ML Basics

CPT_S 434/534 Neural network design and application

Course overview

Machine learning foundations
Deep learning foundations

Convolutional neural networks
Recurrent neural networks
Graph neural networks
Generative adversarial networks
Neural architecture search
……

Machine learning

Deep learning

Computer vision

Natural language processing
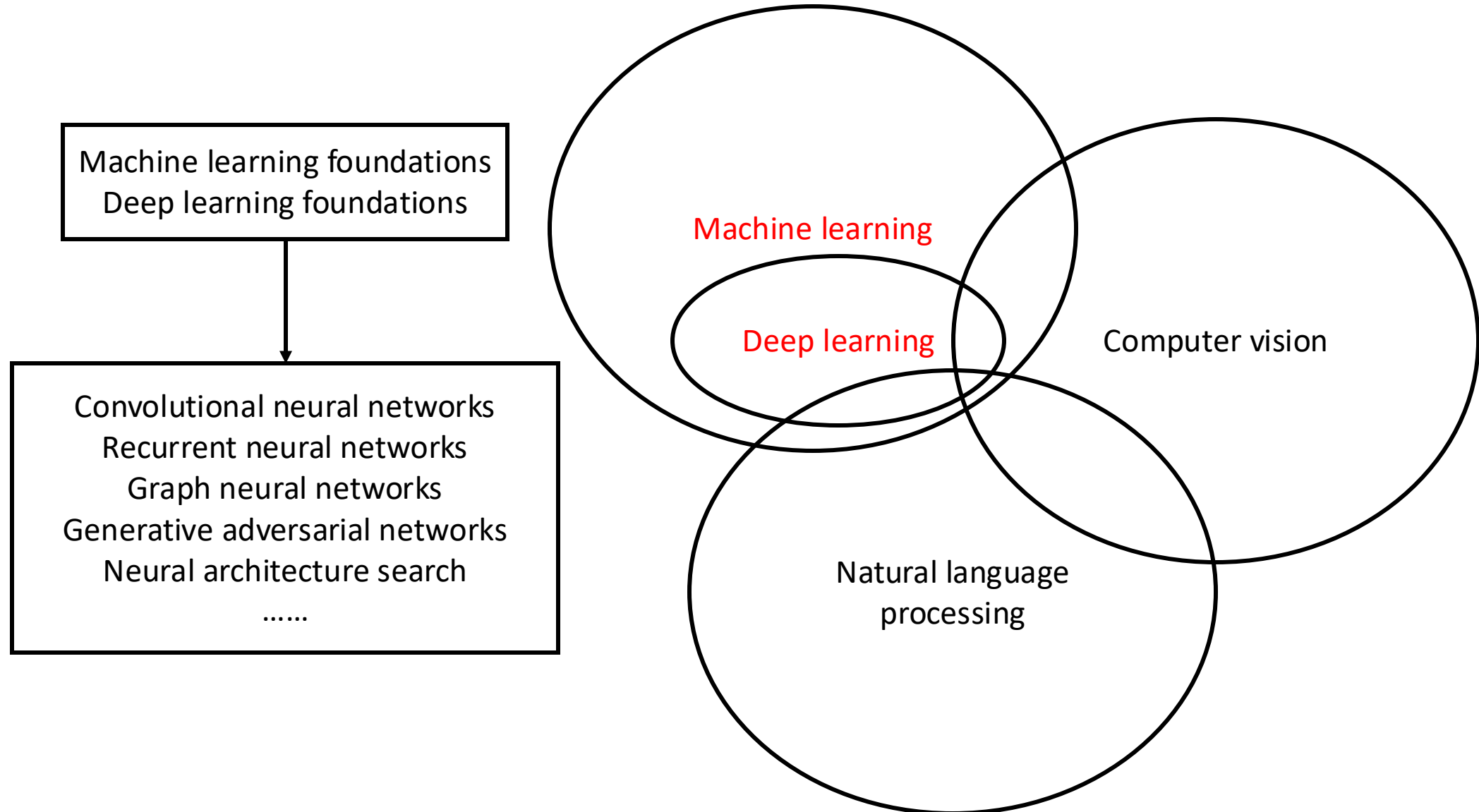
Deep learning? What is learning?

What is in this picture?

Deep learning? What is learning?

Past data

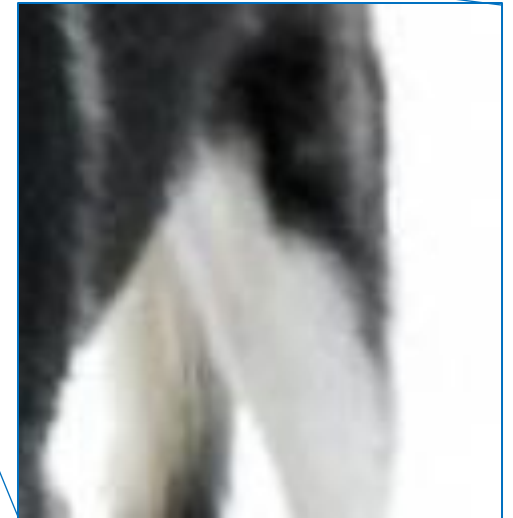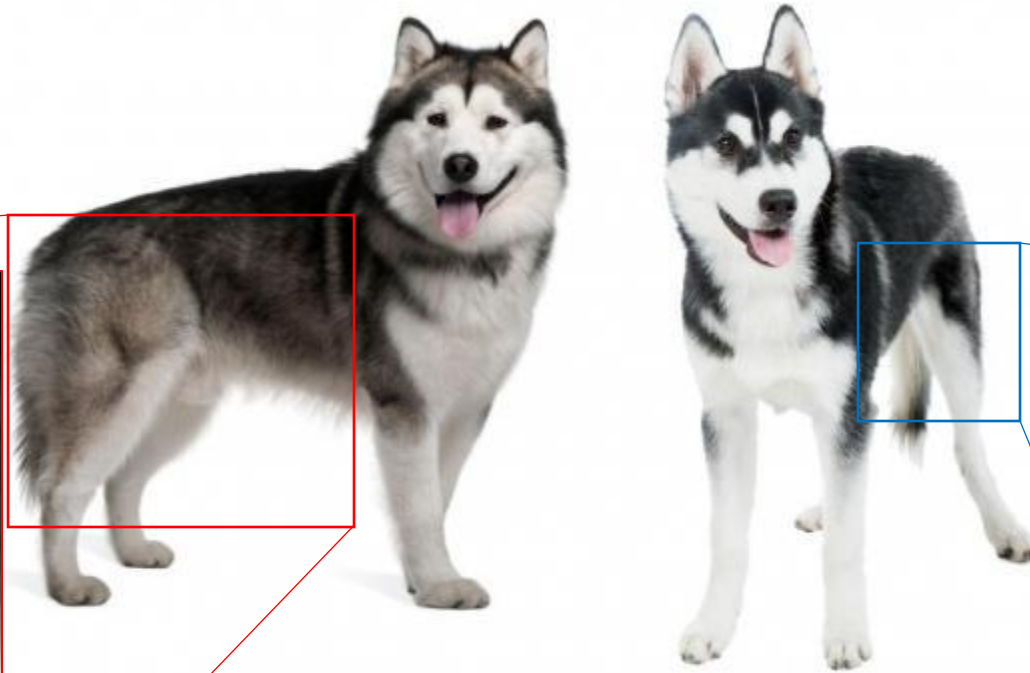Learning system

What is it?

Future data

Husky vs Malamute

How to differentiate two breeds of dogs?
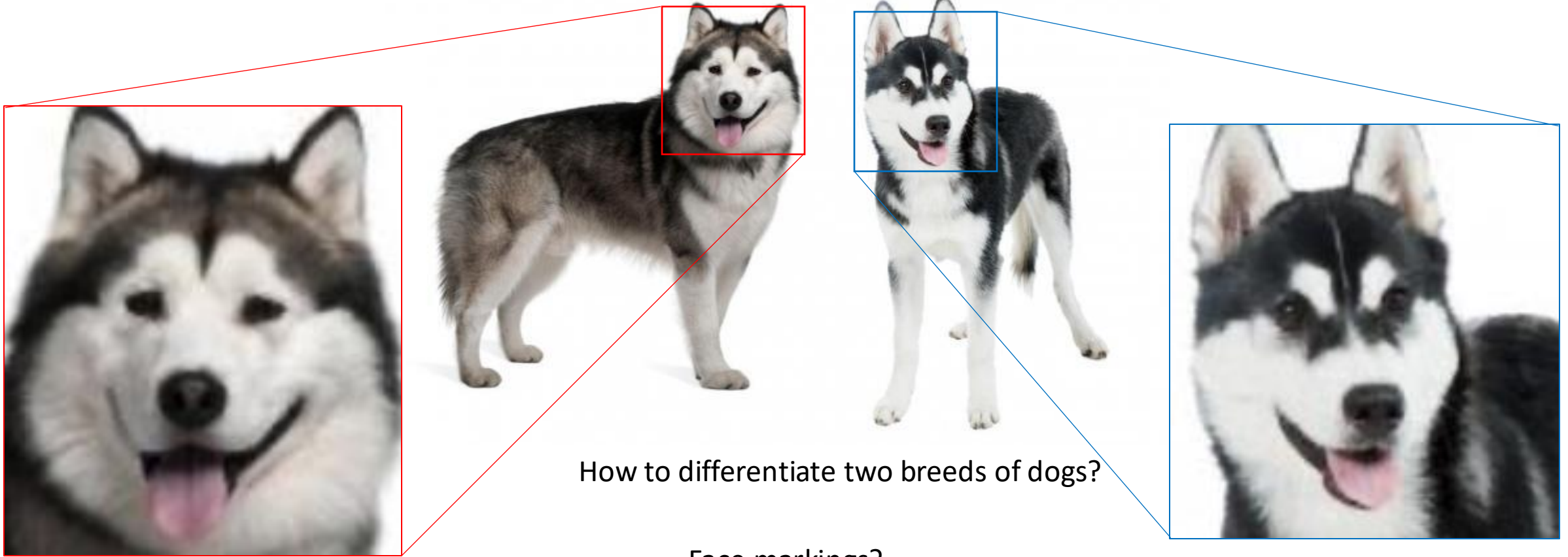
Husky vs Malamute

How to differentiate two breeds of dogs?

Hair length?

Husky vs Malamute

How to differentiate two breeds of dogs?

Face markings?

Husky vs Malamute

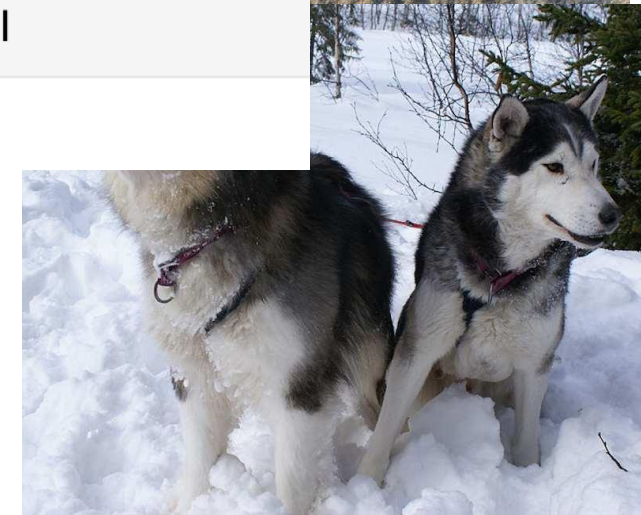How to differentiate two breeds of dogs?

Size?

Husky vs Malamute

Alaskan Malamute vs Siberian Husky Comparison

	Alaskan Malamute	Siberian Husky
Size:	20-25 inches tall	20-22 inches tall
Weight:	85-100lbs	35-60lbs

How to differentiate two breeds of dogs?

Size?

Data from https://www.perfectdogbreeds.com/malamute-vs-husky/
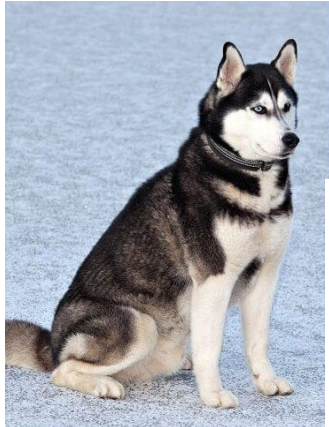
Deep learning? What is learning?

Q: can we specify those key components?

Past data

Learning system

What is it?

Future data

Machine learning paradigm

Past data: features

Learning **model**

Prediction on future data

Task: prediction/decision

(pre-defined setting)

Machine learning paradigm

Past data: features

Q: How to choose/generate useful features?

Learning model

Prediction on future data

Task: prediction/decision

(pre-defined setting)

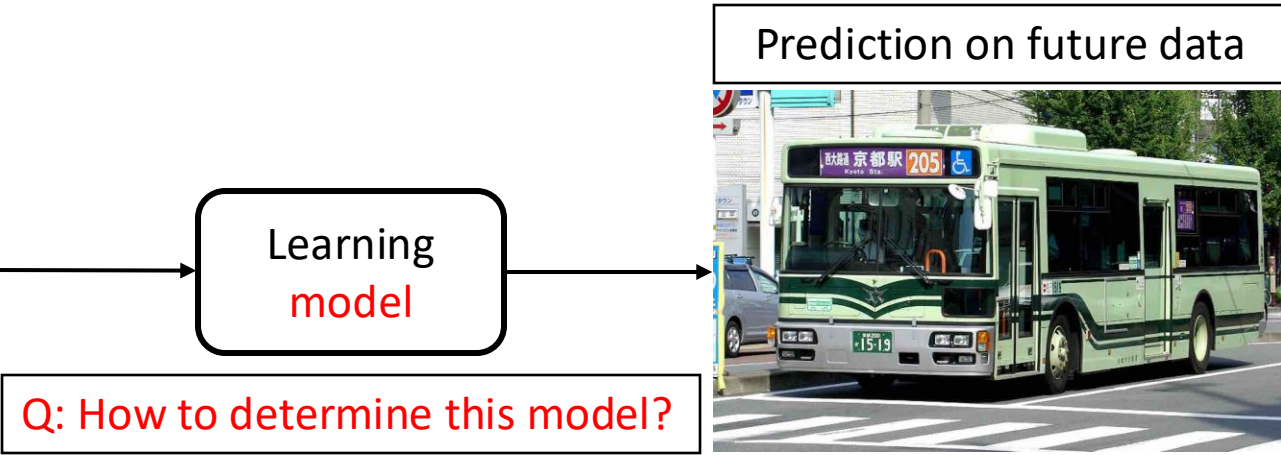# Machine learning paradigm

Prediction on future data

Learning
model

Q: How to determine this model?

Task: prediction/decision

(pre-defined setting)

Past data: features

Q: How to choose/generate useful features?

Machine learning paradigm

Past data: features

Q: How to choose/generate useful features?

Learning model

Q: How to determine this model?

Prediction on future data

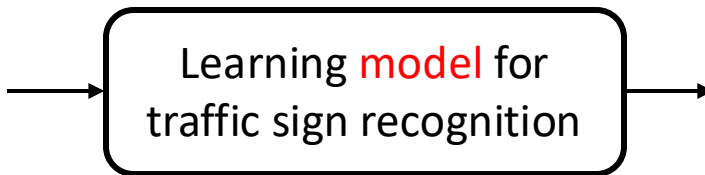Task: prediction/decision
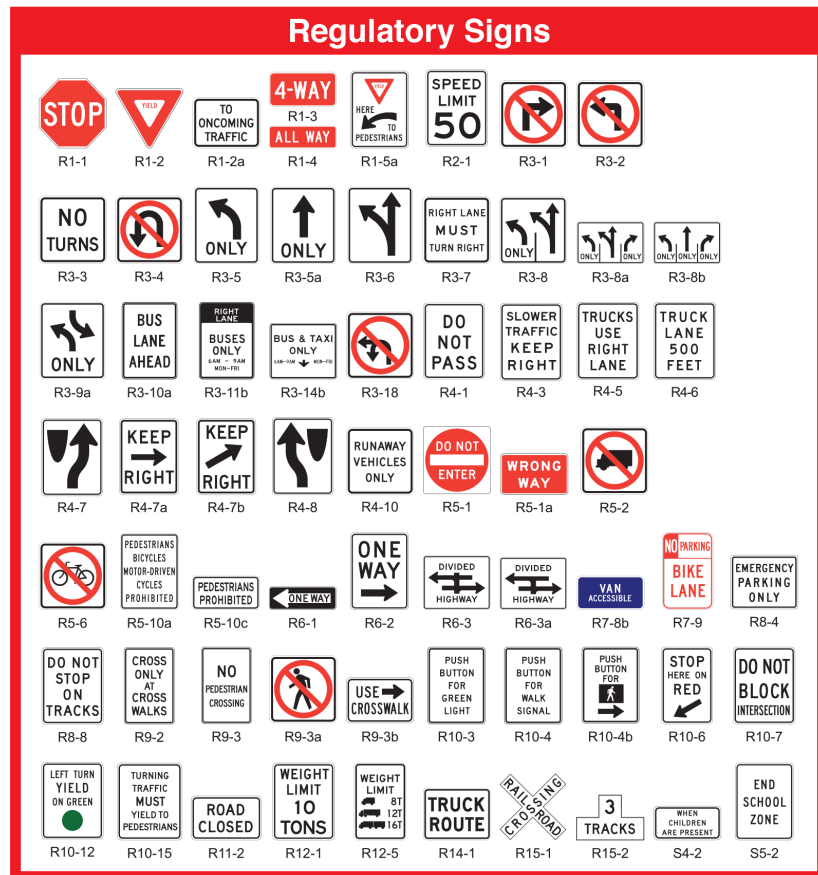
(pre-defined setting)

In practice:
We first inspect what TASK it is

Pre-defined problem settings (by task)

- **Classification**: traffic sign recognition

Learning model for traffic sign recognition
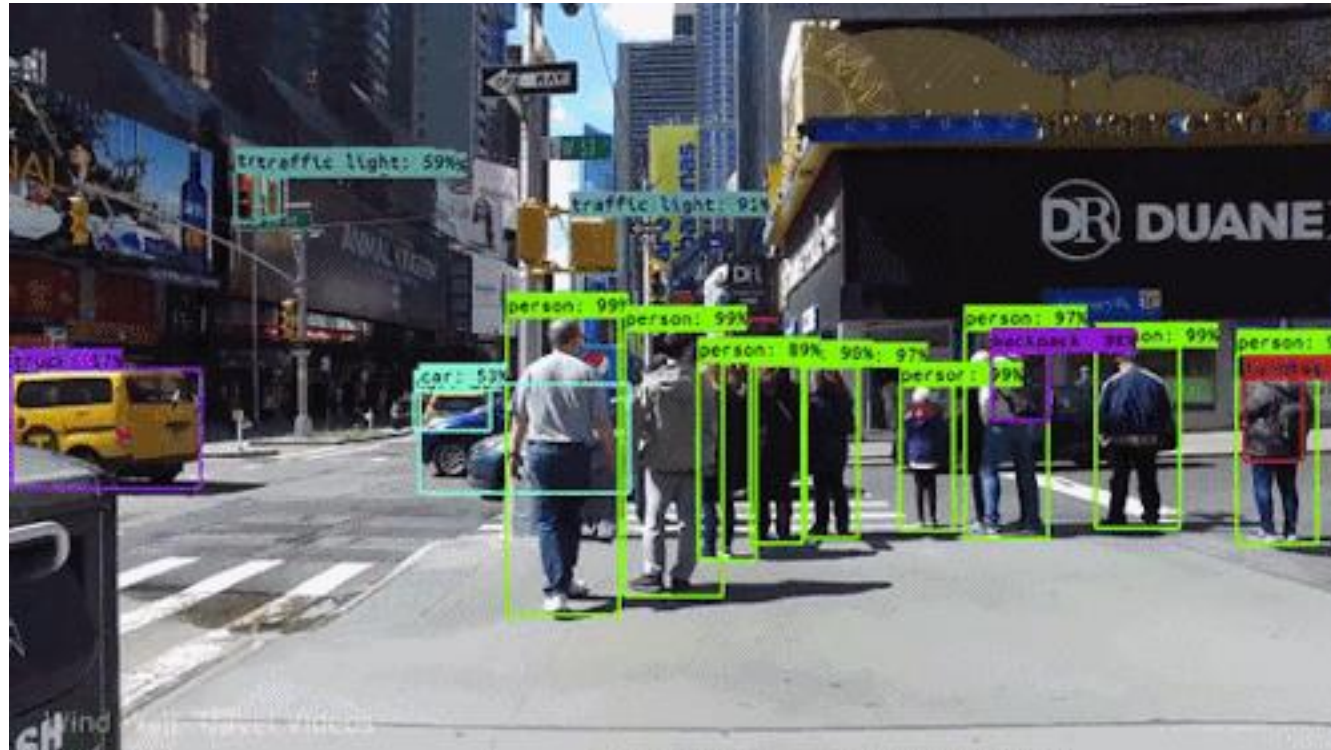

Q: How we can use recognition in practice?

Pre-defined problem settings (by task)

- **Classification**: traffic sign recognition

A use example: autonomous driving system

Pre-defined problem settings (by task)

- **Classification**: camera translate app
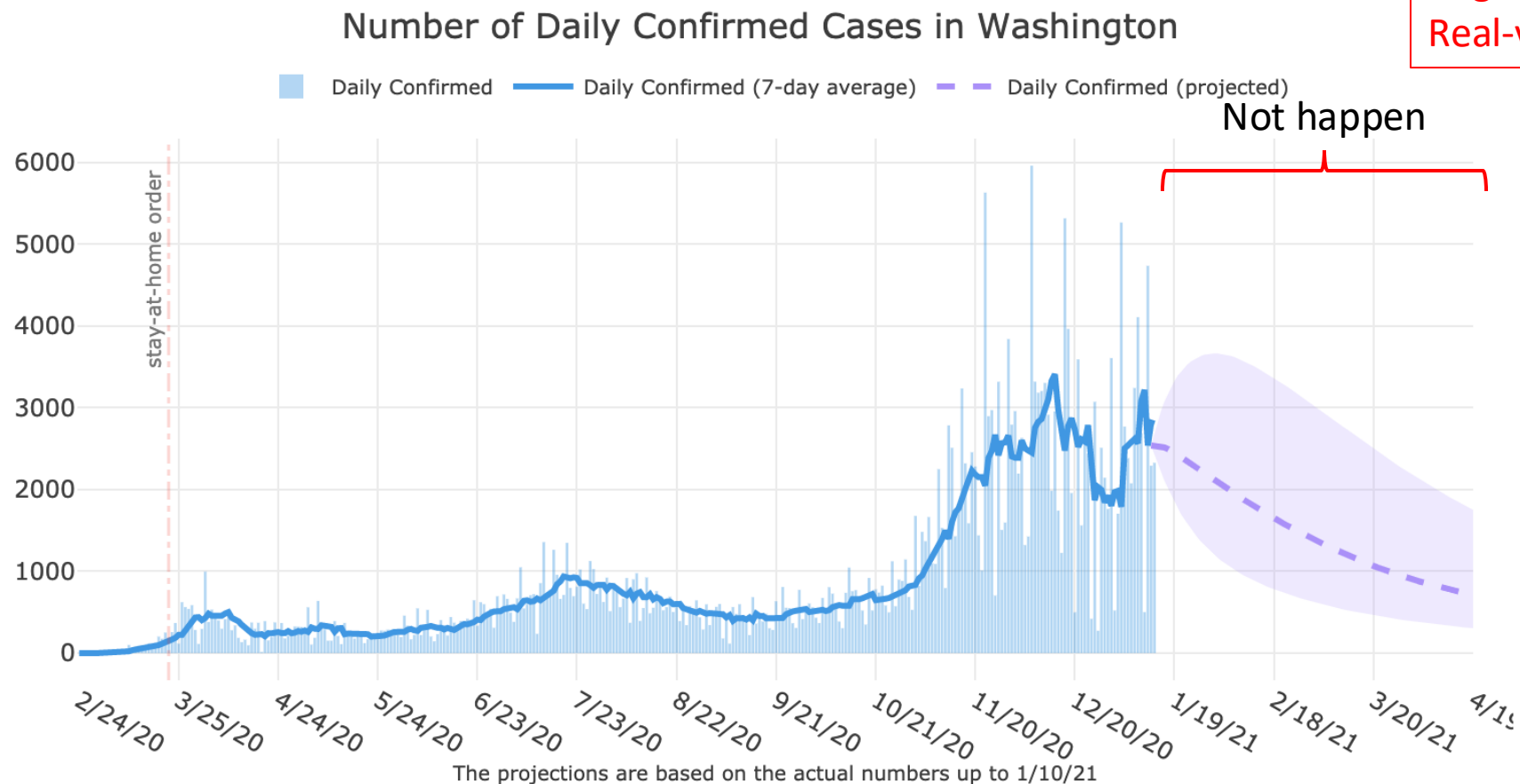
Image from https://petapixel.com/2015/01/14/googles-translate-app-can-now-use-camera-translate-world-real-time/

Pre-defined problem settings (by task)

- **Prediction** vs decision making

Regression:
Real-valued outputs

Number of Daily Confirmed Cases in Washington

Daily Confirmed   Daily Confirmed (7-day average)   Daily Confirmed (projected)

Not happen

The projections are based on the actual numbers up to 1/10/21

Retrieved from https://covid19.uclaml.org/

Pre-defined problem settings (by task)

- **Prediction** vs decision making

Regression:
Real-valued outputs

Zestimate history

— This home	— Denny - Blaine	---- Seattle
NA	**NA**	**NA**

$15M

$10M

$5M

Forecas

2012   2014   2016   2018   2020

No trade

Screen-print from zillow.com
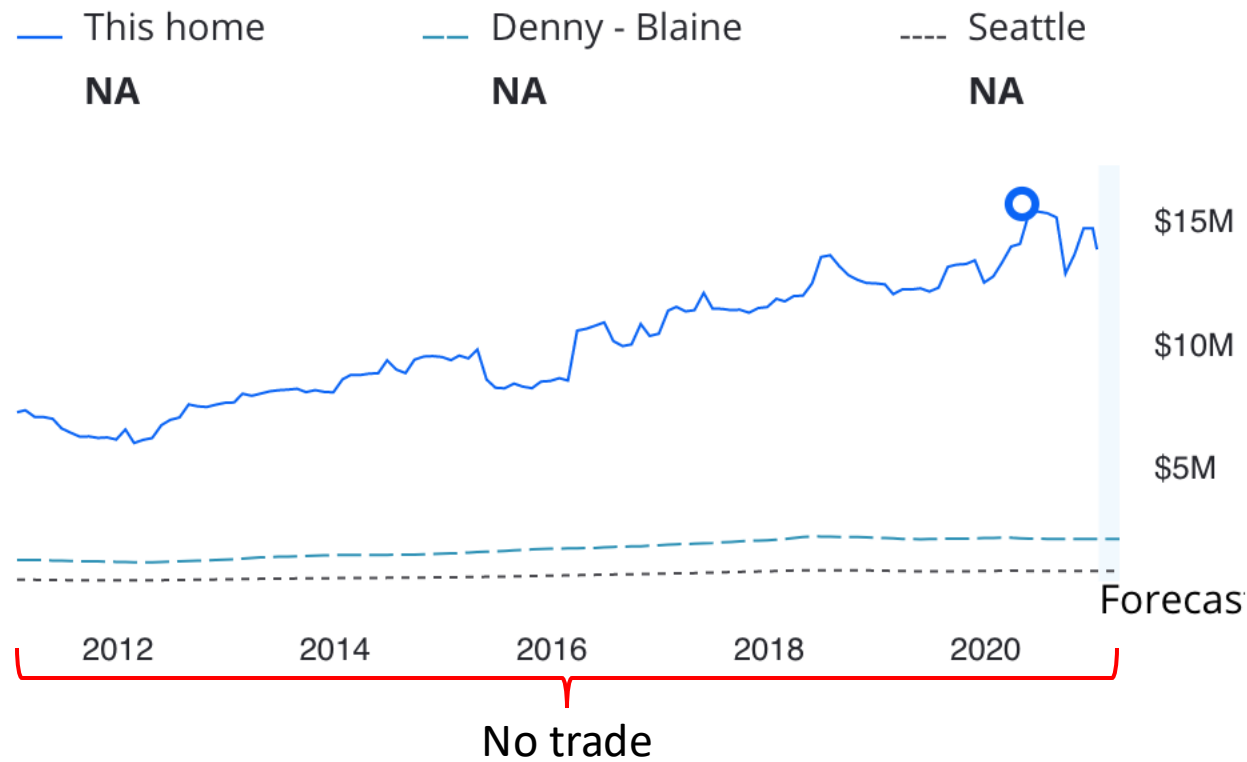
Pre-defined problem settings (by task)

- Prediction vs decision making
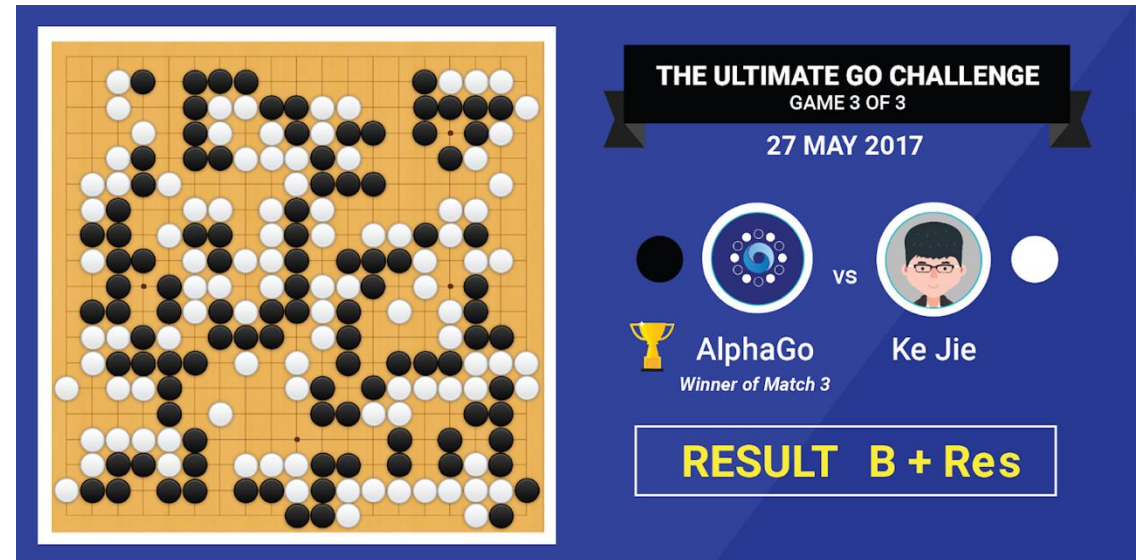
Pre-defined problem settings (by task)

- Prediction vs decision making

Machine learning paradigm

Prediction on future data

Learning
model

Q: How to determine this model?

Task: prediction/decision

(pre-defined setting)

In practice:
We first inspect what TASK it is

Past data: features

Q: How to choose/generate useful features?

Pre-defined problem settings (by label info)

- Supervised learning

bus

bus

dog

dog

Complete label information: supervised learning

Pre-defined problem settings (by label info)

- Non-supervised learning?

bus

dog

Labeled and unlabeled data: semi-supervised learning

Pre-defined problem settings (by label info)

- Non-supervised learning?

Unlabeled data: unsupervised learning
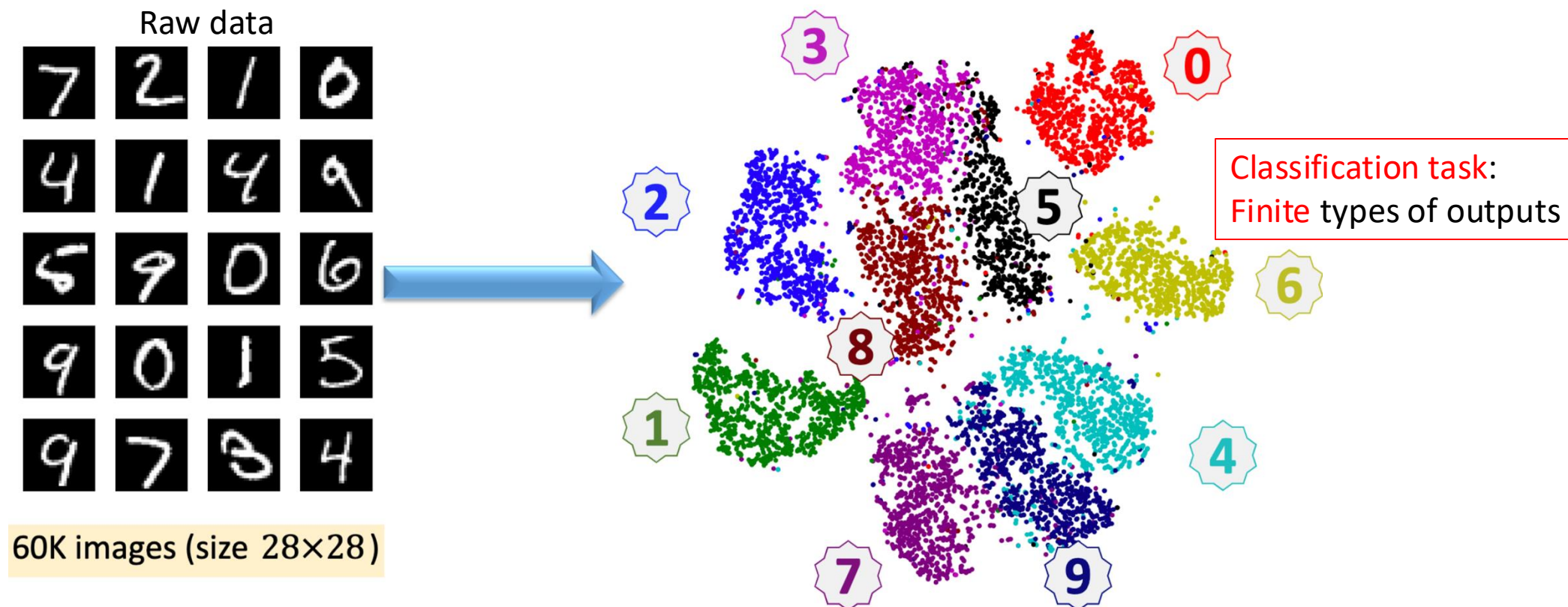
Pre-defined problem settings (by label info)

- **Unsupervised** learning

Raw data

60K images (size 28×28)

Classification task:
Finite types of outputs

Autoencoder for hand-written digit data, retrieved from Shusen Wang's slides at
https://github.com/wangshusen/DeepLearning/blob/master/Slides/1_ML_Basics.pdf

Pre-defined problem settings (by label info)

- **Unsupervised** learning

Raw data

2d x-y coordinate

Classification task:
Finite types of outputs

60K images (size 28×28)

Autoencoder for hand-written digit data, retrieved from Shusen Wang's slides at
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Pre-defined problem settings (by label info)

- **Unsupervised** learning

Raw data → model → 2d x-y coordinate

Classification task:
Finite types of outputs

60K images (size 28×28)

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Raw data → model → 2d x-y coordinate

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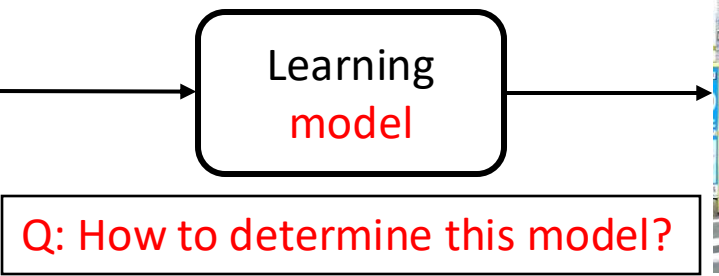
31

Machine learning paradigm

Past data: features

Q: How to choose/generate useful features?

Learning model
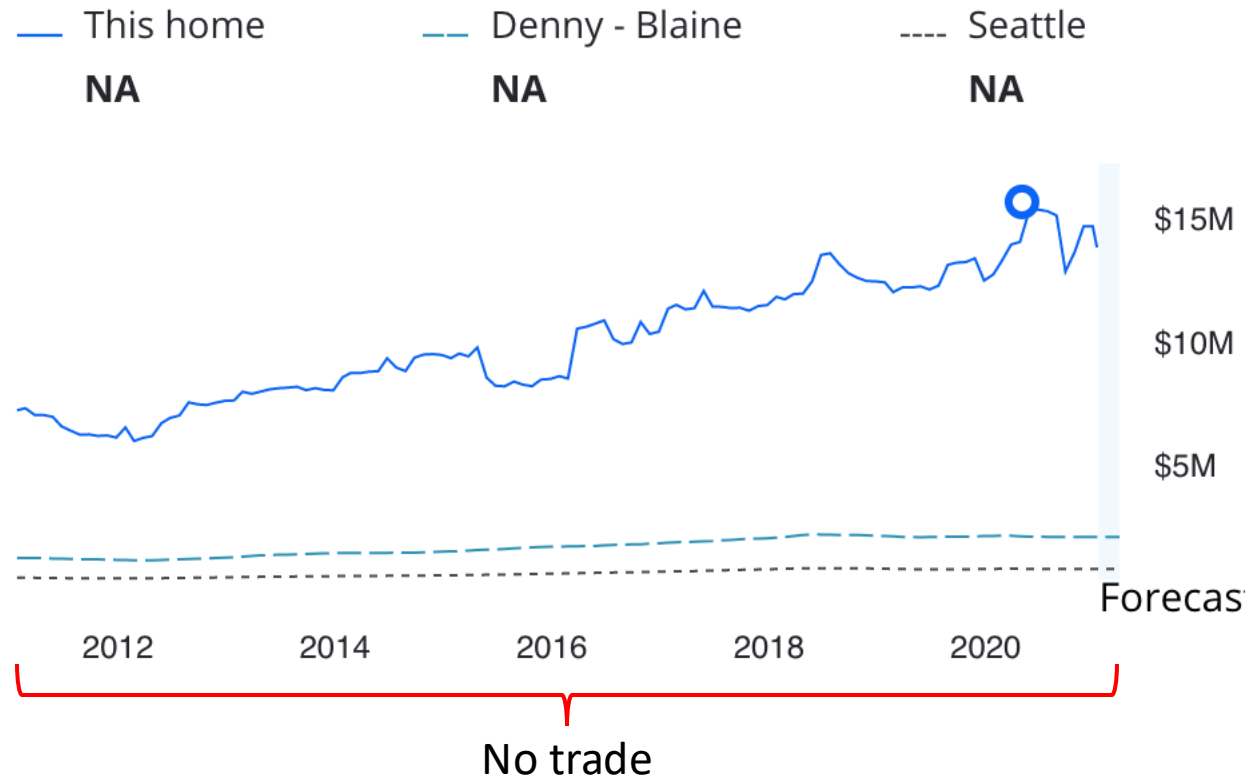
Q: How to determine this model?

Prediction on future data

Task: prediction/decision

(pre-defined setting)

In practice:
We first inspect what TASK it is

Features

Q: What features can we use?

Zestimate history

— This home   — — Denny - Blaine   ---- Seattle
NA   **NA**   **NA**

$15M

$10M

$5M

Forecast

2012   2014   2016   2018   2020

No trade

Screen-print from zillow.com

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Feature in house price prediction

- Home characteristics: lot size, location, #bedrooms
- Unique features: hardwood floors, granite countertops or a landscaped backyard
- On-market data: listing price, description, days on the market
- Off-market data: tax assessments, prior sales

https://www.zillow.com/z/zestimate/

Feature in house price prediction

Existing physical properties

Land size (sqft)

#bedrooms

Zip code

Carpet (Y/N)

Description text

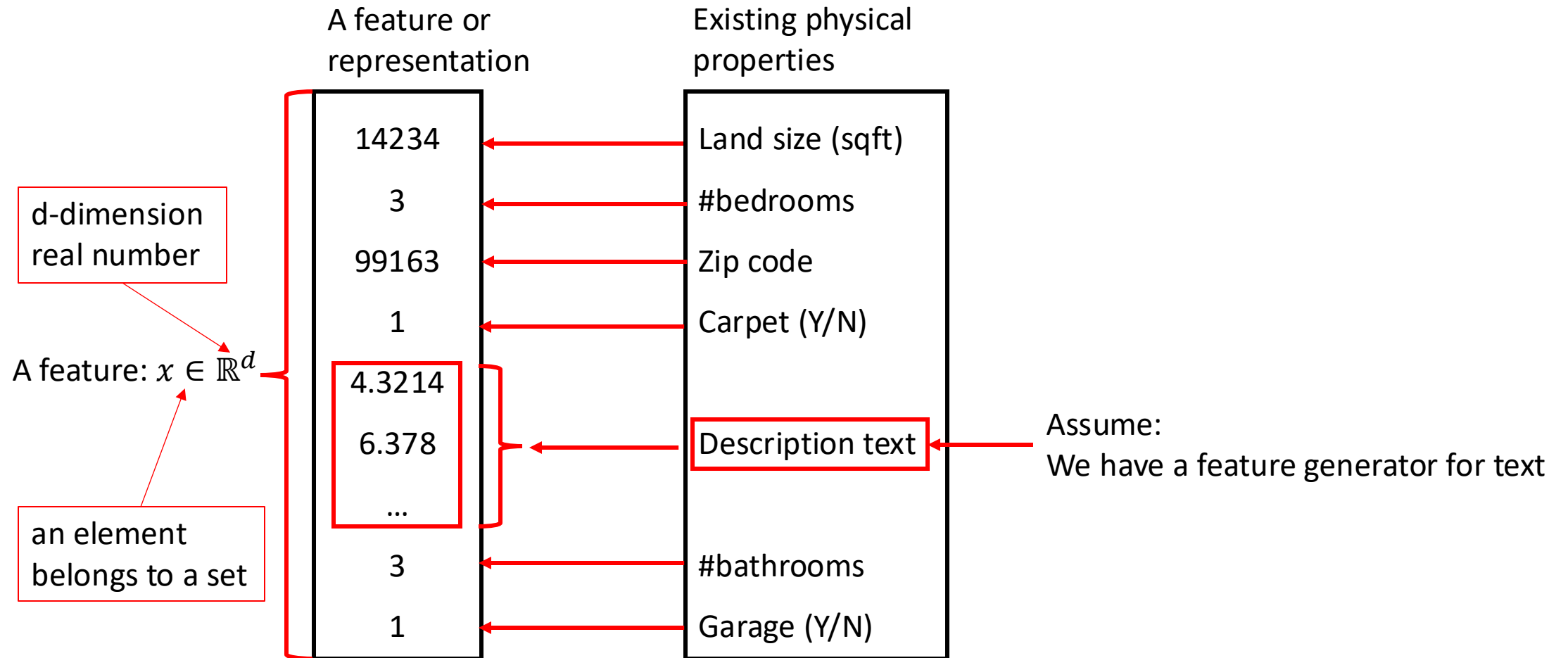#bathrooms

Garage (Y/N)

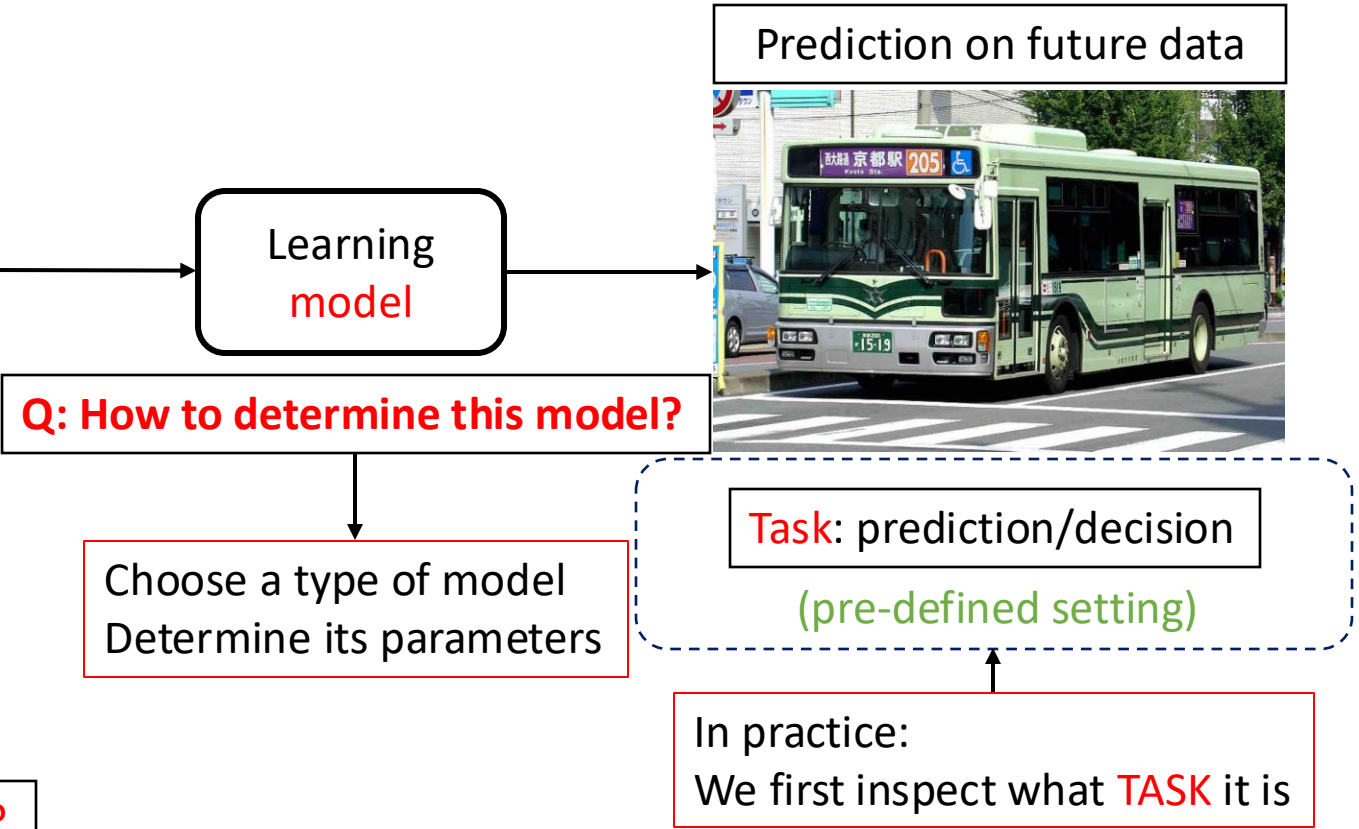# Feature in house price prediction

Existing physical properties

14234 ← Land size (sqft)

3 ← #bedrooms

99163 ← Zip code

1 ← Carpet (Y/N)

4.3214
6.378
…
← Description text

Assume:
We have a feature generator for text

3 ← #bathrooms

1 ← Garage (Y/N)

Feature in house price prediction

A feature or representation

Existing physical properties

d-dimension real number

A feature: $x \in \mathbb{R}^d$

an element belongs to a set

14234	Land size (sqft)
3	#bedrooms
99163	Zip code
1	Carpet (Y/N)
4.3214	
6.378	Description text
…	
3	#bathrooms
1	Garage (Y/N)

Assume:
We have a feature generator for text

Machine learning paradigm

Prediction on future data

Learning
model

Q: How to determine this model?

Choose a type of model
Determine its parameters

Task: prediction/decision

(pre-defined setting)

Past data: features

Q: How to choose/generate useful features?

In practice:
We first inspect what TASK it is

Build a model

- What is a model

Try to separate two classes

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

Try to separate two classes
Q: how to separate them?

• What is a model

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

Try to separate two classes

Q: how to separate them?

- What is a model

A linear function

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

- What is a model

A hypothesis class

A linear function

$$y = ax + b$$
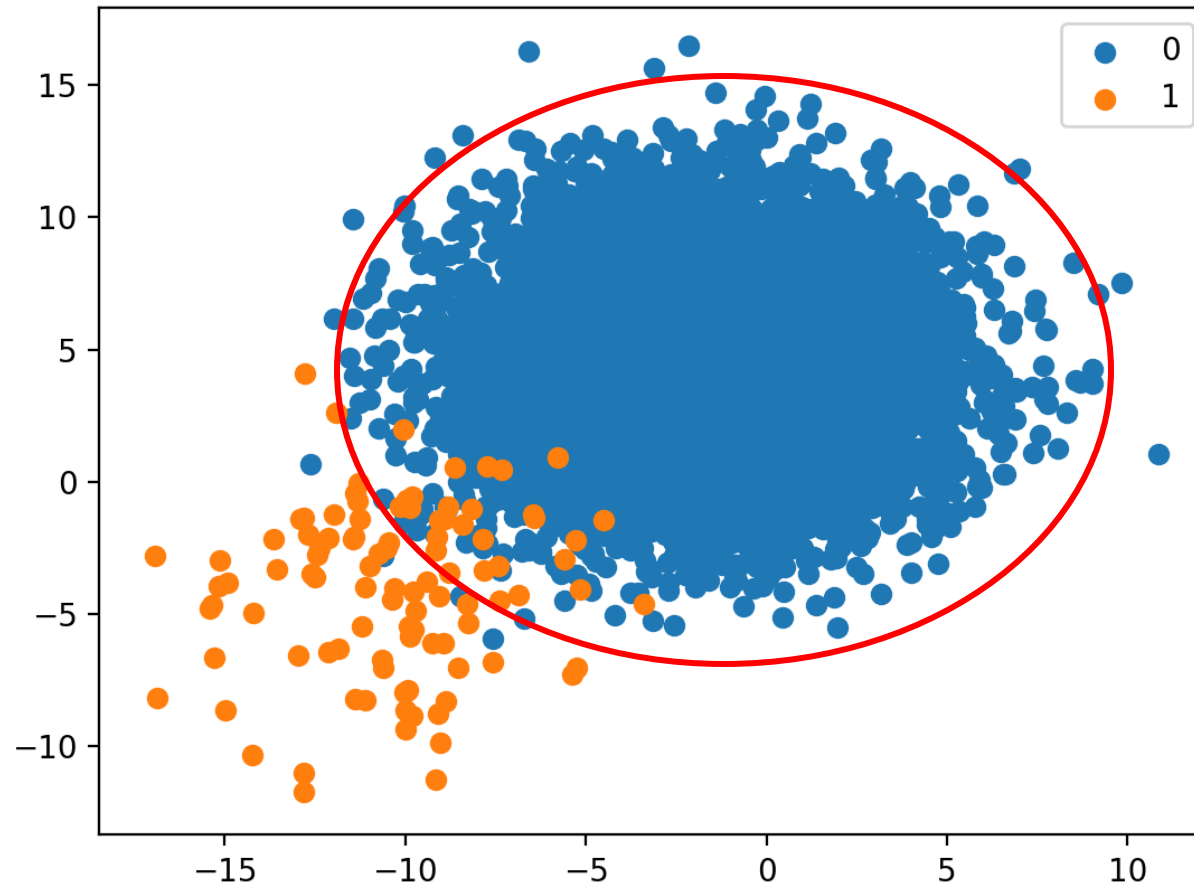
Try to separate two classes
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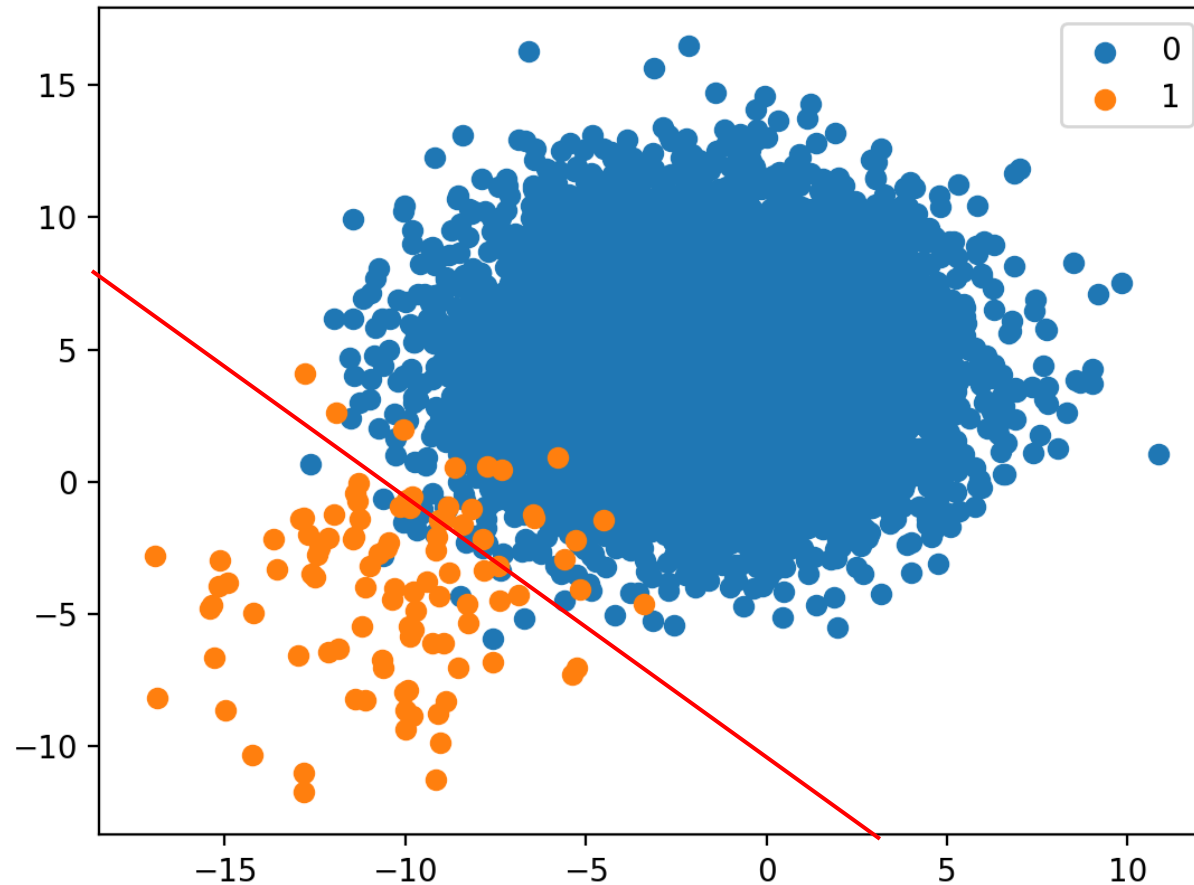
Build a model

- ## What is a model

An ellipse (nonlinear function)

Try to separate two classes

Q: how to separate them?

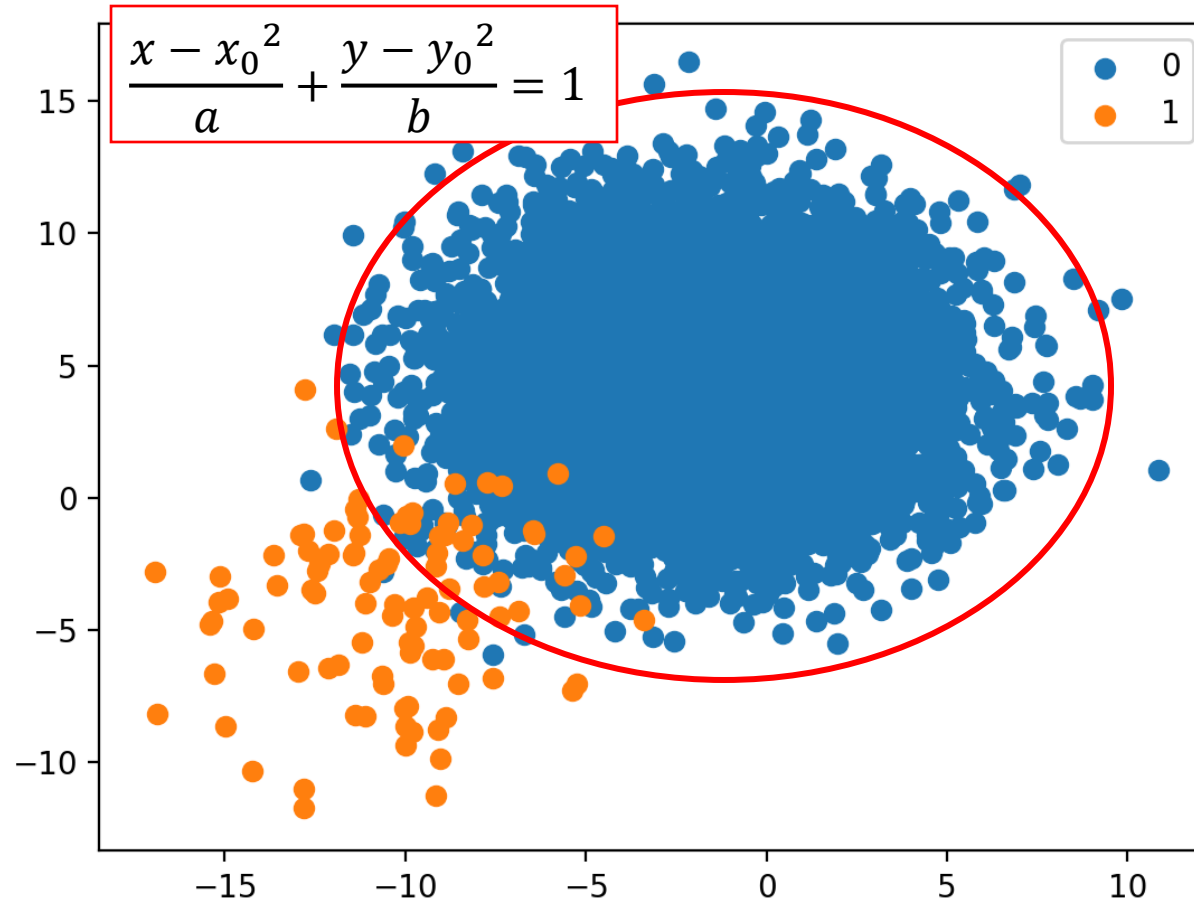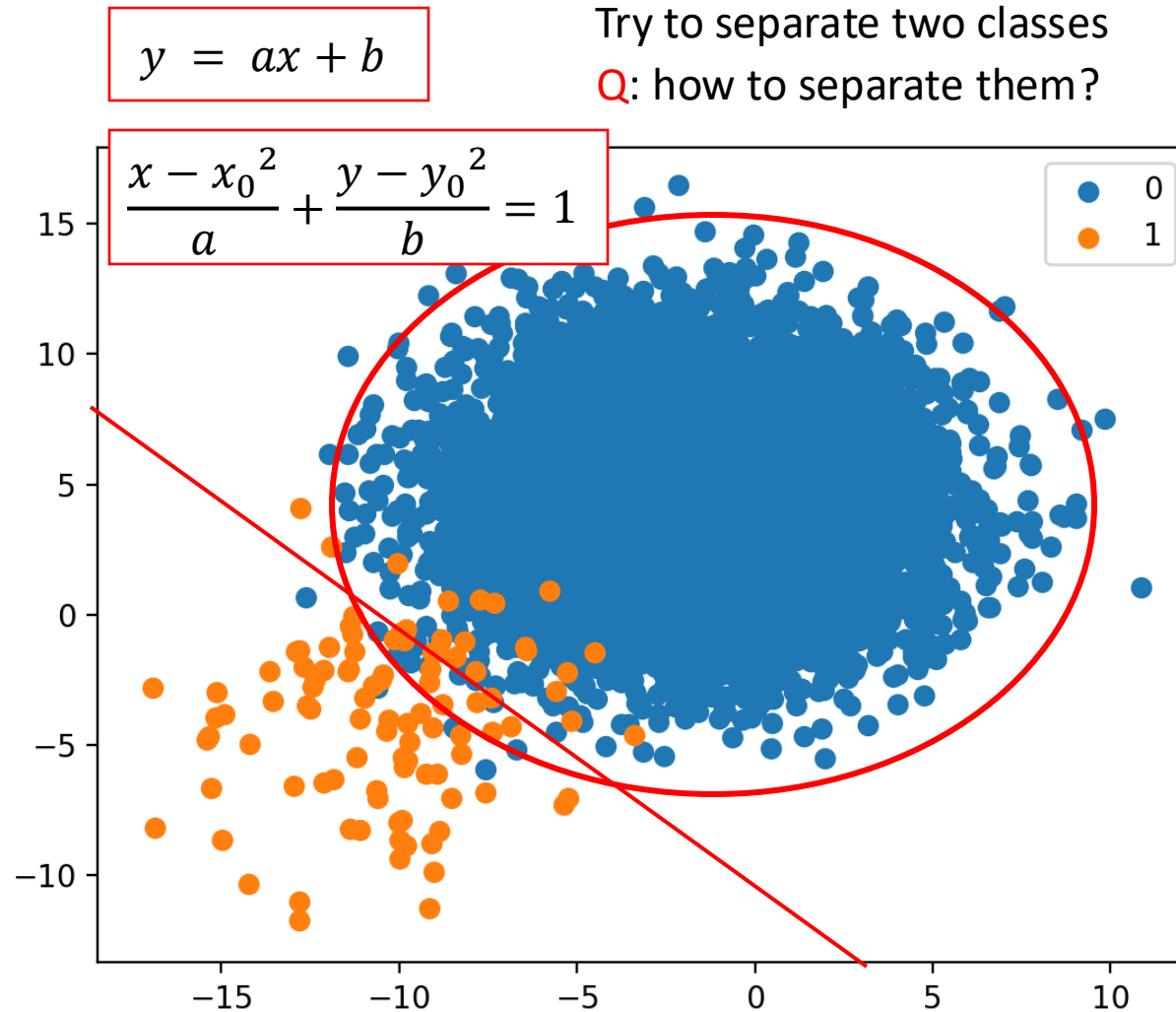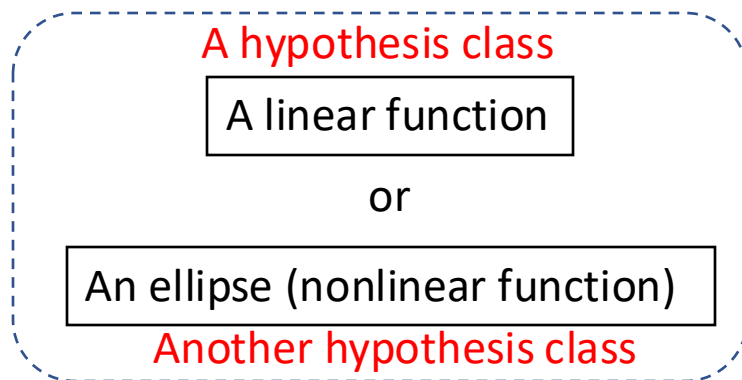Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

- What is a model

An ellipse (nonlinear function)

Another hypothesis class
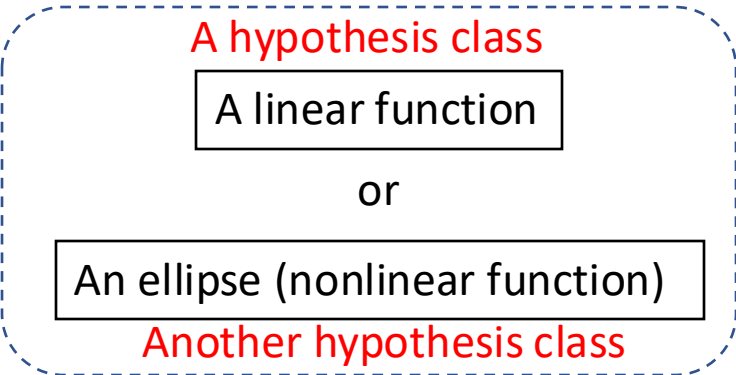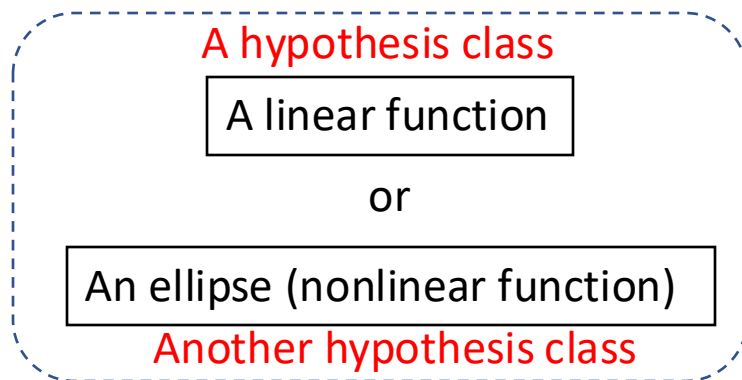
Try to separate two classes

Q: how to separate them?

$$\frac{x - x_0^2}{a} + \frac{y - y_0^2}{b} = 1$$

Build a model

- What is a model

A hypothesis class

A linear function

or

An ellipse (nonlinear function)

Another hypothesis class

$$y = ax + b$$

$$\frac{x - x_0{}^2}{a} + \frac{y - y_0{}^2}{b} = 1$$

Try to separate two classes
Q: how to separate them?

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Build a model

- ## What is a model

$$y = ax + b$$

$$\frac{x - x_0{}^2}{a} + \frac{y - y_0{}^2}{b} = 1$$

A hypothesis class

A linear function

or

An ellipse (nonlinear function)

Another hypothesis class

Q: what is the feature used here?

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

- ## What is a model

Q: what is the feature used here?

A: x-y coordinates
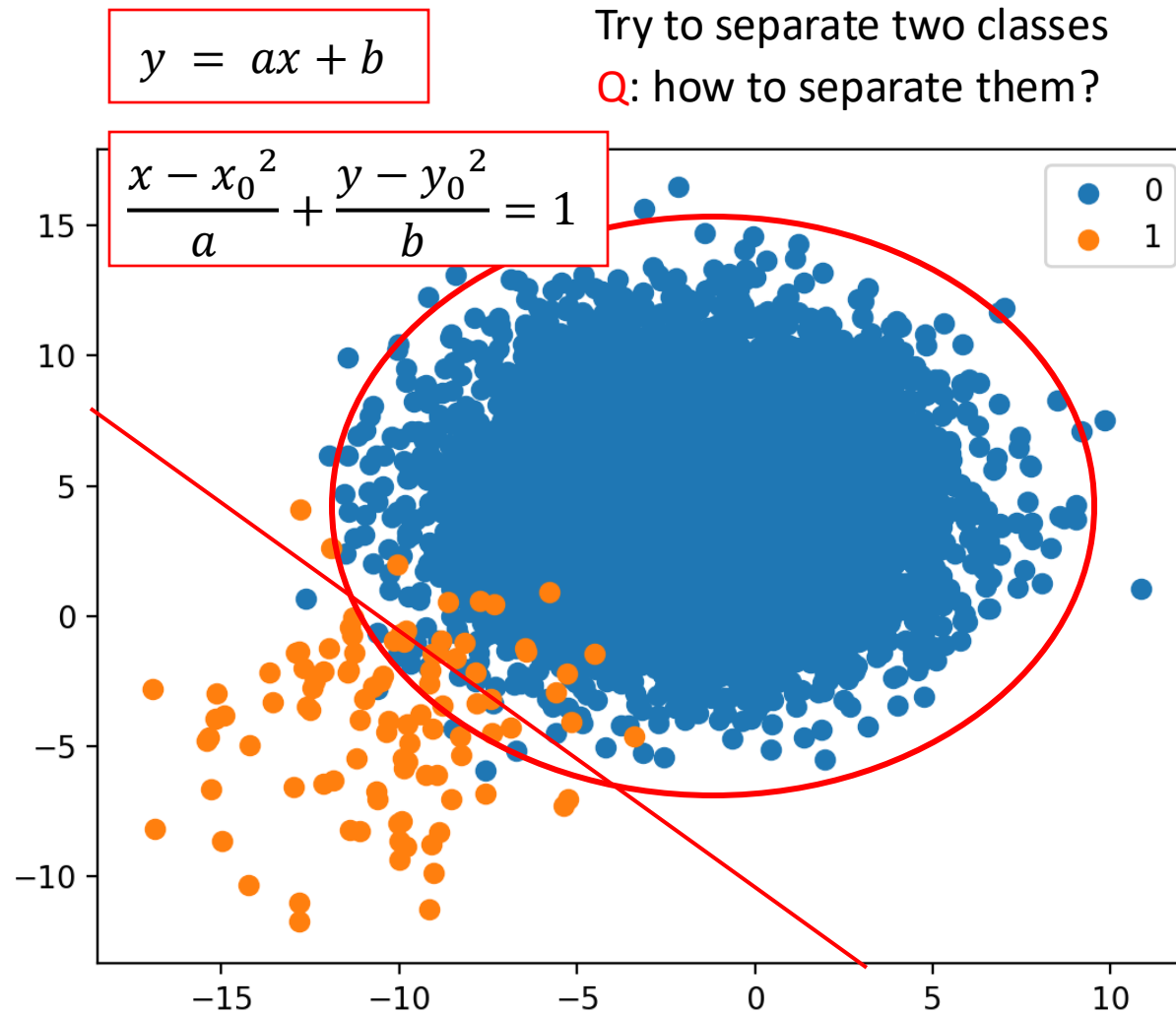
$$y = ax + b$$

$$\frac{x - {x_0}^2}{a} + \frac{y - {y_0}^2}{b} = 1$$

Try to separate two classes

Q: how to separate them?

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

- ## What is a model

A hypothesis class

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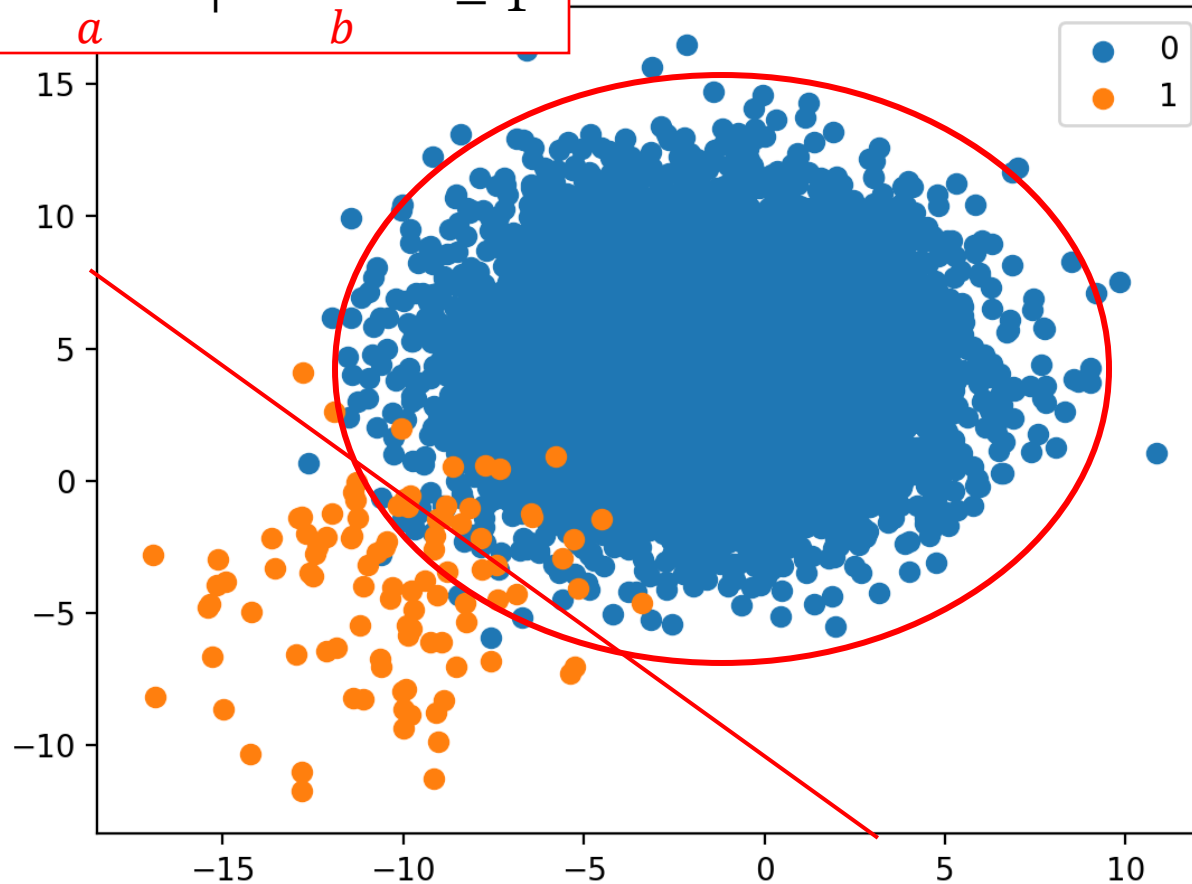
Another hypothesis class
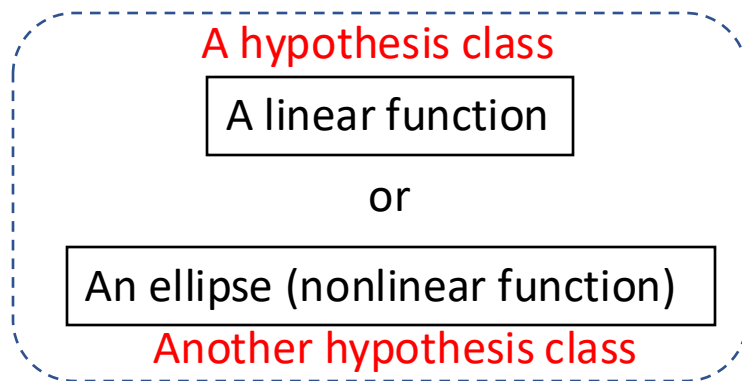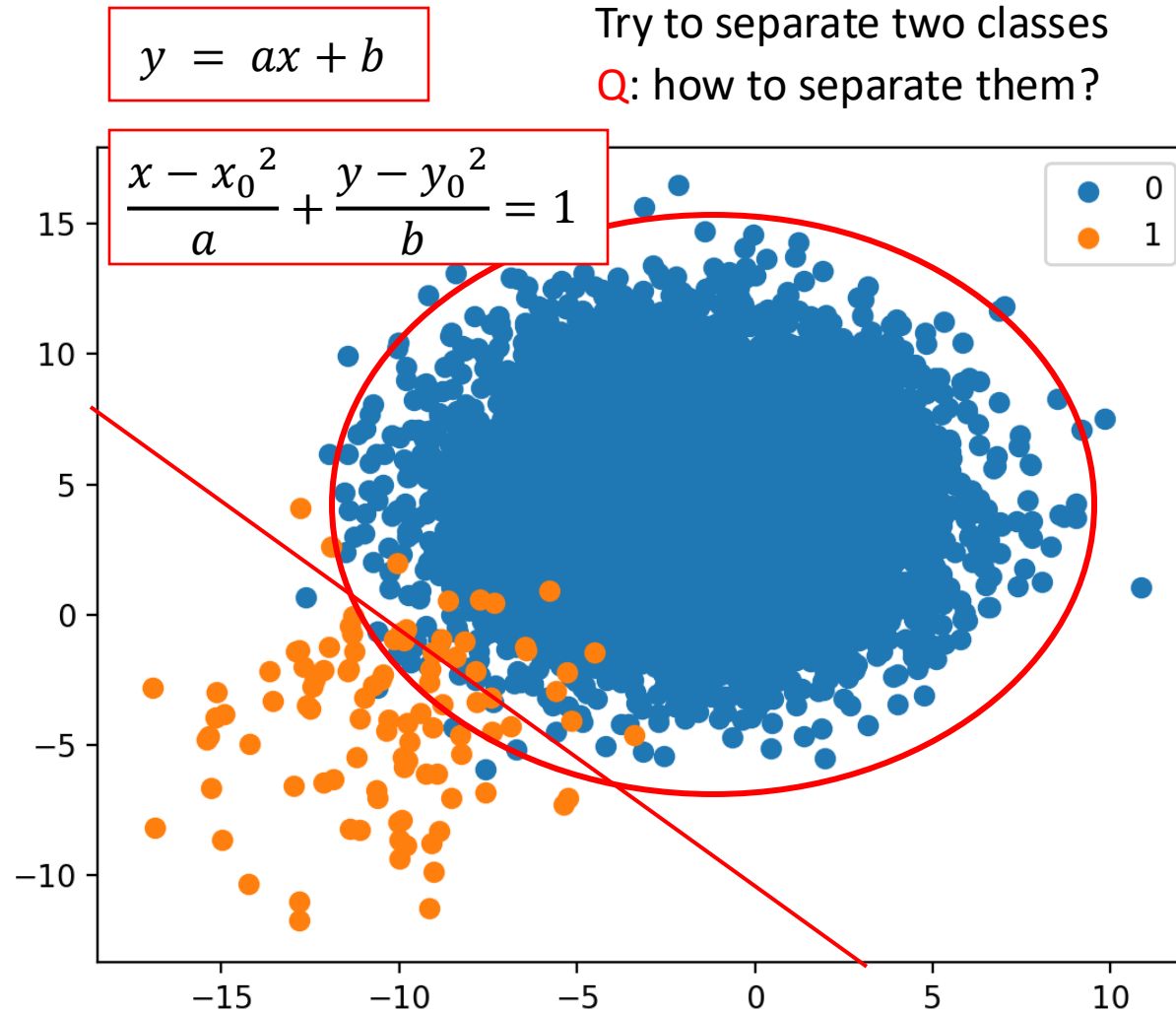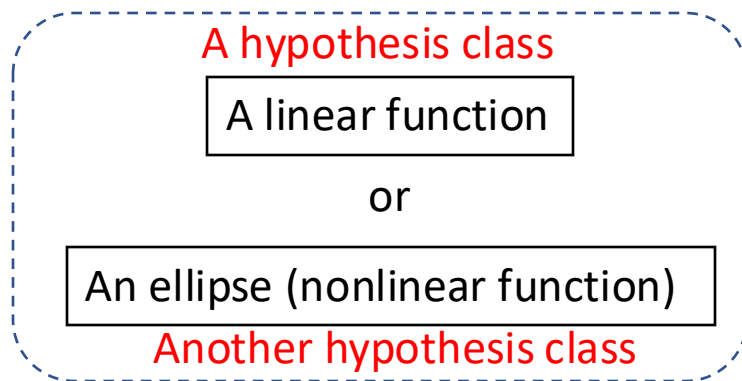
Q: what are their parameters?

$$y = ax + b$$

$$\frac{x - x_0{}^2}{a} + \frac{y - y_0{}^2}{b} = 1$$

Try to separate two classes

Q: how to separate them?

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Build a model

$$y = ax + b$$

$$\frac{(x - x_0)^2}{a} + \frac{(y - y_0)^2}{b} = 1$$

• What is a model

Try to separate two classes

Q: how to separate them?

A hypothesis class

A linear function

or

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Another hypothesis class

Q: what are their parameters?

Image retrieved from https://machinelearningmastery.com/how-to-develop-an-intuition-skewed-class-distributions/

Analogous to Thermometers

- Types of thermometers
  - Liquid thermometers
  - Dial thermometers
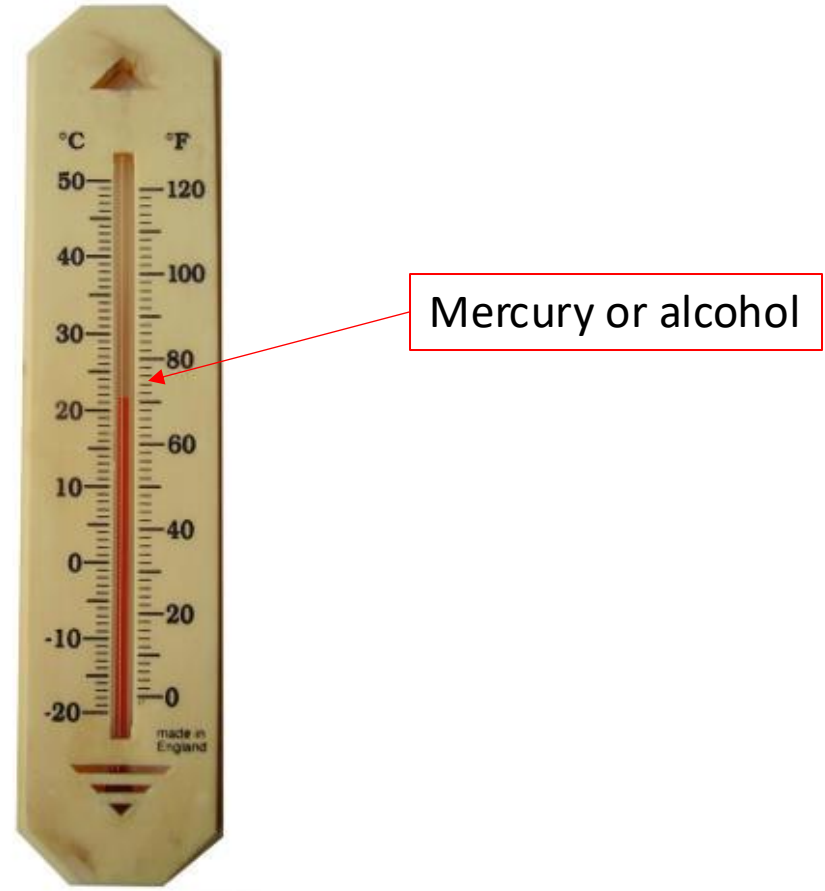 - Electronic thermometers

Analogous to Thermometers

- Types of thermometers
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www.explainthatstuff.com

Image from www.explainthatstuff.com

Analogous to Thermometers

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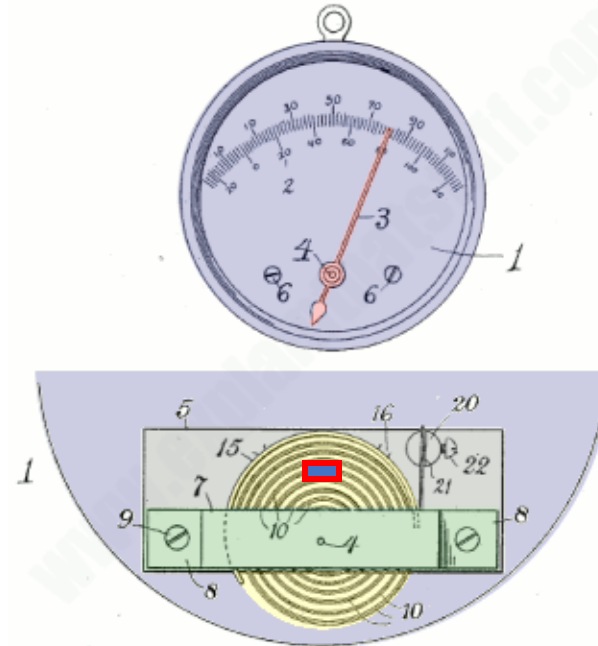Mercury or alcohol

www.explainthatstuff.com

Image from www.explainthatstuff.com

Analogous to Thermometers

- Types of thermometers
  - Liquid thermometers
  - Dial thermometers
  - Electronic thermometers

Mercury or alcohol

1. Expands when temperature goes higher
2. Thermal expansion coefficients

www.explainthatstuff.com

Image from www.explainthatstuff.com

Analogous to Thermometers

- Types of thermometers
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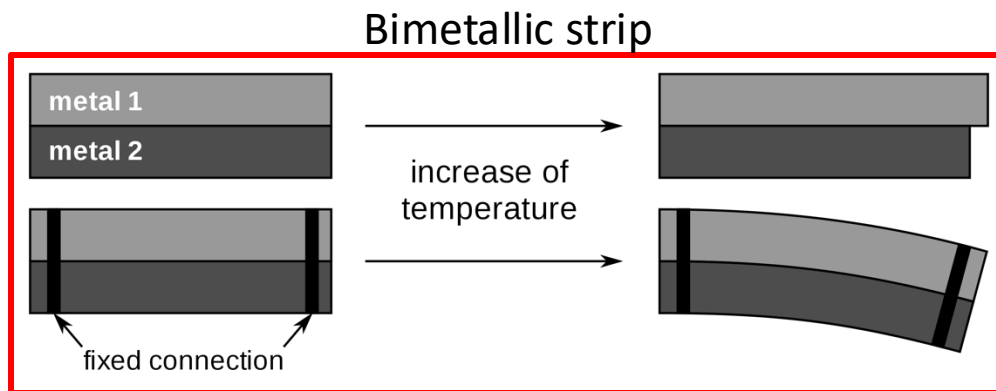

No. 798,211. C. W. PUTNAM. PATENTED AUG. 29, 1905.
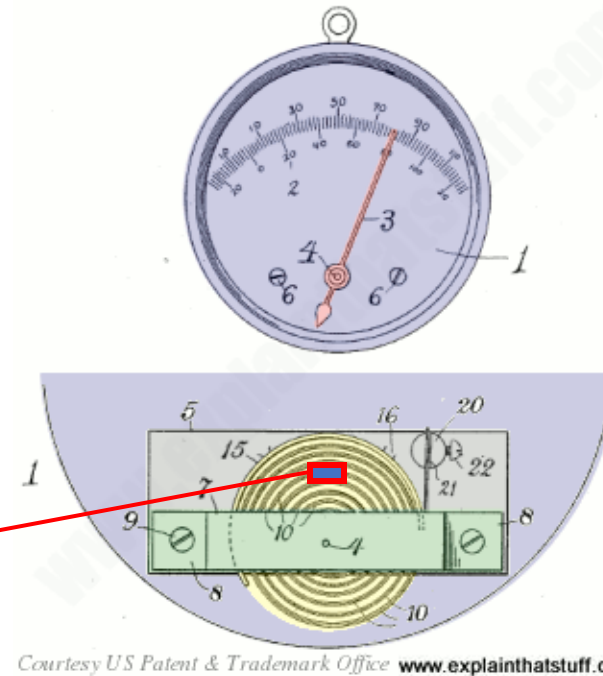THERMOMETER.
APPLICATION FILED OCT. 10, 1904.

Courtesy US Patent & Trademark Office **www.explainthatstuff.com**

Image from
www.explainthatstuff.com

Analogous to Thermometers

- Types of thermometers
  - Liquid thermometers
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Bimetallic strip

metal 1	
metal 2	

increase of temperature

fixed connection

No. 798,211. C. W. PUTNAM. PATENTED AUG. 29, 1905.
THERMOMETER.
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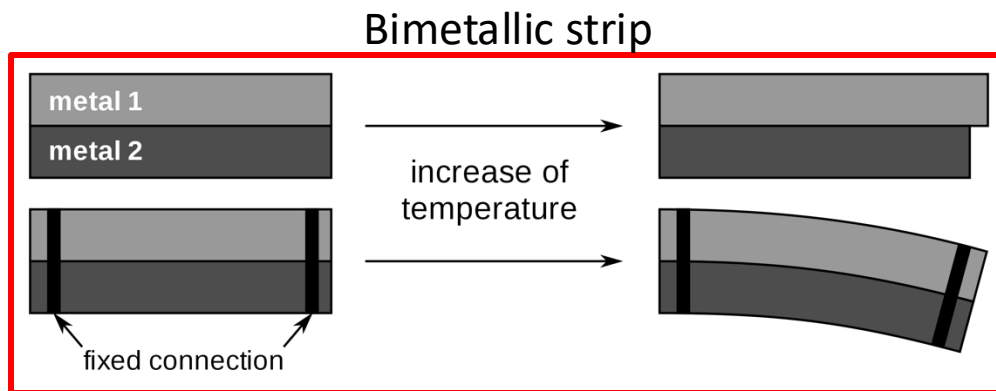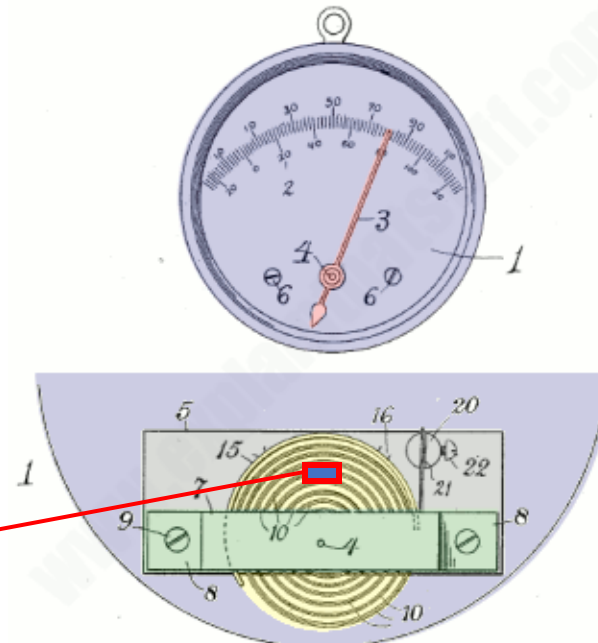 - Dial thermometers
  - Electronic thermometers

Bimetallic strip

| metal 1 | |
| metal 2 | |

increase of temperature

fixed connection

1. Metal 1 expands faster than metal 2 when heating
2. Convert to temperature difference
   by thermal expansion coefficients

No. 798,211. C. W. PUTNAM. PATENTED AUG. 29, 1905.
THERMOMETER.
APPLICATION FILED OCT. 10, 1904.

Courtesy US Patent & Trademark Office www.explainthatstuff.com

Right image from
www.explainthatstuff.com

Left image from https://en.wikipedia.org/wiki/Bimetallic_strip

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Analogous to Thermometers

- **Types of thermometers**
  - Liquid thermometers
  - Dial thermometers
  - Electronic thermometers

www.explainthatstuff.com

Image from www.explainthatstuff.com

Analogous to Thermometers

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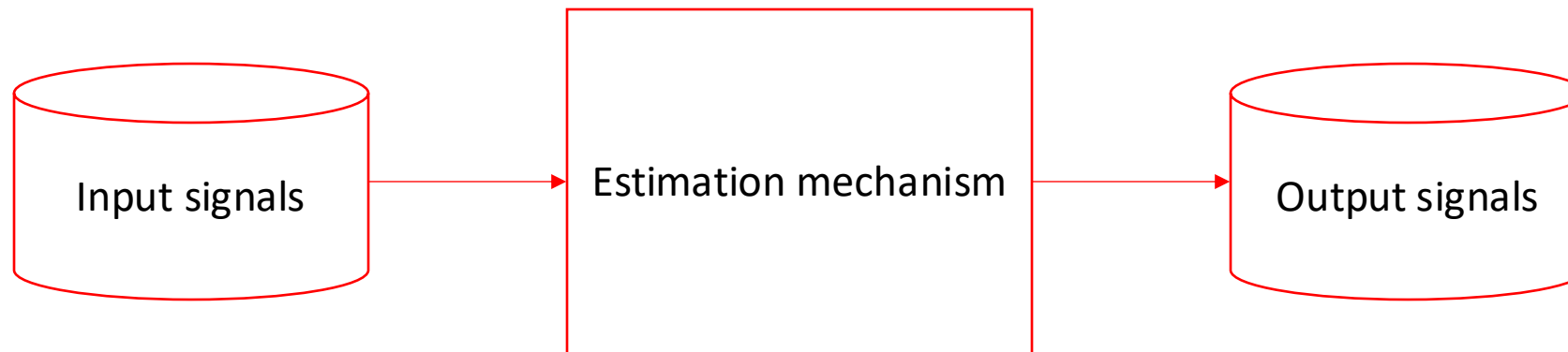 - Electronic thermometers

www.explainthatstuff.com

1. Read voltage across its metal probe
2. Measure how much current flow through it and the resistance
3. Convert resistance into a measurement of temperature

Image from www.explainthatstuff.com

Analogous to Thermometers

- Types of thermometers
  - Liquid thermometers
  - Dial thermometers
  - Electronic thermometers

```
Input signals  →  Estimation mechanism  →  Output signals
```
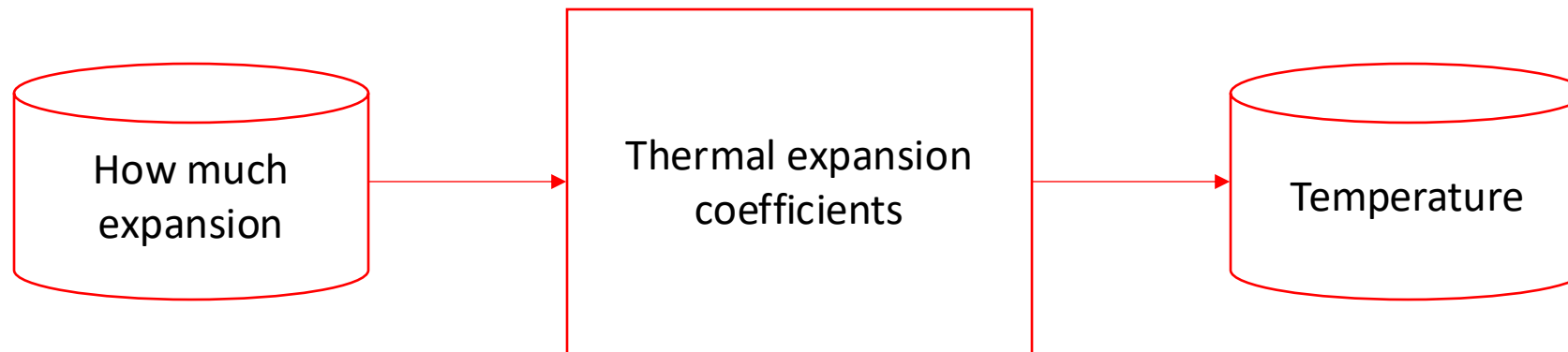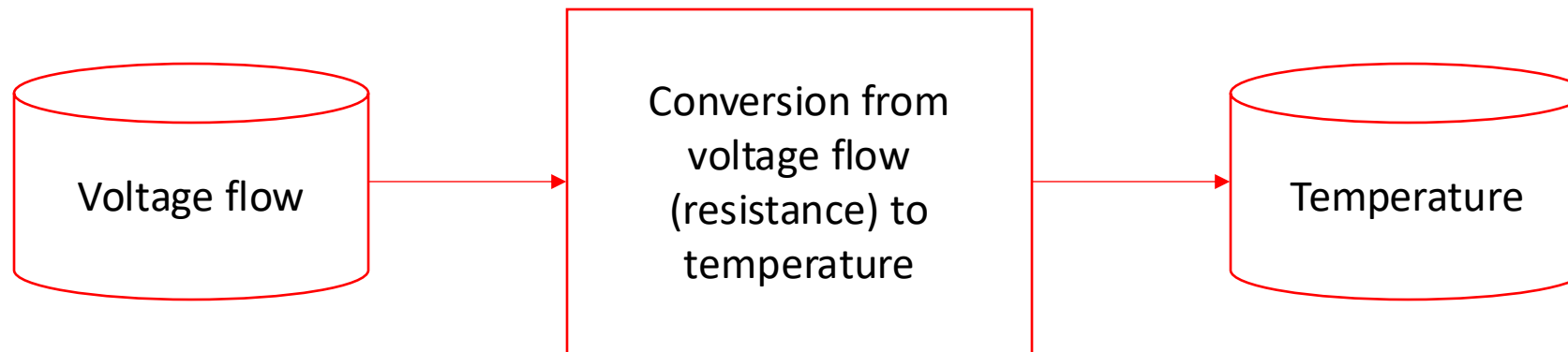
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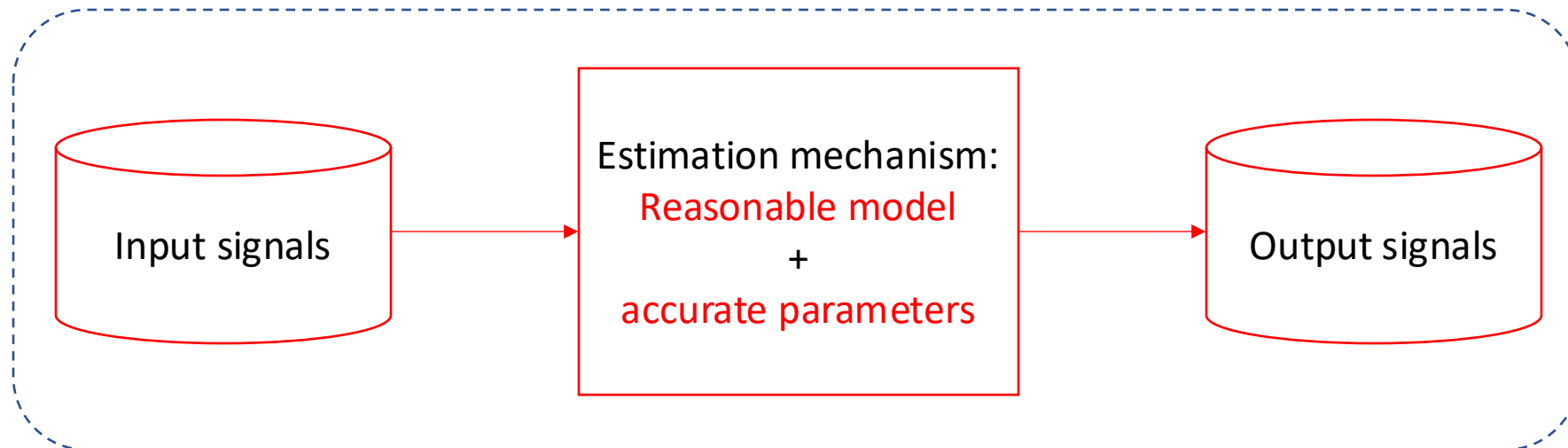 - Dial thermometers
  - Electronic thermometers

Voltage flow → Conversion from voltage flow (resistance) to temperature → Temperature

Analogous to Thermometers

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Analogous to machine learning paradigm

Analogous to Thermometers

- Types of thermometers
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Input signals

Estimation mechanism:
Reasonable model
+
accurate parameters

Output signals

Machine learning learns these parameters