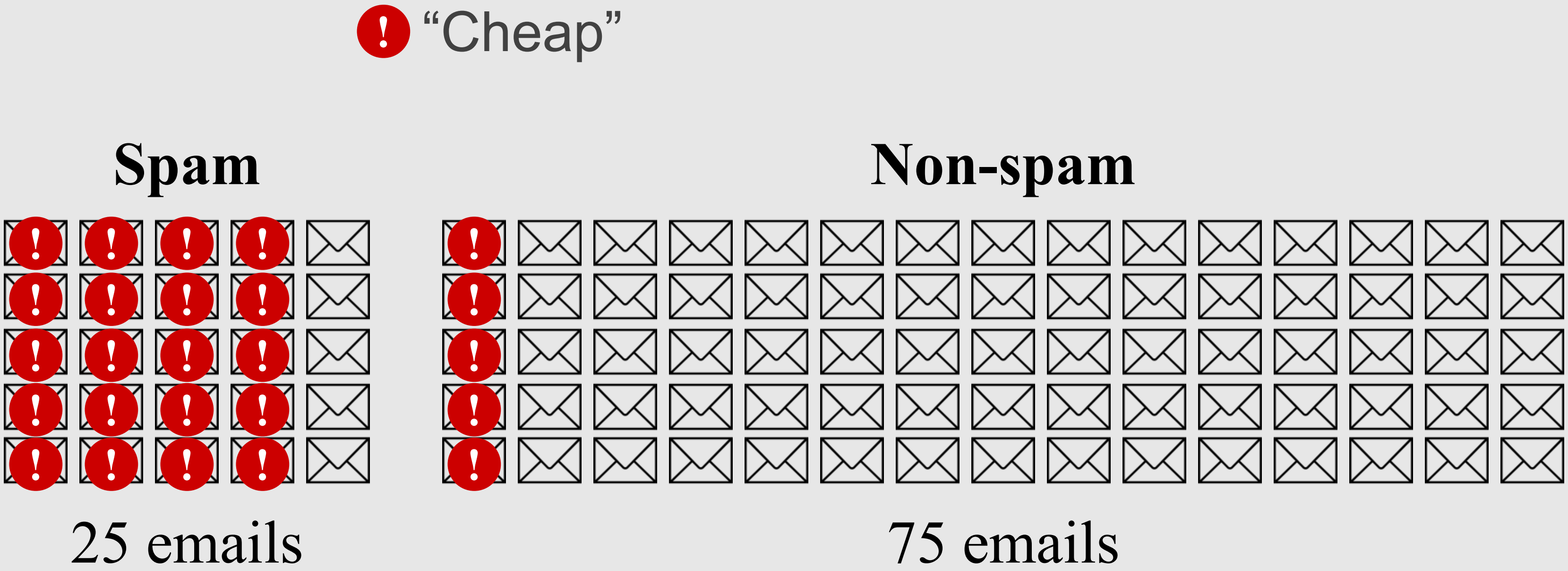
**Non-spam**



25 emails

75 emails

# Spam Filtering



❗ “Cheap”

**Spam**

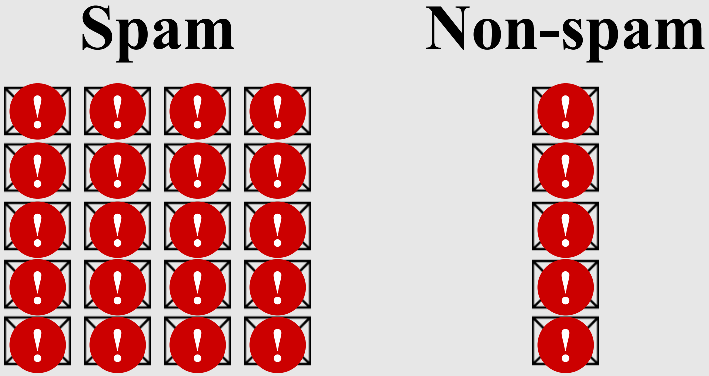
**Non-spam**

25 emails

75 emails

# Spam Filtering

❗ “Cheap”



Spam

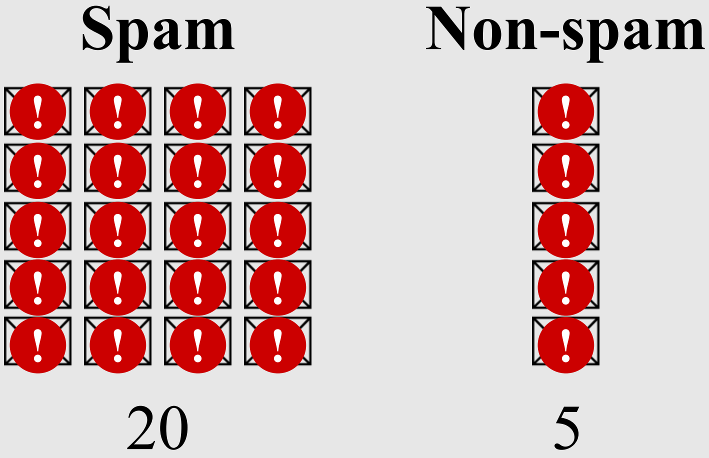
Non-spam

If an email contains the word “cheap”, what is the probability of it being spam?

- □ 40%
- □ 60%
- □ 80%

# Spam Filtering

❗ “Cheap”



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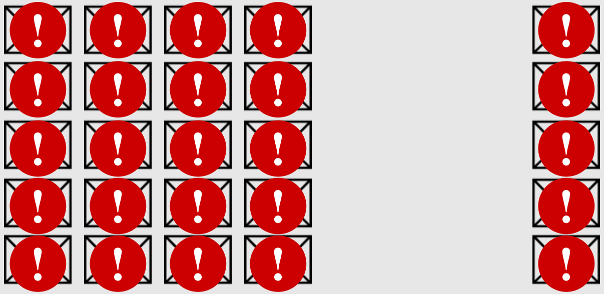
# Spam Filtering

❗ “Cheap”



**Spam** 80%

**Non-spam** 20%

If an email contains the word “cheap”, what is the probability of it being spam?

- ☐ 40%
- ☐ 60%
- ☑ 80%

# Spam Filtering

- “Cheap” → 80%
- Spelling mistake → 70%
- Missing title → 95%
- etc …

If an email contains the word “cheap”, what is the probability of it being spam?

☐ 40%

☐ 60%

☑ 80%

**Conclusion:** If an email contains the word “cheap”, the probability of it being spam is 80%.

# Naïve Bayes Algorithm

- “Cheap” → 80%
- Spelling mistake → 70%
- Missing title → 95%
- etc ...

If an email contains the word “cheap”, what is the probability of it being spam?

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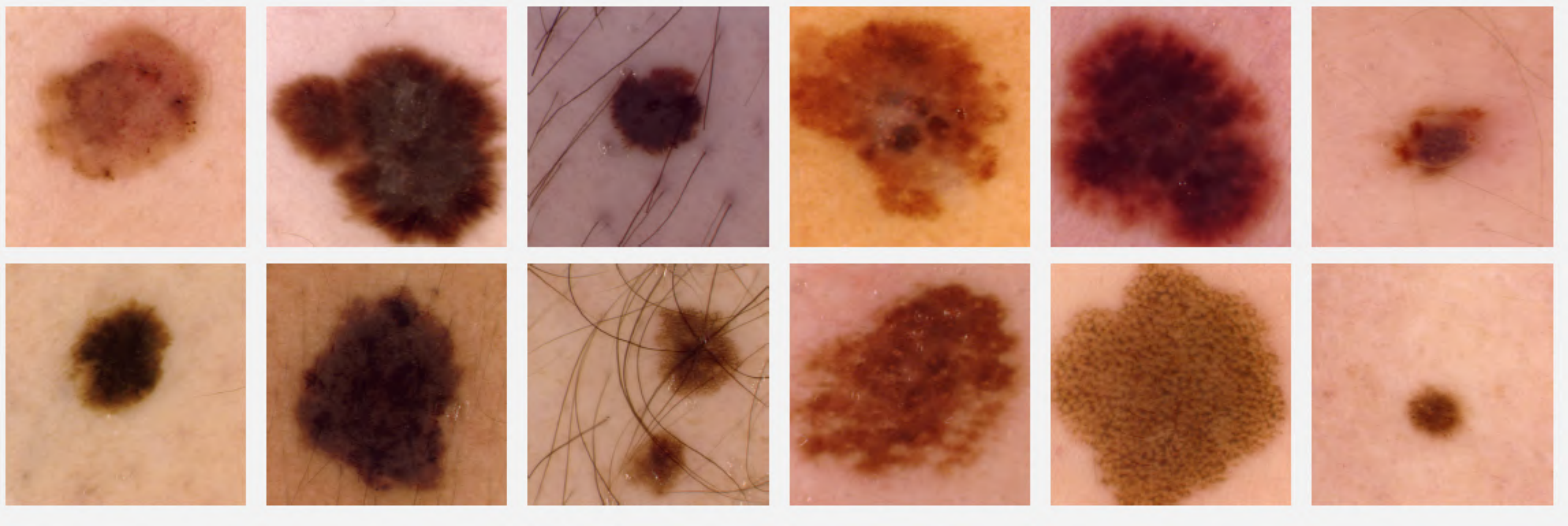
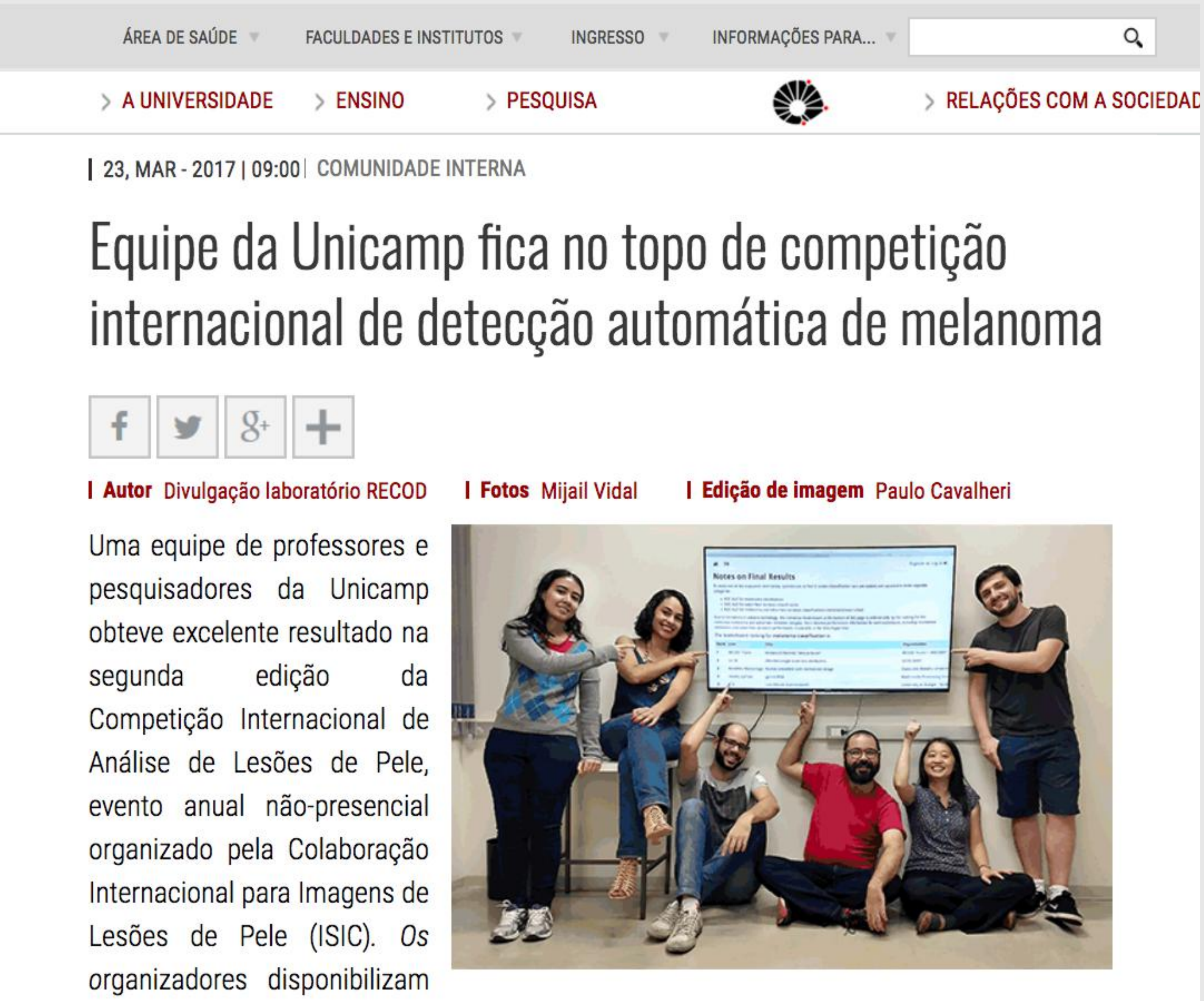
☑ 80%

**Conclusion:** If an email contains the word “cheap”, the probability of it being spam is 80%.

# Skin Cancer Classification



**Melanomas** (top row) and **benign** skin lesions (bottom row)



23, MAR - 2017 | 09:00 | COMUNIDADE INTERNA

# Equipe da Unicamp fica no topo de competição internacional de detecção automática de melanoma

**Autor** Divulgação laboratório RECOD | **Fotos** Mijail Vidal | **Edição de imagem** Paulo Cavalheri

Uma equipe de professores e pesquisadores da Unicamp obteve excelente resultado na segunda edição da Competição Internacional de Análise de Lesões de Pele, evento anual não-presencial organizado pela Colaboração Internacional para Imagens de Lesões de Pele (ISIC). *Os* organizadores disponibilizam

https://www.unicamp.br/unicamp/noticias/2017/03/17/equipe-da-unicamp-fica-no-topo-de-competicao-internacional-de-deteccao

# Sensitive Content Classification

# Unicamp cria tecnologia para barrar pornografia e violência

**Segurança.** Pesquisadores lançaram método que identifica cerca de 97% do conteúdo impróprio em telas de celulares e computador

Em parceria com pesquisadores do Samsung Research Institute Brazil, o IC (Instituto de Computação) da Unicamp (Universidade Estadual de Campinas) desenvolveu um método capaz de filtrar 97% do conteúdo pornográfico e 80% do material de violência exibido em telas de celulares, computadores e tablets.

No novo método, os pesquisadores buscaram a combinação do uso de informações estáticas e de movimento com uma metodologia de aprendizado de máquina conhecida como deep learning ou "aprendizagem profunda". Com isso, a solução que o grupo desenvolveu extrai um quadro por segundo de cada vídeo que é acessado em tempo real em celular ou computador. Os quadros com as imagens estáticas são em seguida analisados aplicando-se o método de classificação de descrições do que é permitido e do que é pornográfico.

Ao mesmo tempo, a sequência de quadros analisados fornece os elementos para sequenciar os movimentos dos objetos e pessoas presentes na cena. Dependendo do tipo de movimento, o vídeo é bloqueado.

"Para a detecção de pornografia, os testes foram realizados em um conjunto de dados contendo aproximadamente 140 horas, sendo 1 mil vídeos pornográficos e 1 mil vídeos não pornográficos", explica a pesquisadora do IC da Unicamp, Sandra Avila, ao comentar sobre o processo de criação da tecnologia, que durou 27 meses.

Sistema garante proteção de crianças | IMAGE SOURCE/FOLHAPRESS

"Filtrar cenas de violência, por ser mais subjetivo, é um problema mais difícil comparado à pornografia. Devido a essa subjetividade e os diferentes conjuntos de dados, a eficácia da nossa solução para filtrar cenas de violência está em torno de 80%", conta Sandra.

Ainda segundo a representante da Unicamp, a tecnologia lançada em parceria com a Samsung pode ajudar as autoridades policiais.

"O método proposto para filtrar conteúdo pornográfico está sendo adaptado para outros tipos de conteúdo sensível. Por exemplo, em parceria com peritos da Polícia Federal, estamos desenvolvendo uma ferramenta para detectar pornografia infantil. Temos hoje uma solução que identifica 88% do conteúdo pornográfico infantil em imagens. Para dar uma ideia da importância do resultado, o melhor resultado alcançado pelas ferramentas forenses testadas foi 58%", relata a pesquisadora.

**HIDAIANA ROSA**
METRO CAMPINAS

# House Price Prediction

## (Regression)

$ 70 000

https://www.youtube.com/watch?v=IpGxLWOIZy4

# House Price Prediction
(Regression)

$ 160 000

# House Price Prediction

## (Regression)

???

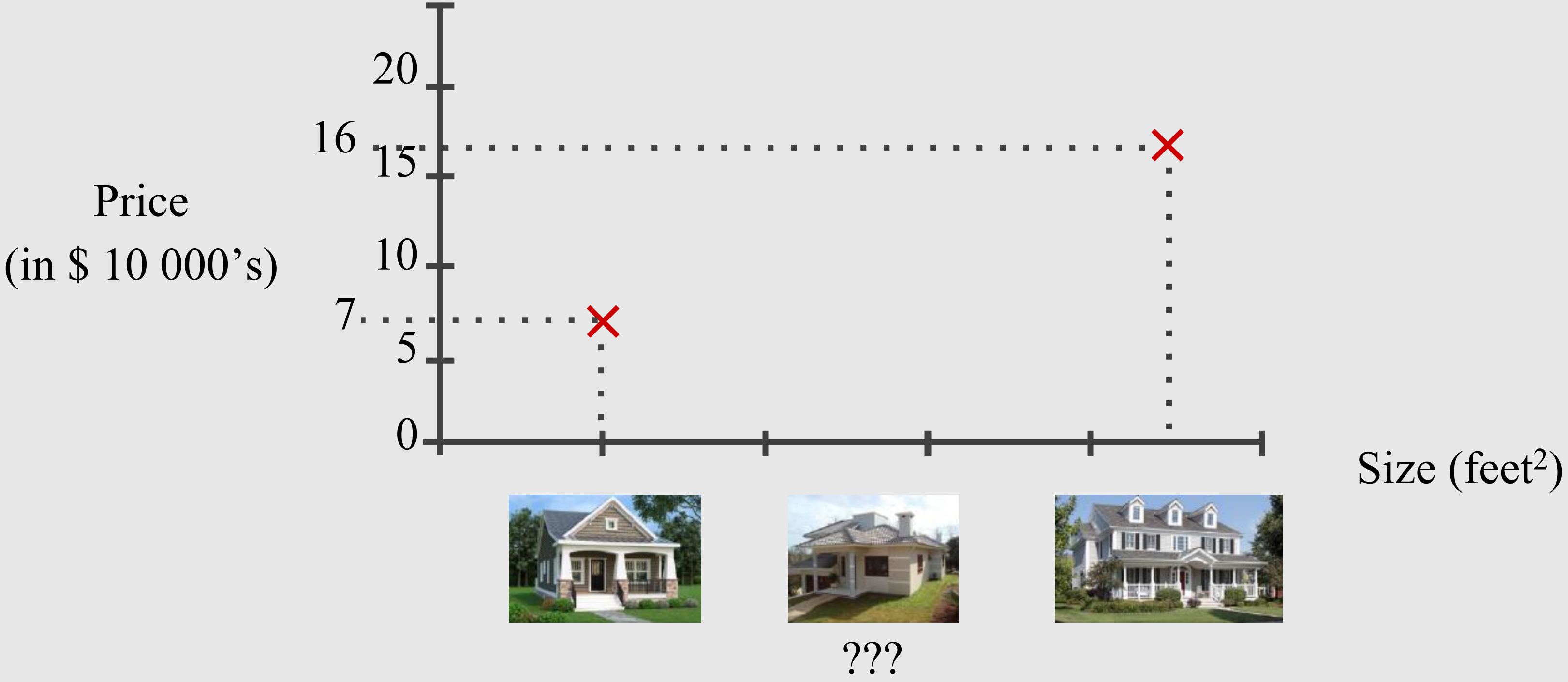
# House Price Prediction

## (Regression)

Price
(in $ 10 000’s)
20
15
10
5
0
Size (feet$^2$)

# House Price Prediction

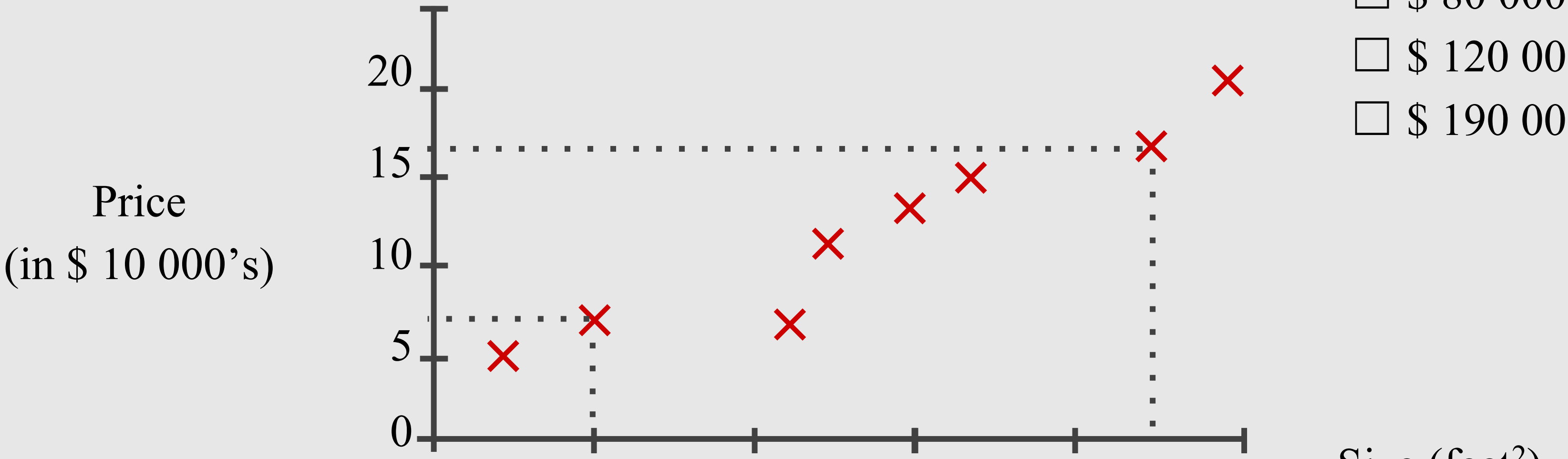
## (Regression)



# House Price Prediction
(Regression)

What’s the best estimate for the price of the house?

□ $ 80 000
□ $ 120 000
□ $ 190 000



???

# House Price Prediction

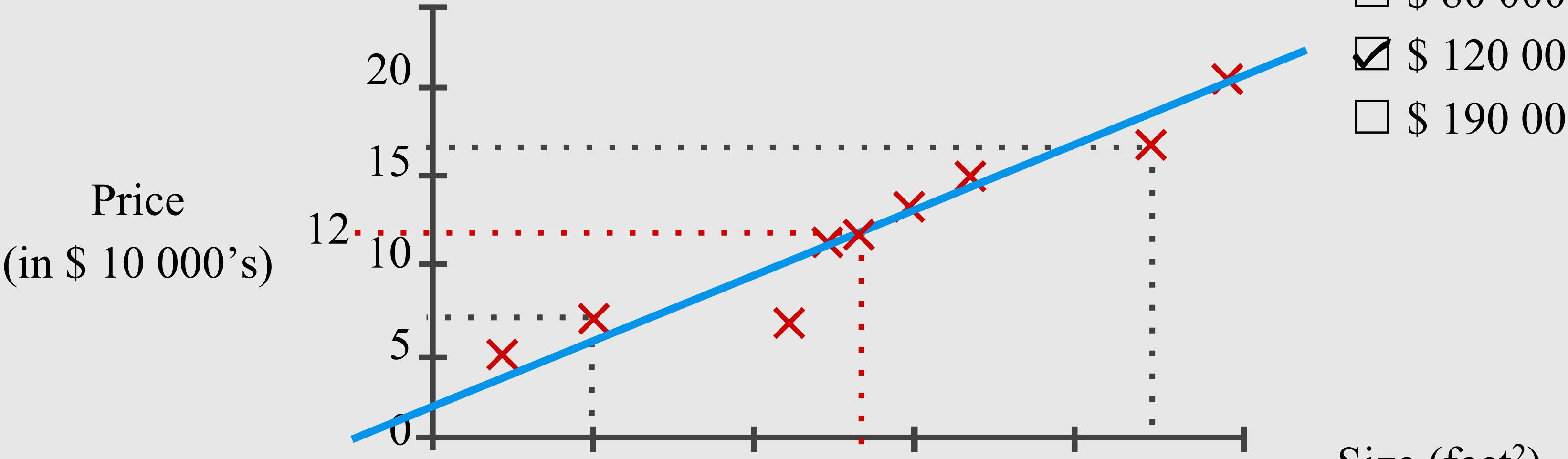
(Regression)

What's the best estimate for the price of the house?

□ $ 80 000

☑ $ 120 000

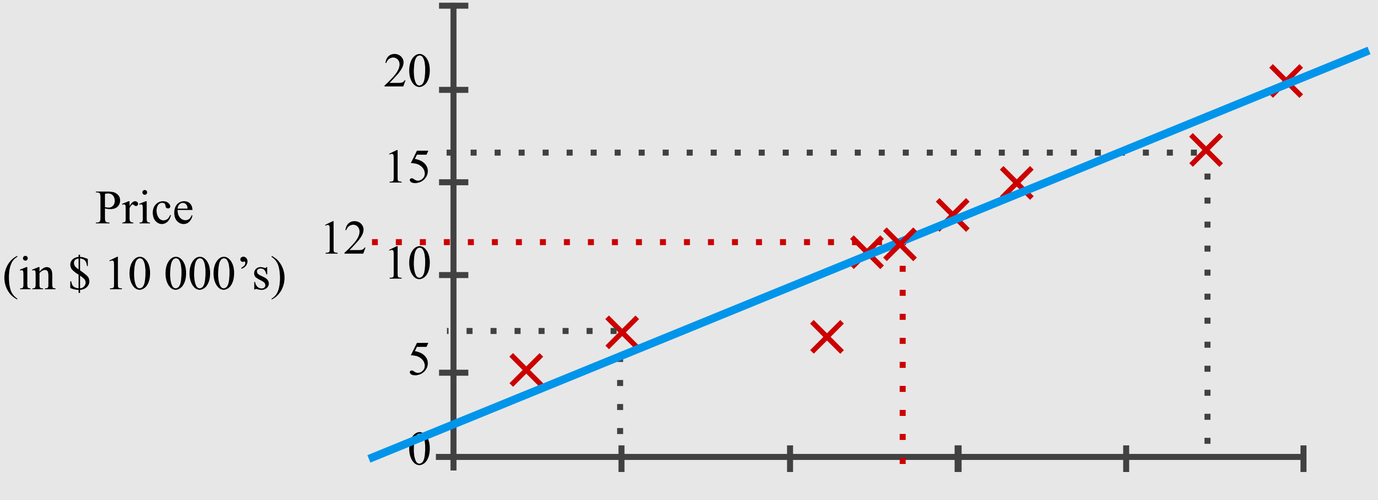
□ $ 190 000



# Linear Regression

What’s the best estimate for the price of the house?

- □ \$ 80 000
- ☑ \$ 120 000
- □ \$ 190 000



# Important Supervised Learning Algorithms

- Linear Regression
- Logistic Regression
- k-Nearest Neighbors
- Support Vector Machines (SVMs)
- Neural Networks
- Decision Trees and Random Forests

# Unsupervised Learning

**Clustering** algorithm tries to detect similar groups.

**Dimensionality reduction** tries to simplify the data without loosing too much information.

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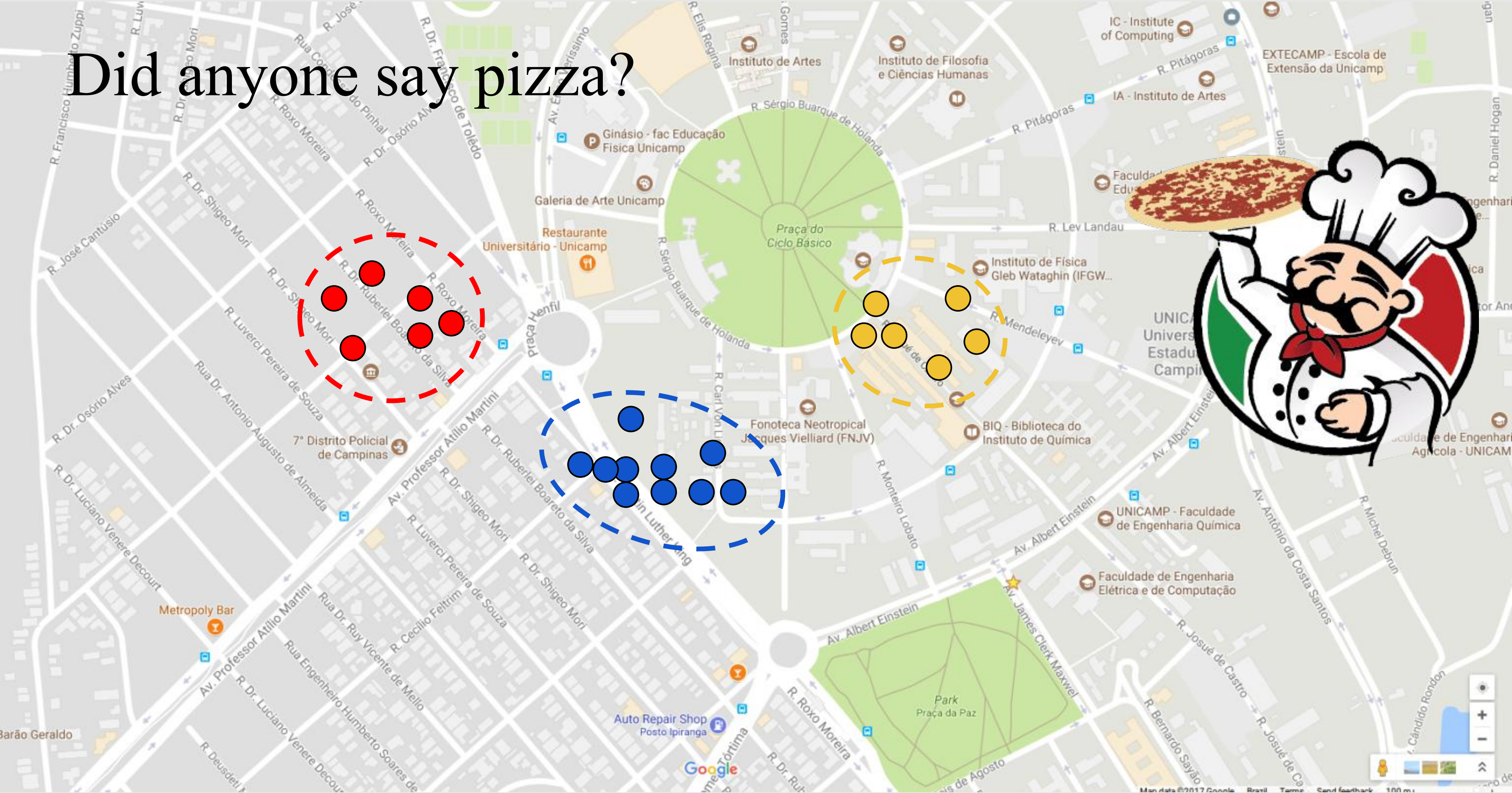

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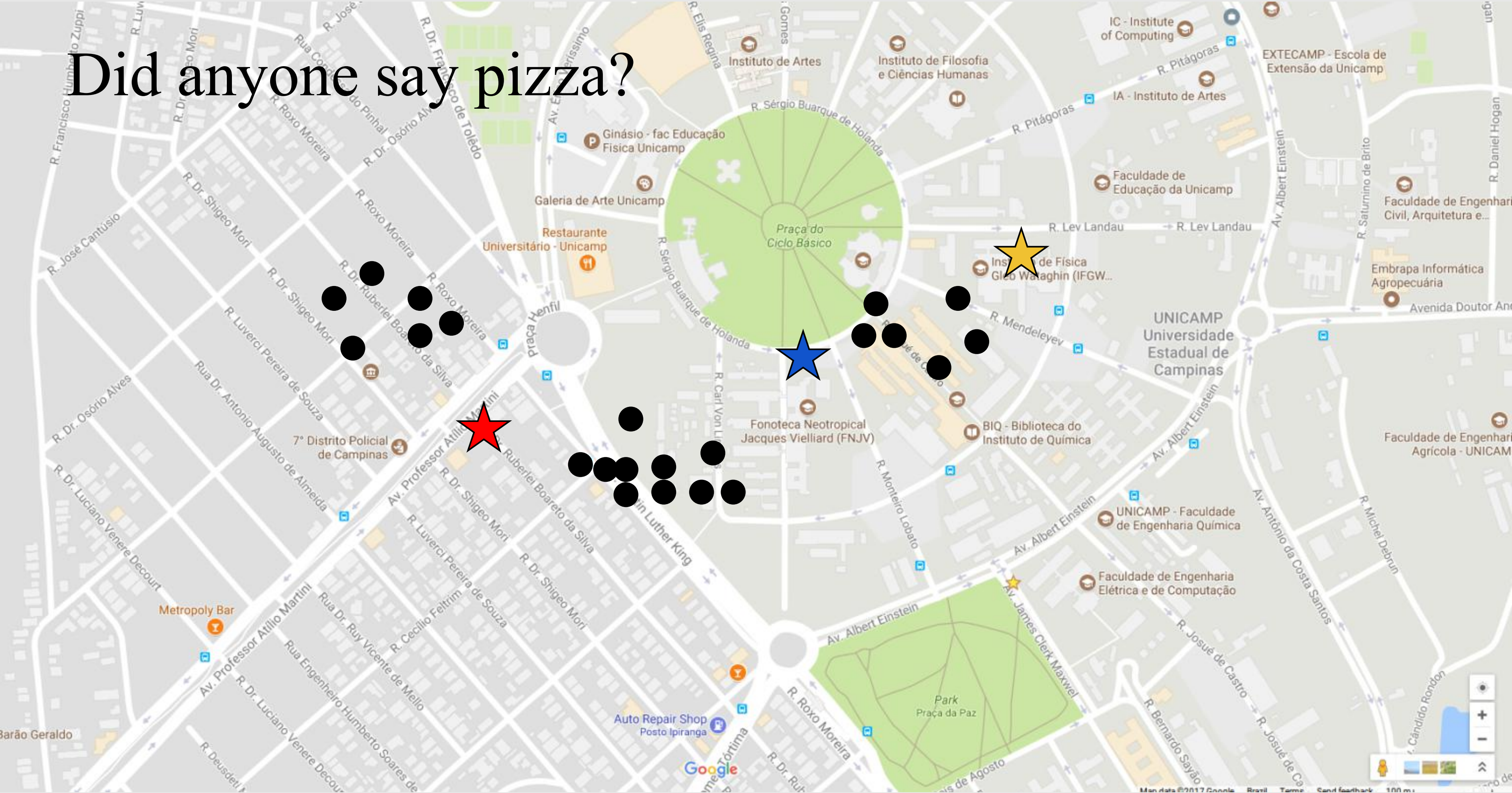
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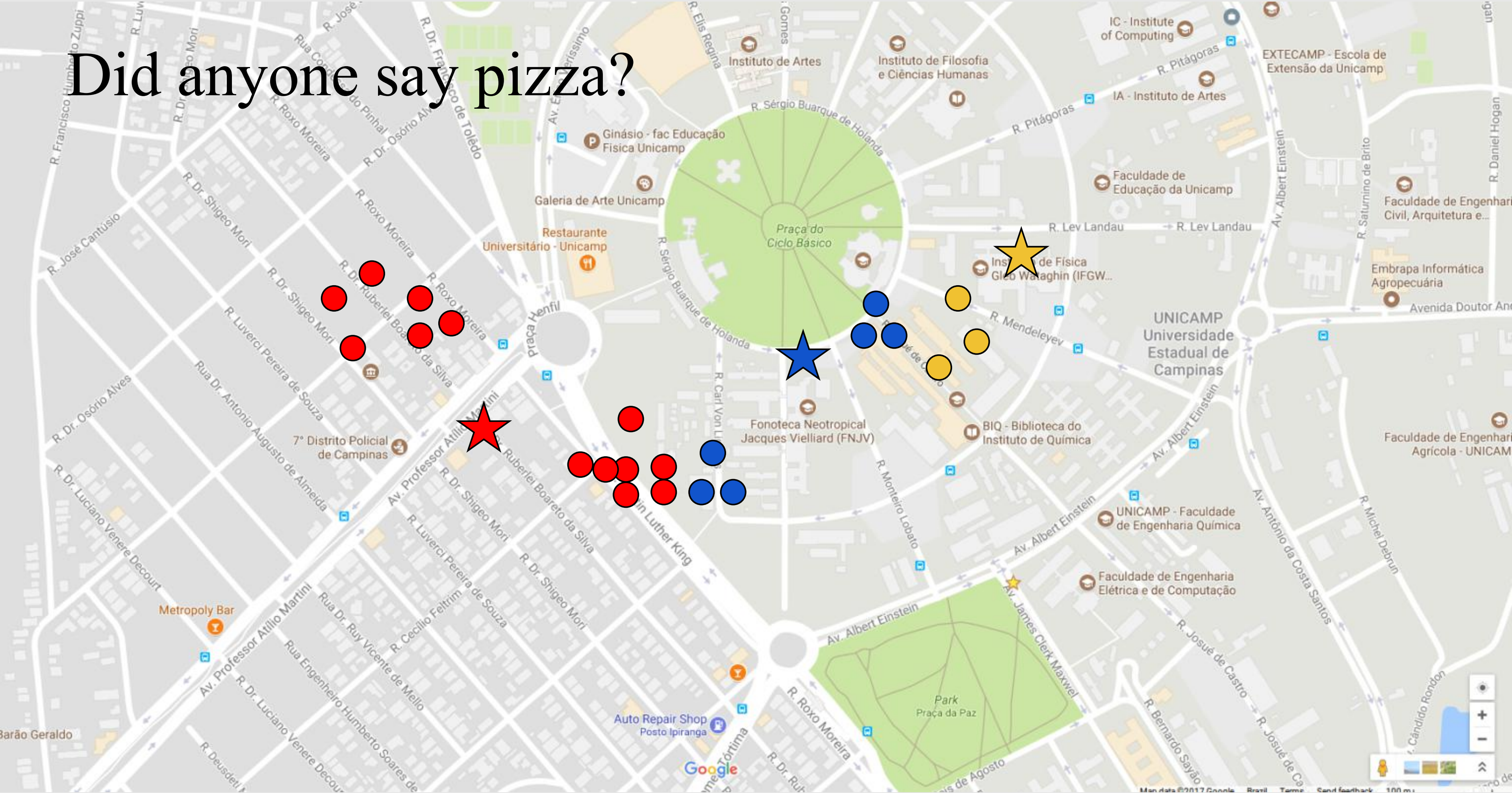
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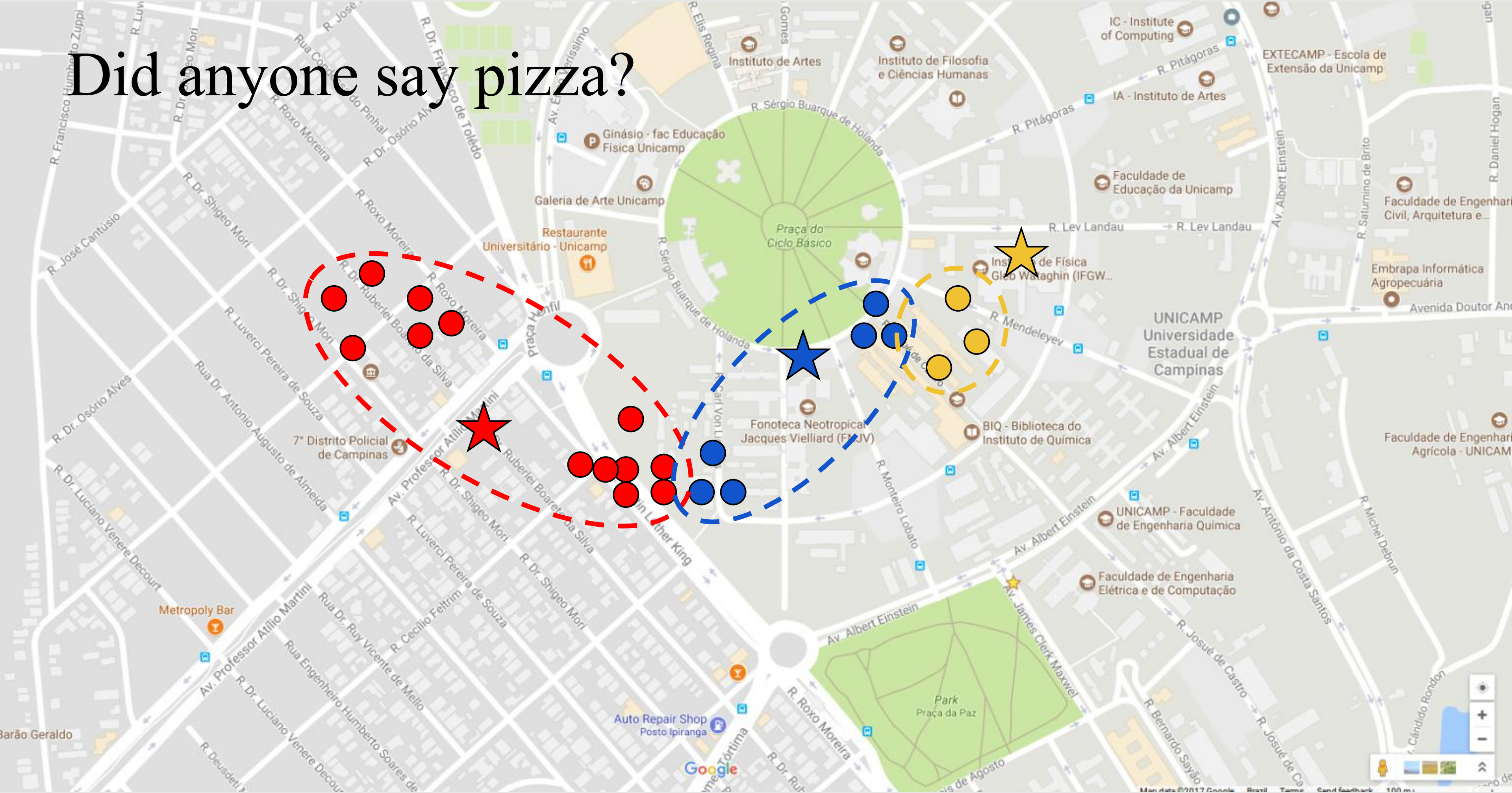
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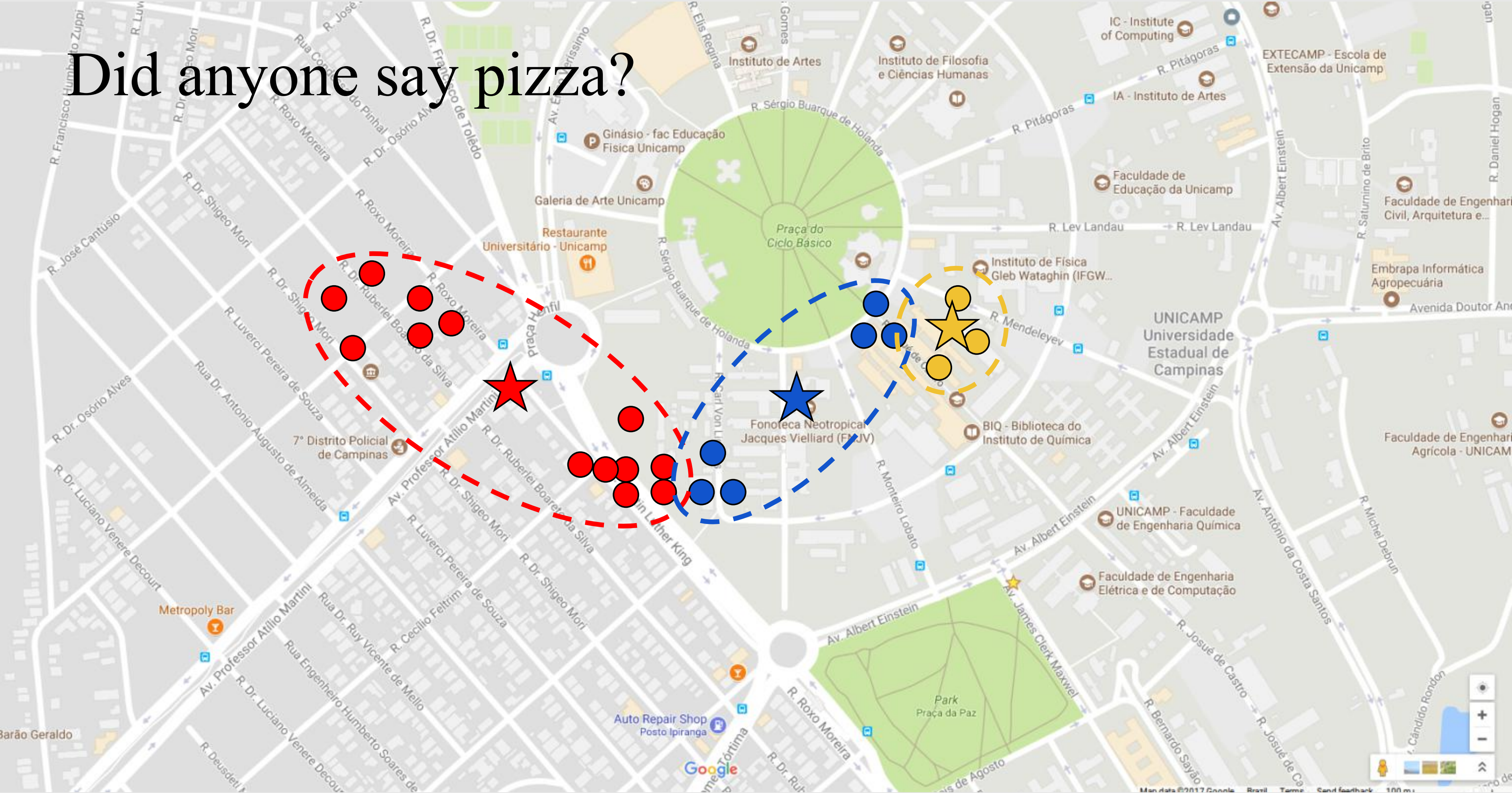
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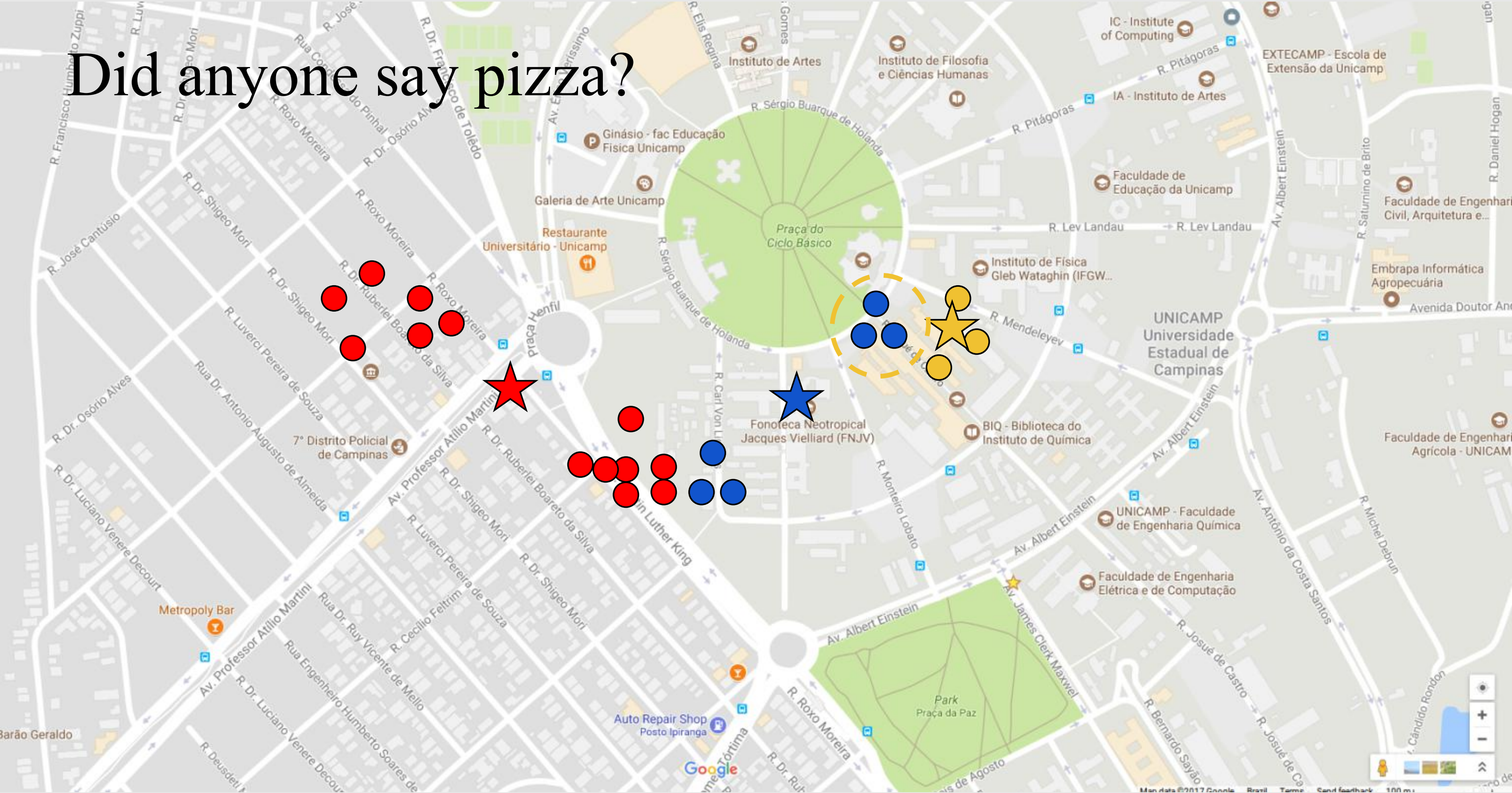
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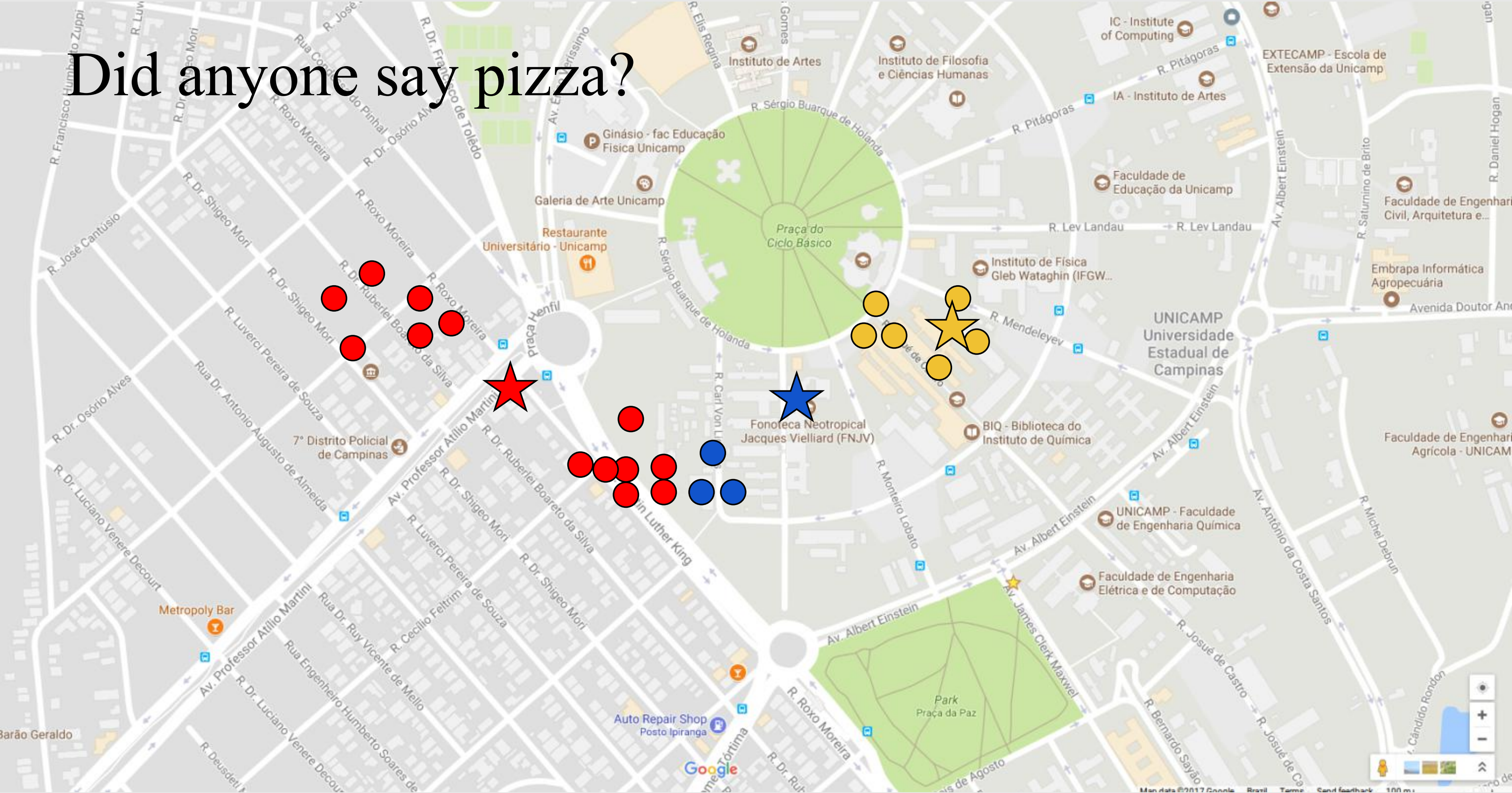
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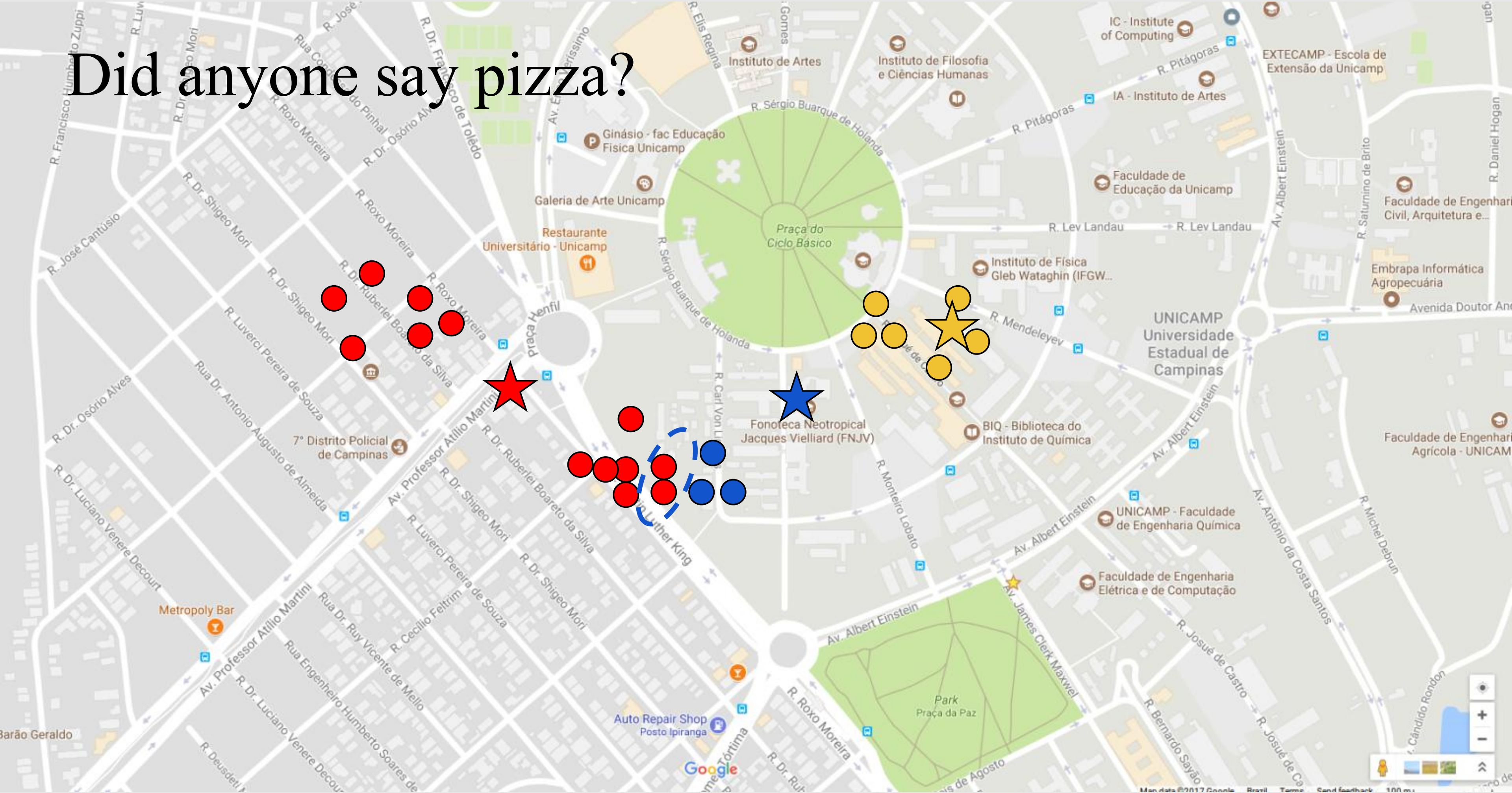
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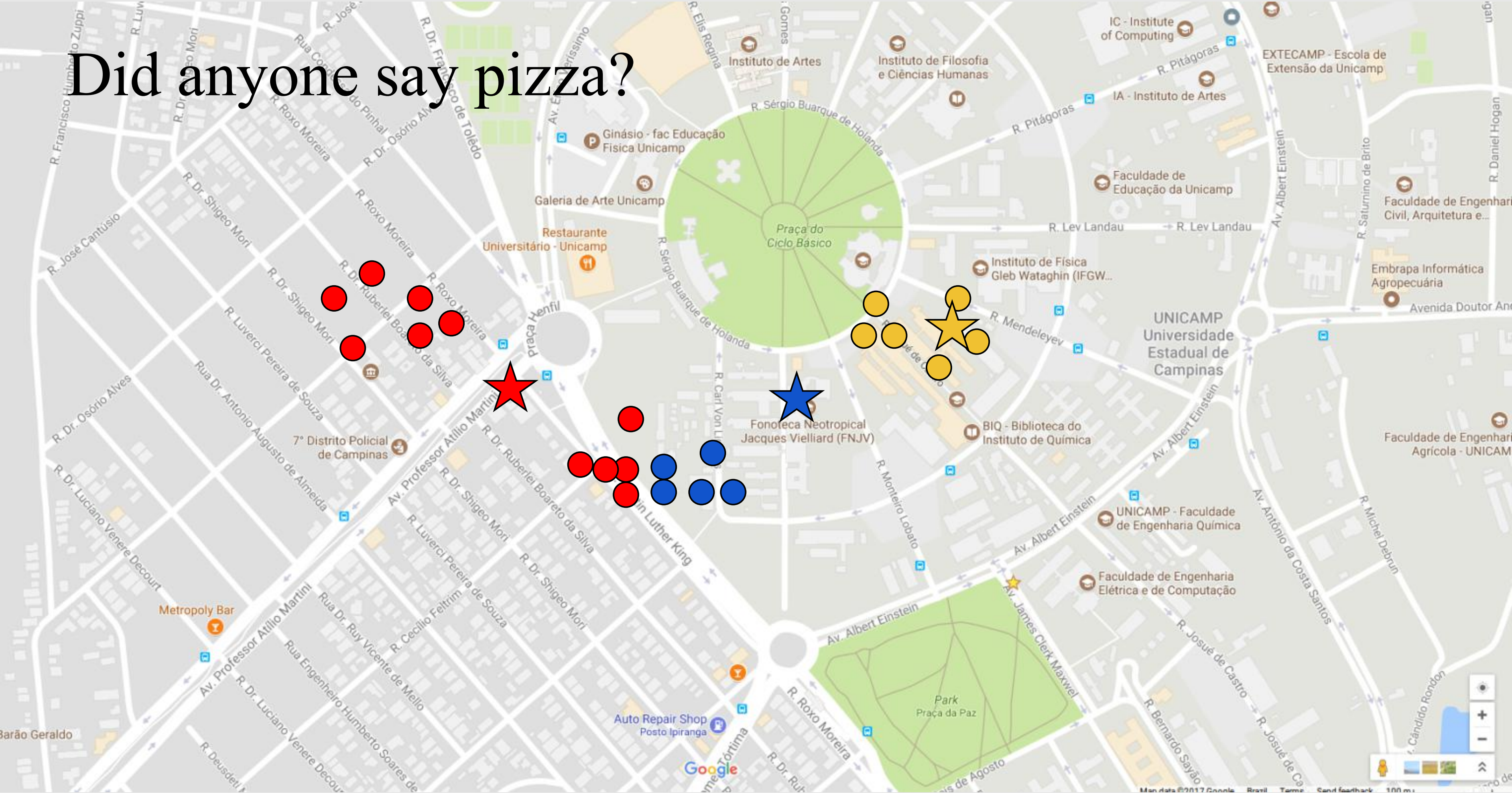
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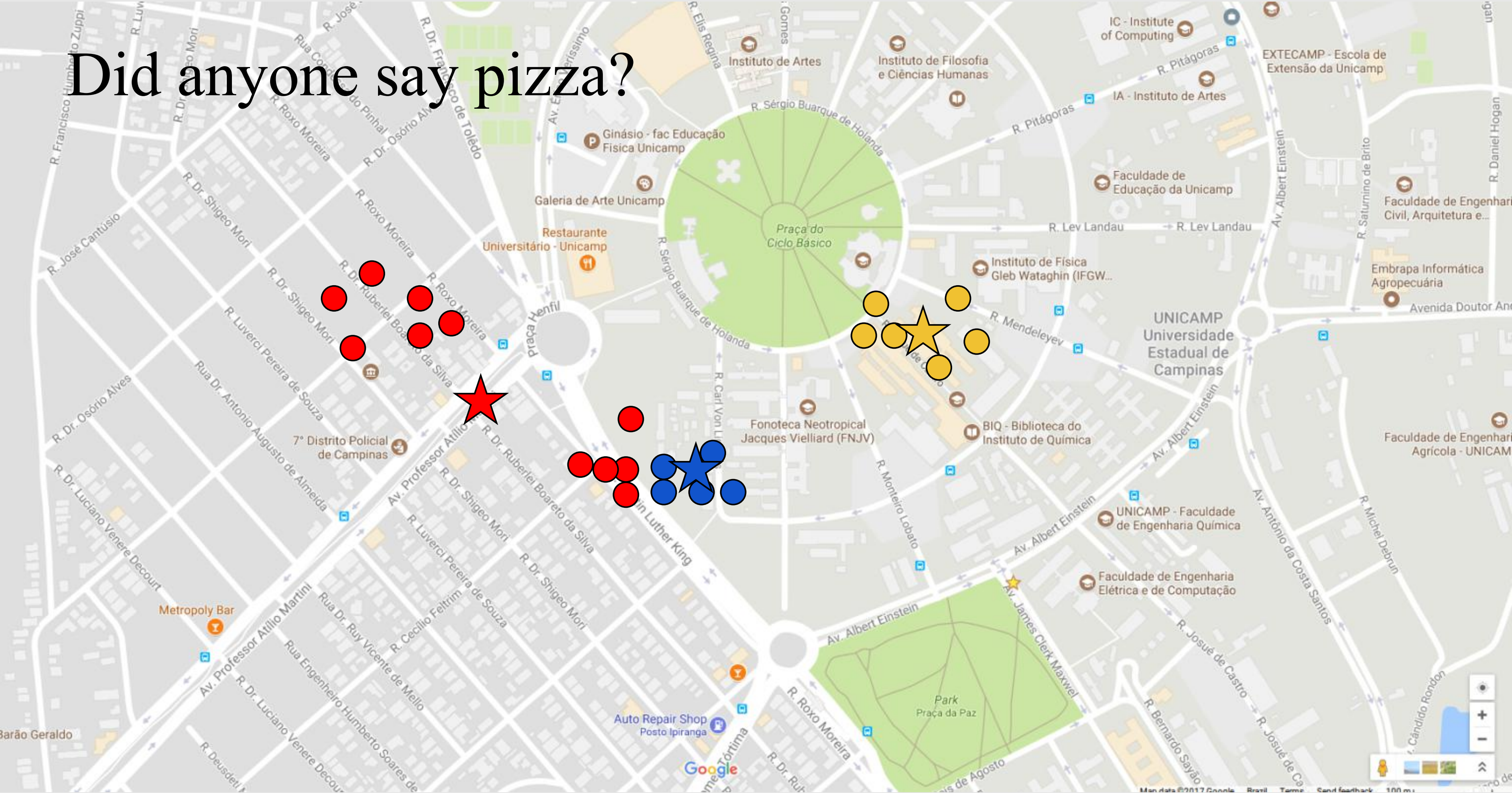
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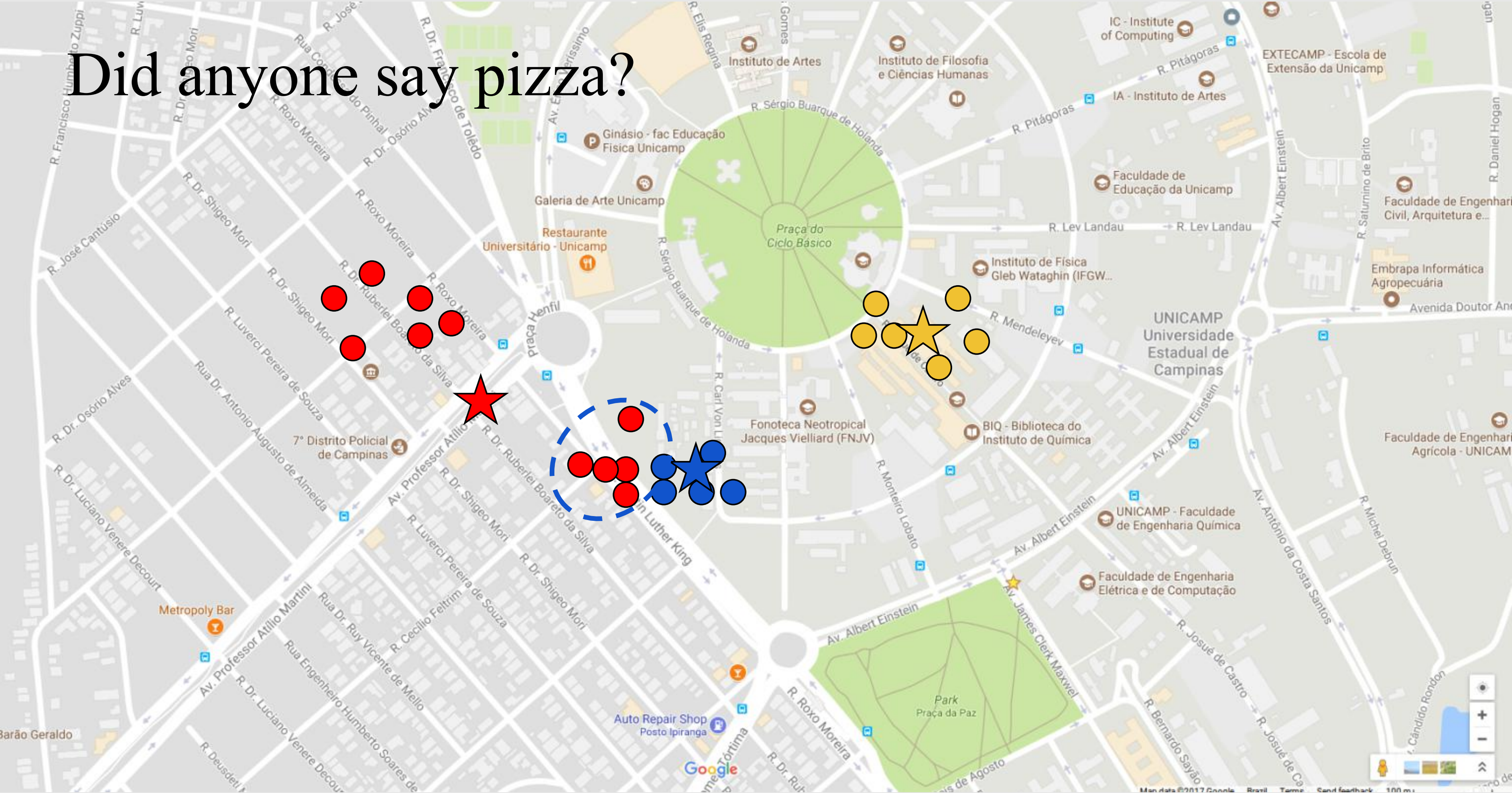
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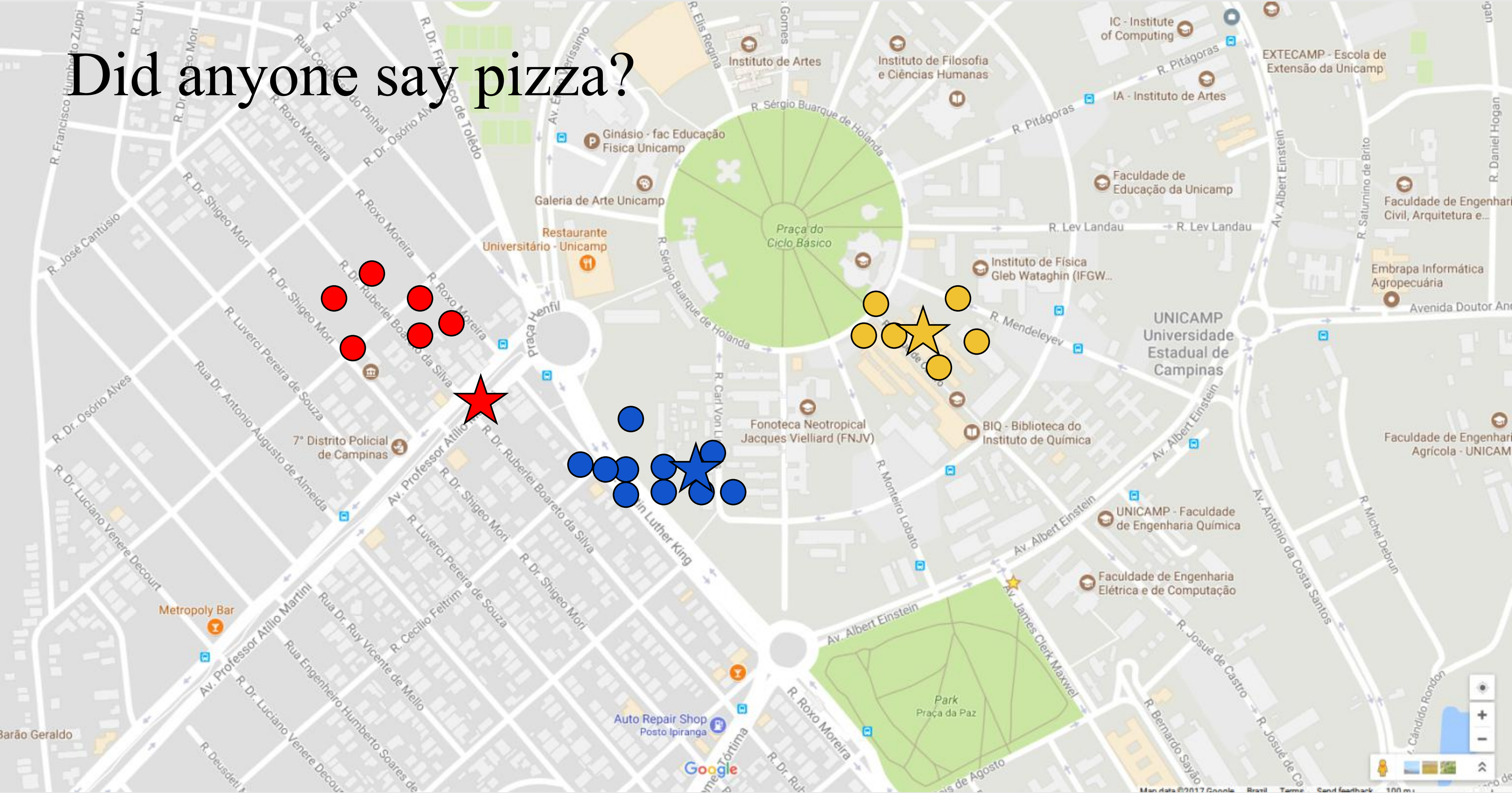
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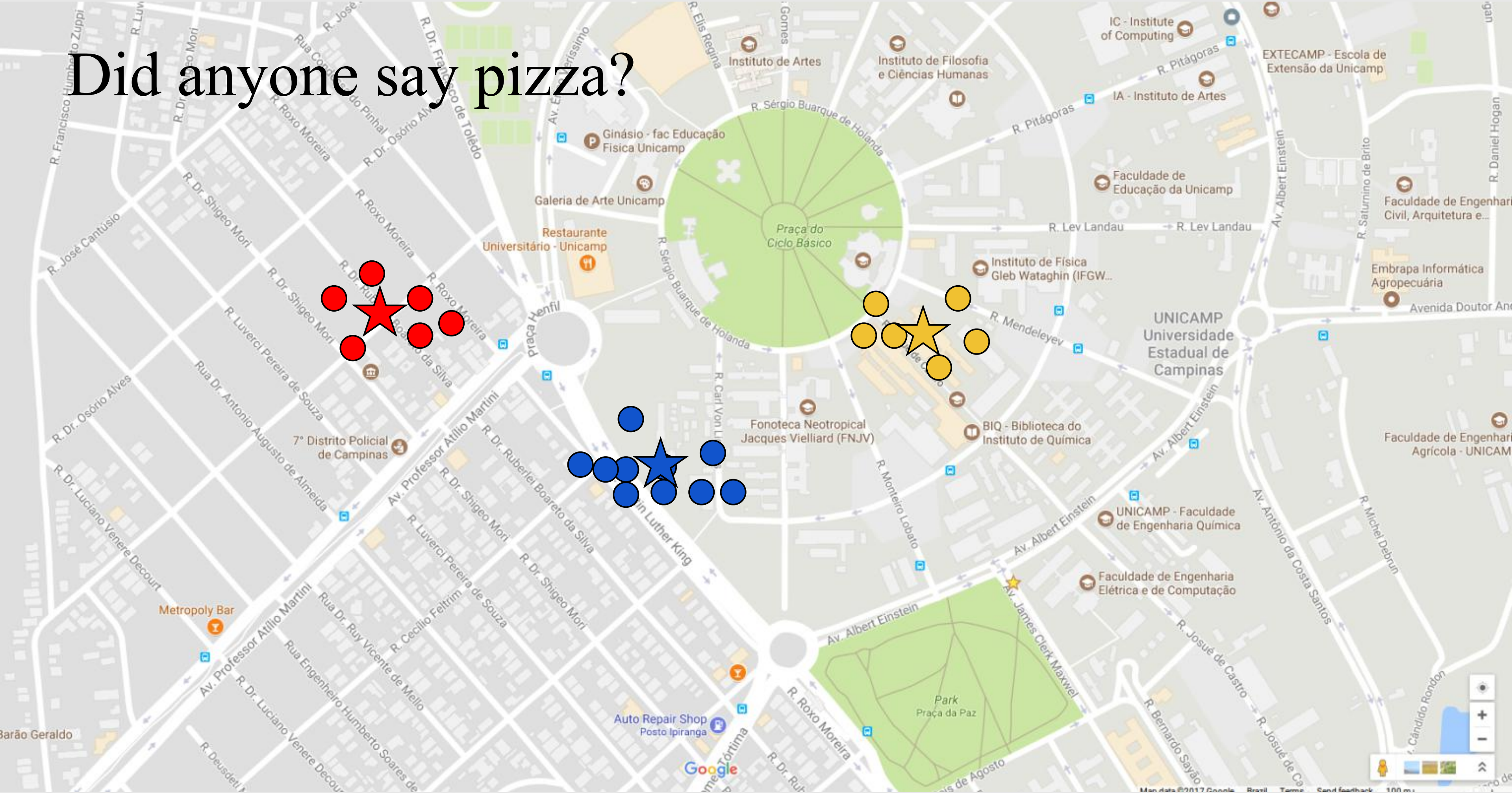
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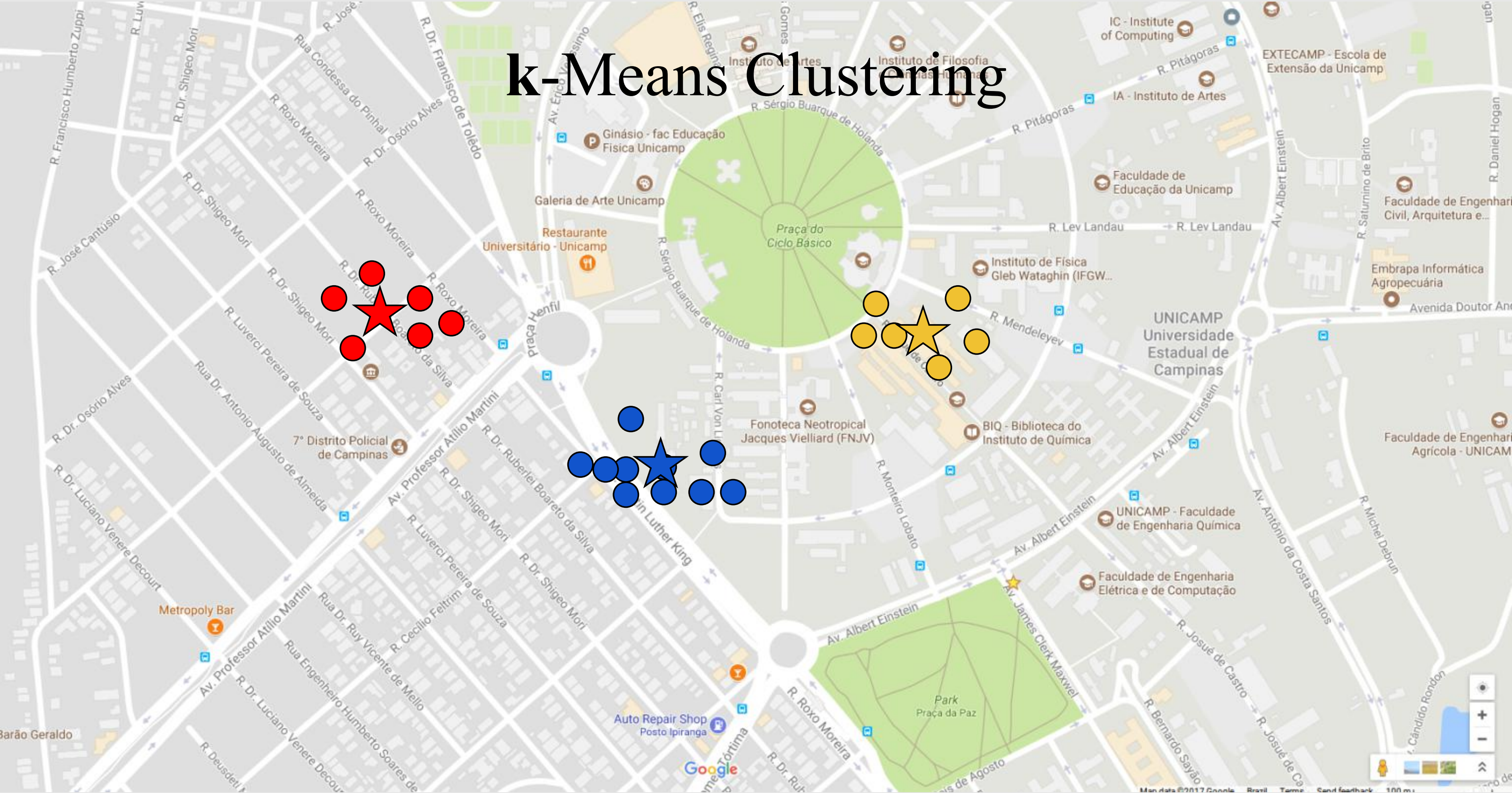
# k-Means Clustering



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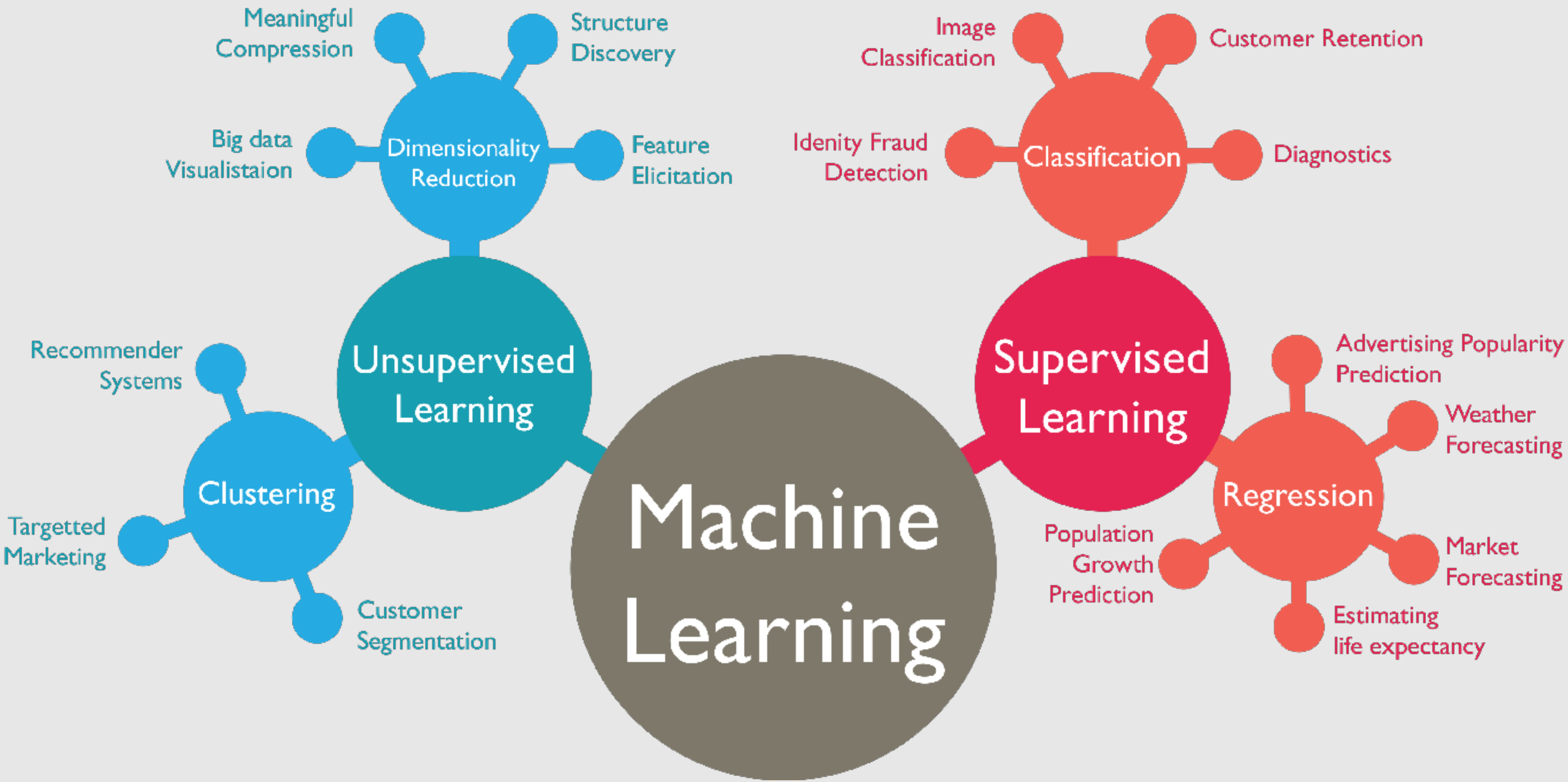
# Important Unsupervised Learning Algorithms

- k-Means
- Hierarchical Cluster Analysis (HCA)
- Expectation Maximization
- Principal Component Analysis (PCA)
- Kernel PCA
- t-distributed Stochastic Neighbor Embedding (t-SNE)



http://www.isaziconsulting.co.za/machinelearning.html

# Main Challenges of Machine Learning

I SEE BAD DATA

# Main Challenges of Machine Learning

- Insufficient quantity of training data
- Non representative training data
- Poor quality data
- Irrelevant features

**“Bad data”**

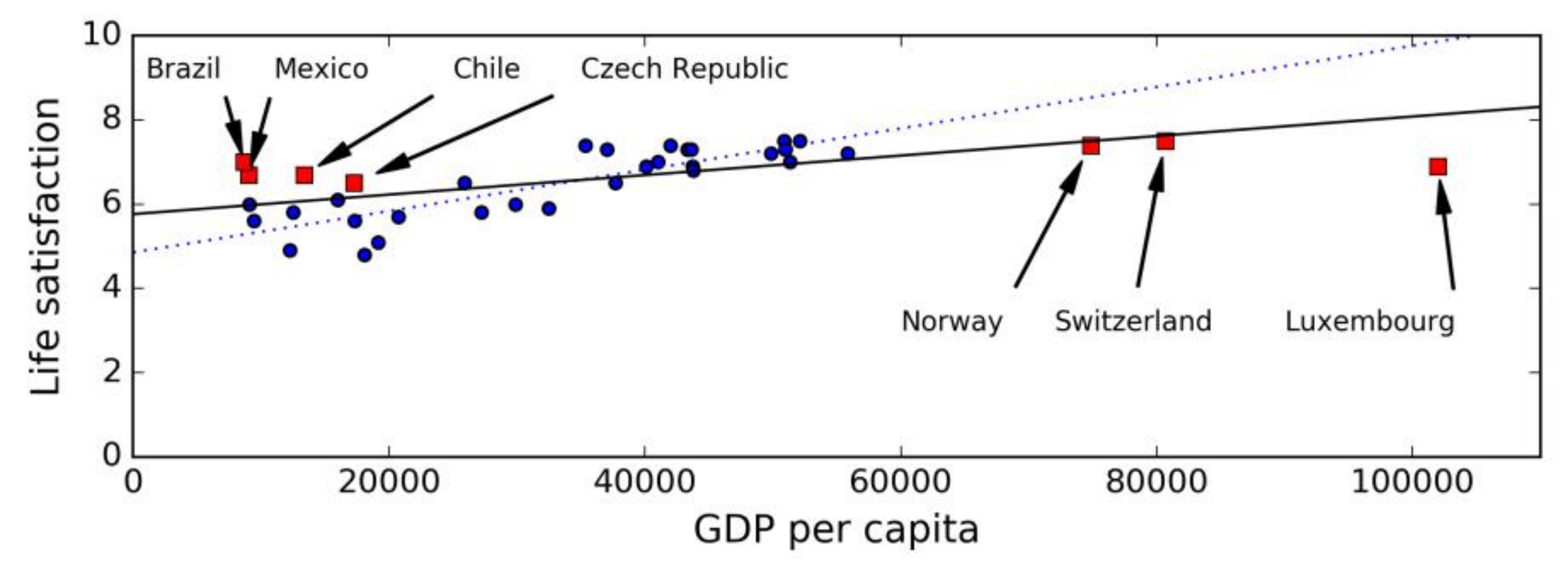
- Overfitting the training data
- Underfitting the training data

**“Bad algorithm”**

# Non Representative Training Data

In order to generalize well, it is crucial that your training data be representative of the new cases you want to generalize to.

# Non Representative Training Data



# Poor Quality Data

Obviously, if your training data is full of errors, outliers and noise, it will make it harder for the system to detect the underlying patterns, so your system is less likely to perform well.

# Irrelevant Features

A critical part of the success of a Machine Learning project is coming up with a good set of features to train on: this is called ***feature engineering***. This involves:

- *Feature selection*: the process of selecting the most useful features to train on among existing features.
- *Feature extraction*: combining existing features to produce a more useful one.

# Main Challenges of Machine Learning

- Insufficient quantity of training data
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- Poor quality data
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**“Bad data”**

- Overfitting the training data
- Underfitting the training data

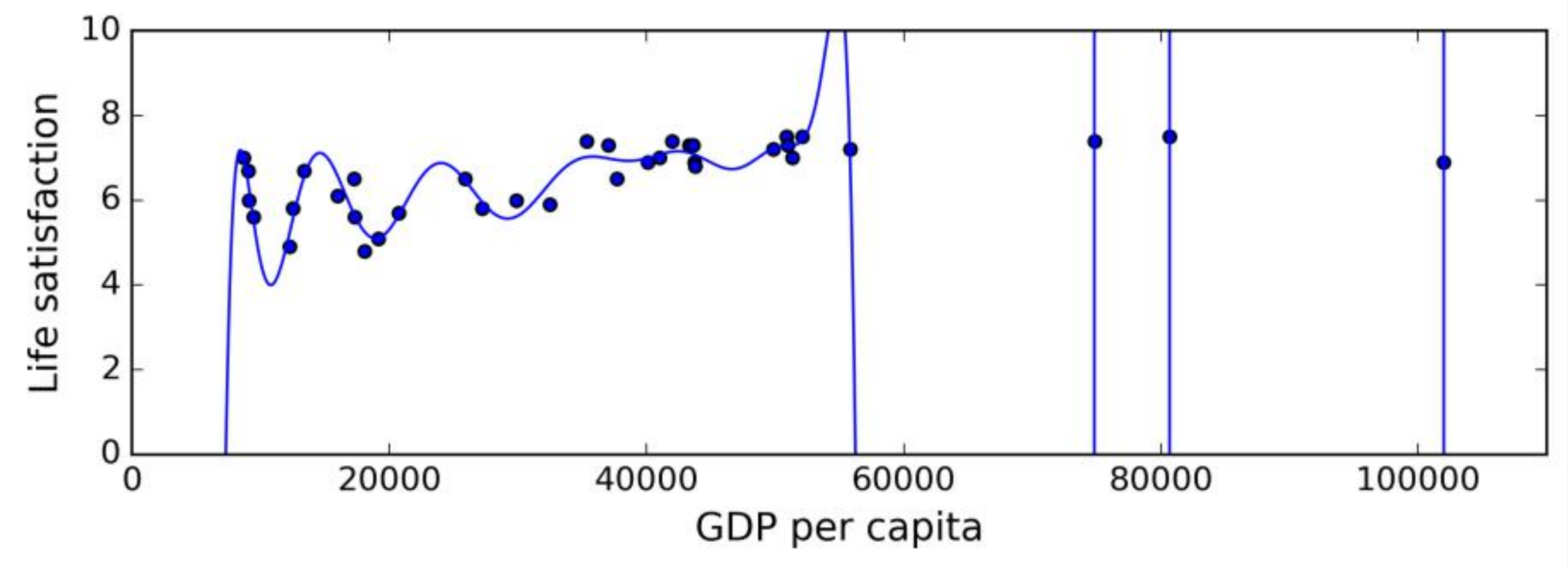
**“Bad algorithm”**

# Overfitting the Training Data

Over-generalizing is something that we humans do all too often, and unfortunately machines can fall into the same trap if we are not careful.

*Overfitting* means that the model performs well on the training data but it does not generalize.

# Overfitting the Training Data



# Overfitting the Training Data

Overfitting happens when the model is **too complex** relative to the amount and noisiness of the training data. The possible solutions are:

- to simplify the model by selecting one with less parameters, by reducing the number of attributes in the training data or by constraining the model,
- to gather more training data,
- to reduce the noise in the training data.

# Underfitting the Training Data

Underfitting is the opposite of overfitting: it occurs when your model is **too simple** to learn the underlying structure of the data.

The main options to fix this problem are:

- selecting a more powerful model, with more parameters,
- feeding better features to the learning algorithm (feature engineering),
- reducing the constraints on the model.

# Main Challenges of Machine Learning

- Insufficient quantity of training data
- Non representative training data
- Poor quality data
- Irrelevant features

**“Bad data”**

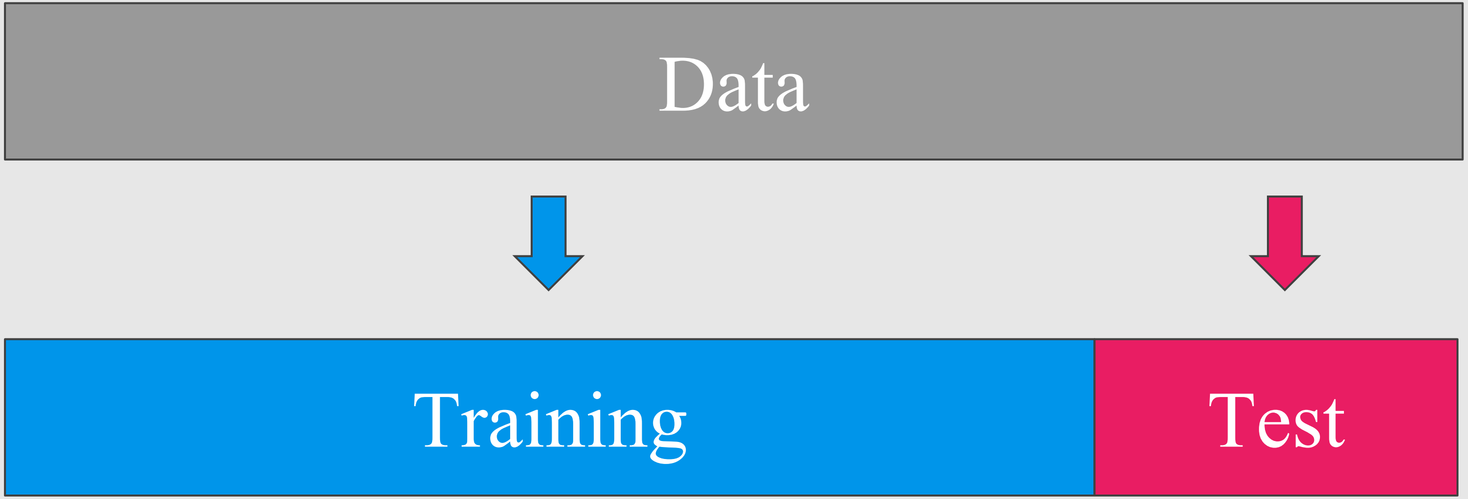
- Overfitting the training data
- Underfitting the training data

**“Bad algorithm”**

# Testing and Validating

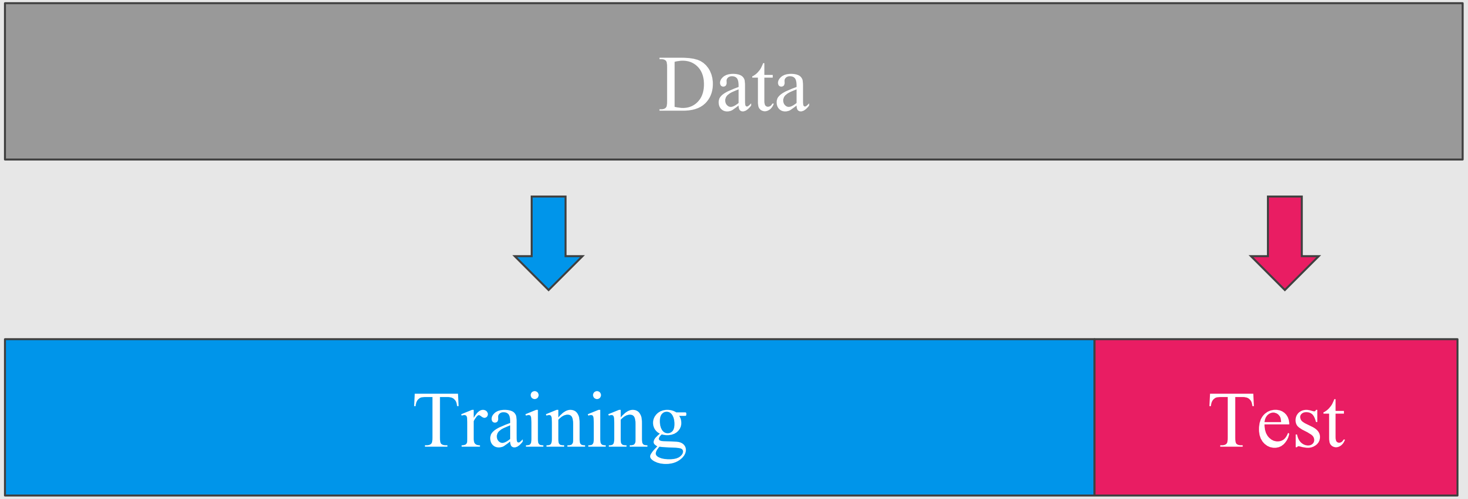
The only way to know how well a model will generalize new cases is to actually try it out on new cases.

# Data



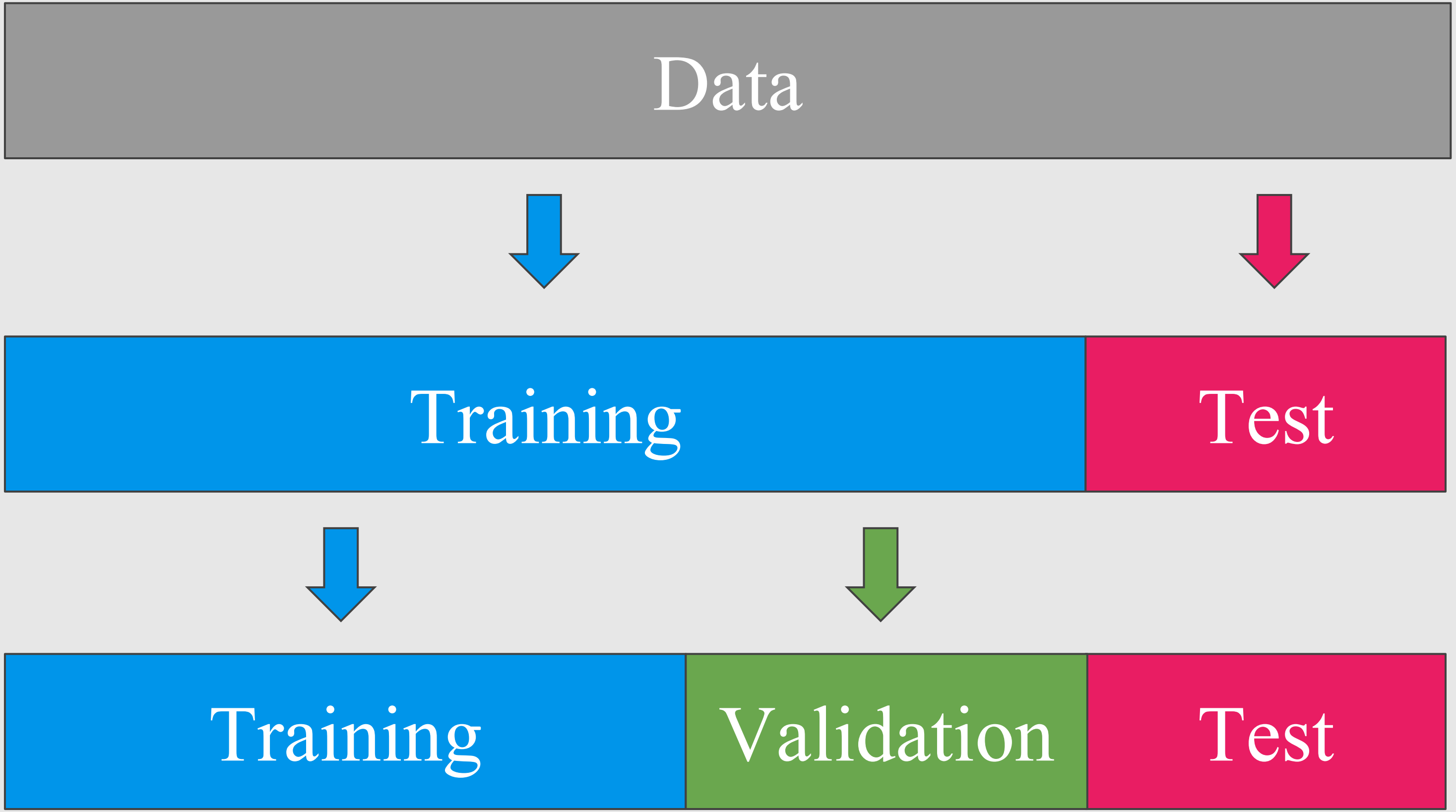
So evaluating a model is simple enough: just use a test set.

It is common to use 80% of the data for training and **hold out** 20% for testing.



So evaluating a model is simple enough: just use a test set.

Now suppose you are hesitating between two models. How can you decide?



Data

Training

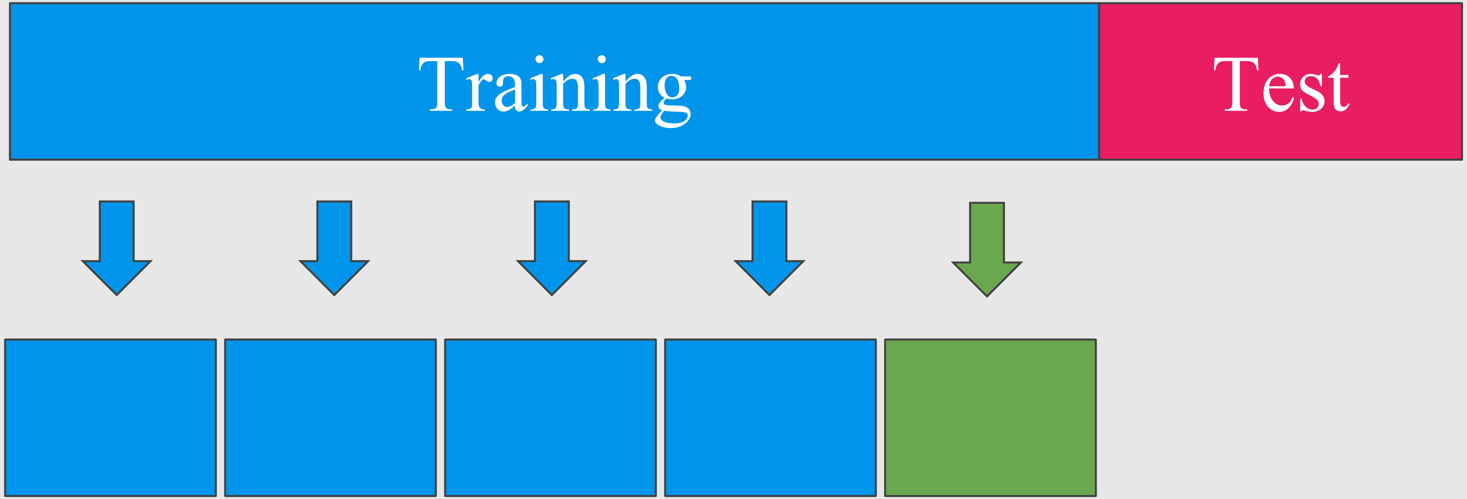
Test

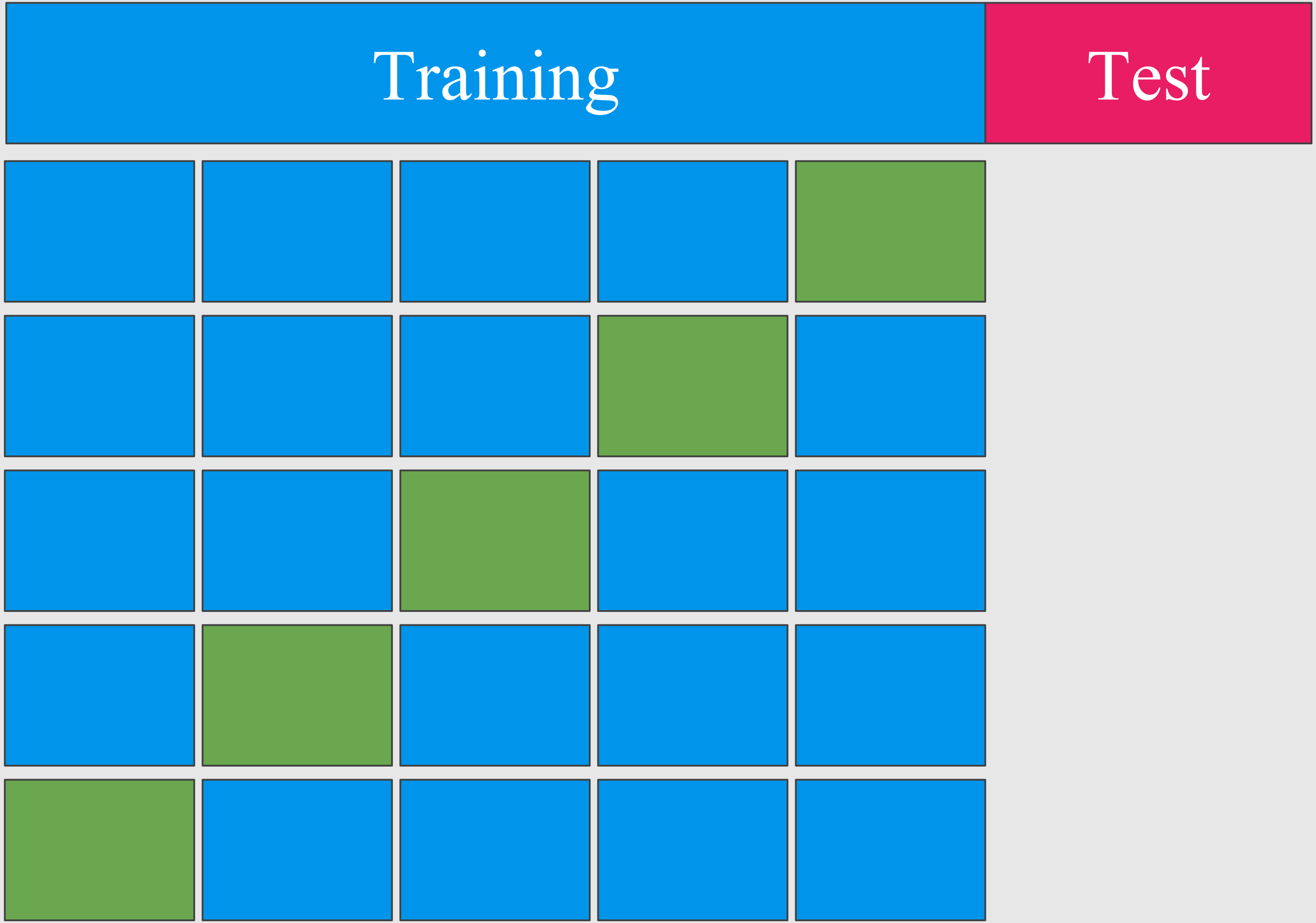
Training

Validation

Test

# Cross Validation



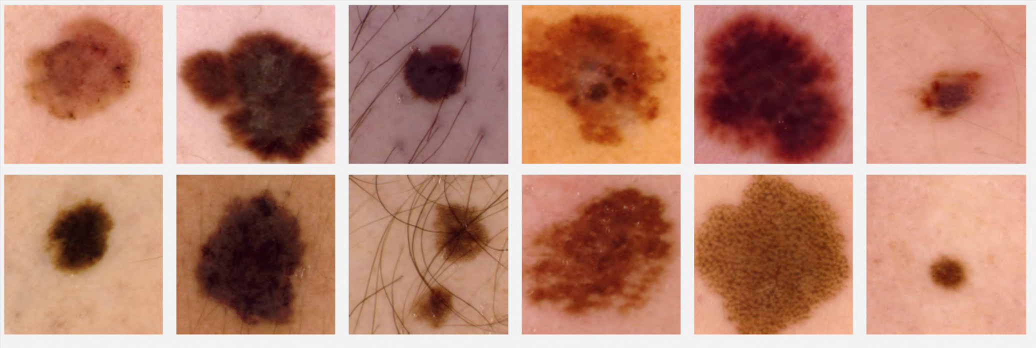


Training

Test

# Skin Cancer Classification

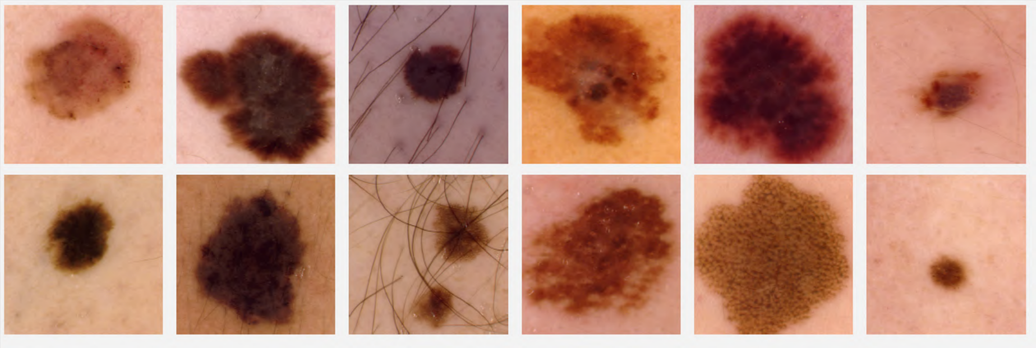
## ISBI Challenge 2017



Training data & Validation data & Test data
2 000 images 150 images 600 images

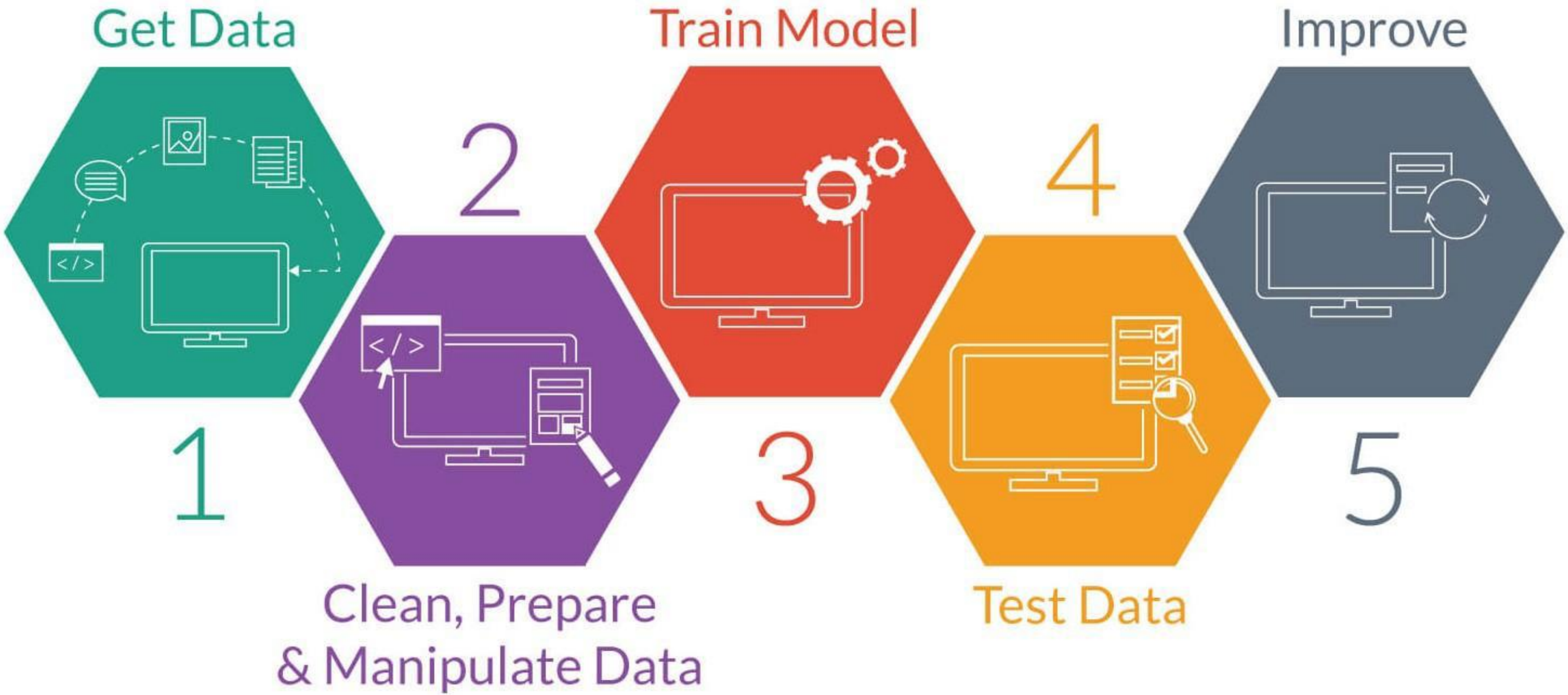
# Skin Cancer Classification

## ISBI Challenge 2017



| Training data & | Validation data & | Test data |
|---|---|---|
| 2 000 images | 150 images | 600 images |
| **95.1%** | **90.8%** | **87.4%** |
| *(internal validation)* | | |

# Summary


Get Data
1
2
Clean, Prepare
& Manipulate Data
Train Model
3
4
Test Data
Improve
5

Credit: http://carlvondrick.com/ihog/

# That’s all!