Spatial Ecology

Introduction to Machine Learning

Antonio Fonseca

Agenda

1) Intro to machine learning

- Defining learning
- Supervised vs Unsupervised learning
- The framework of learning algorithms

2) Example of Supervised learning

- Support Vector Machine (SVM)
- Optimization of SVM
- Extension of SVM to regression (SVR)

What is machine learning?

Machine learning is the process of identifying patterns in data.

Two kinds of machine learning

Supervised learning

- Have a bunch of labelled data,
  want to label new data

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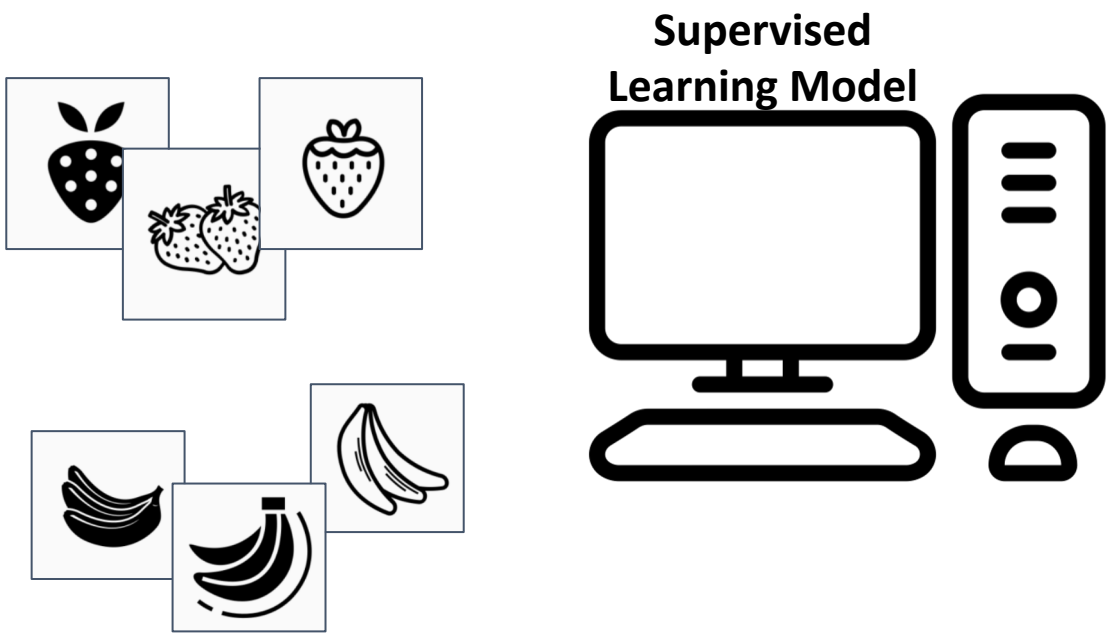

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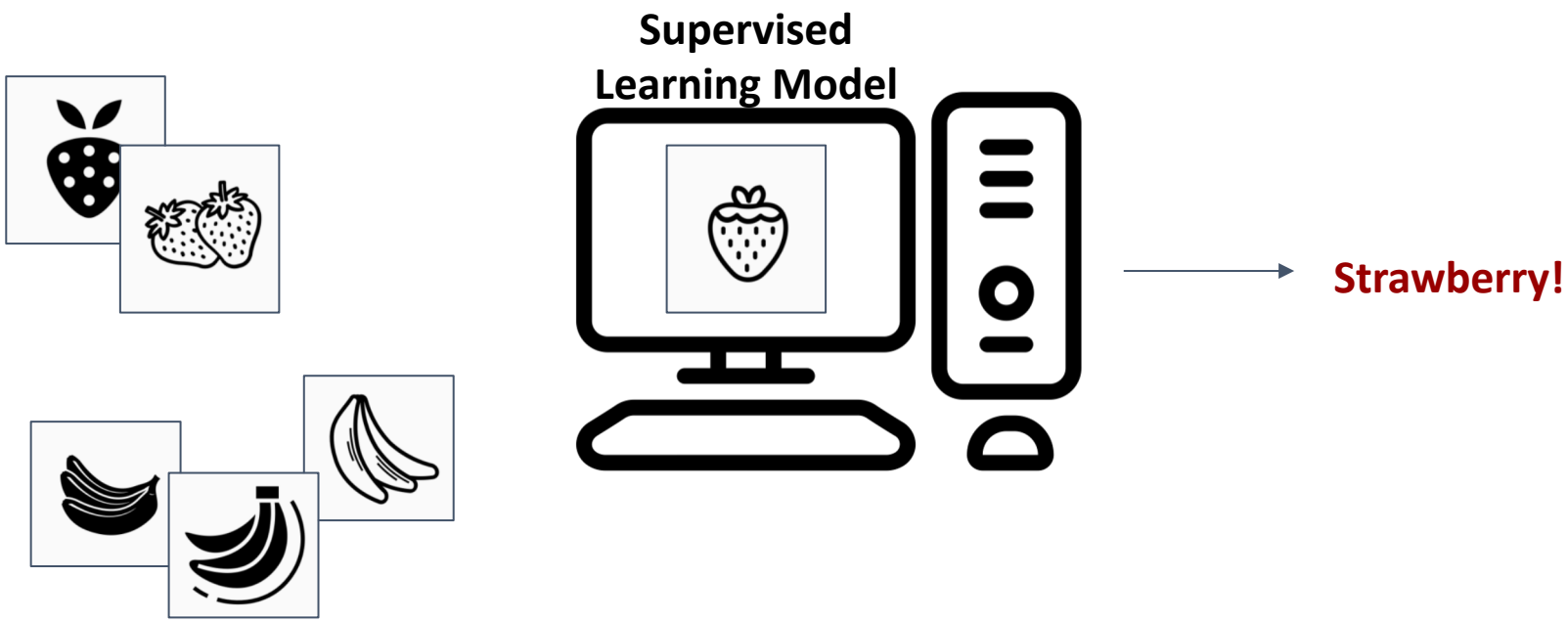

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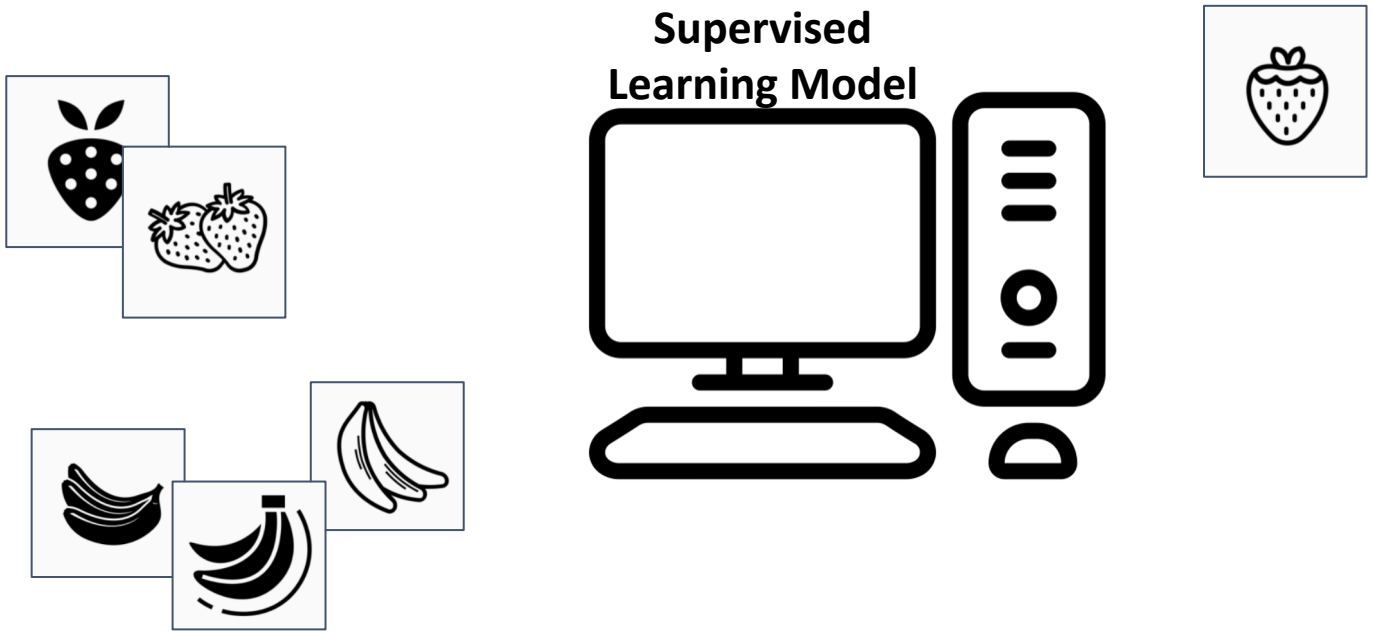

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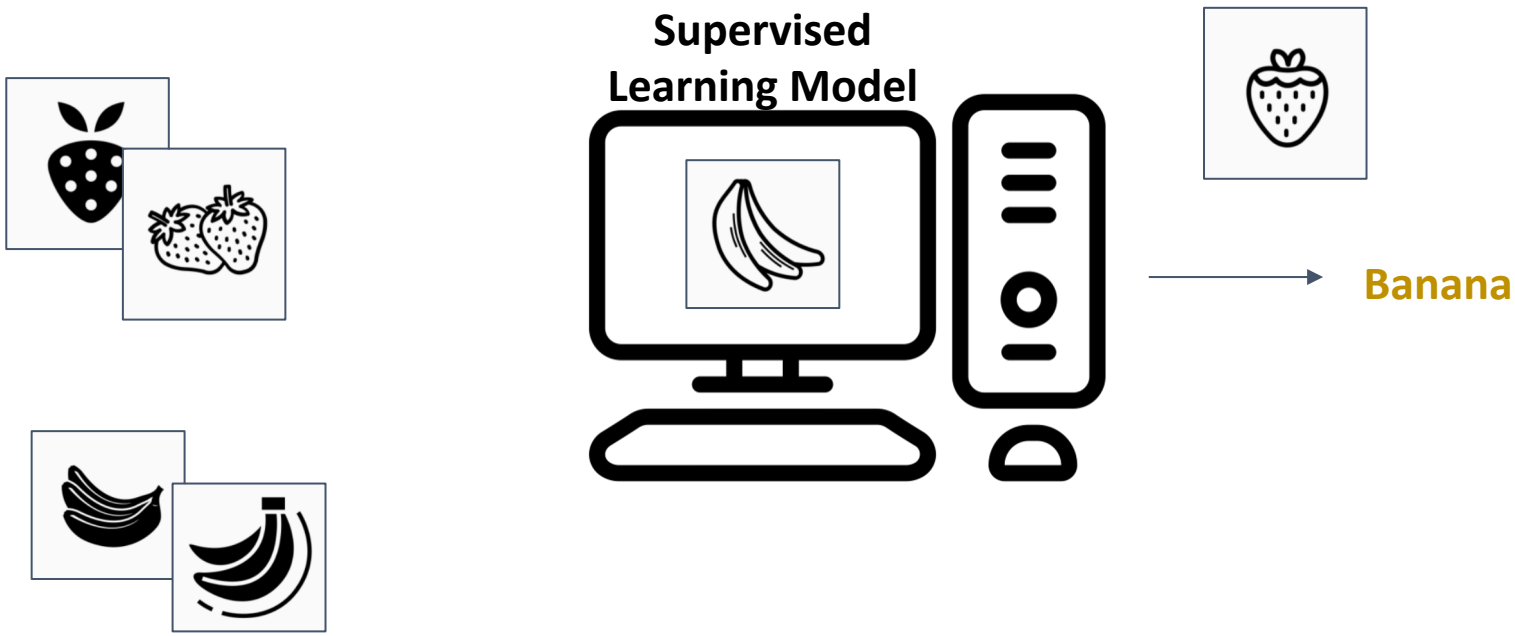

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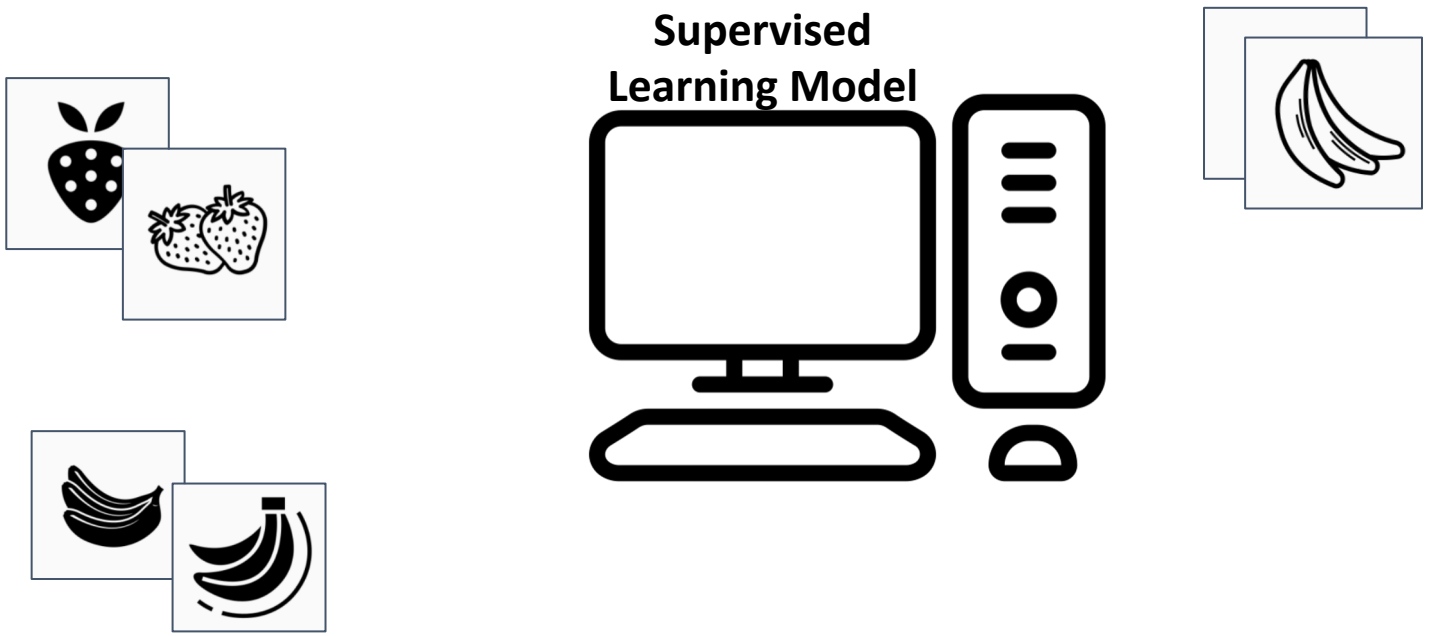

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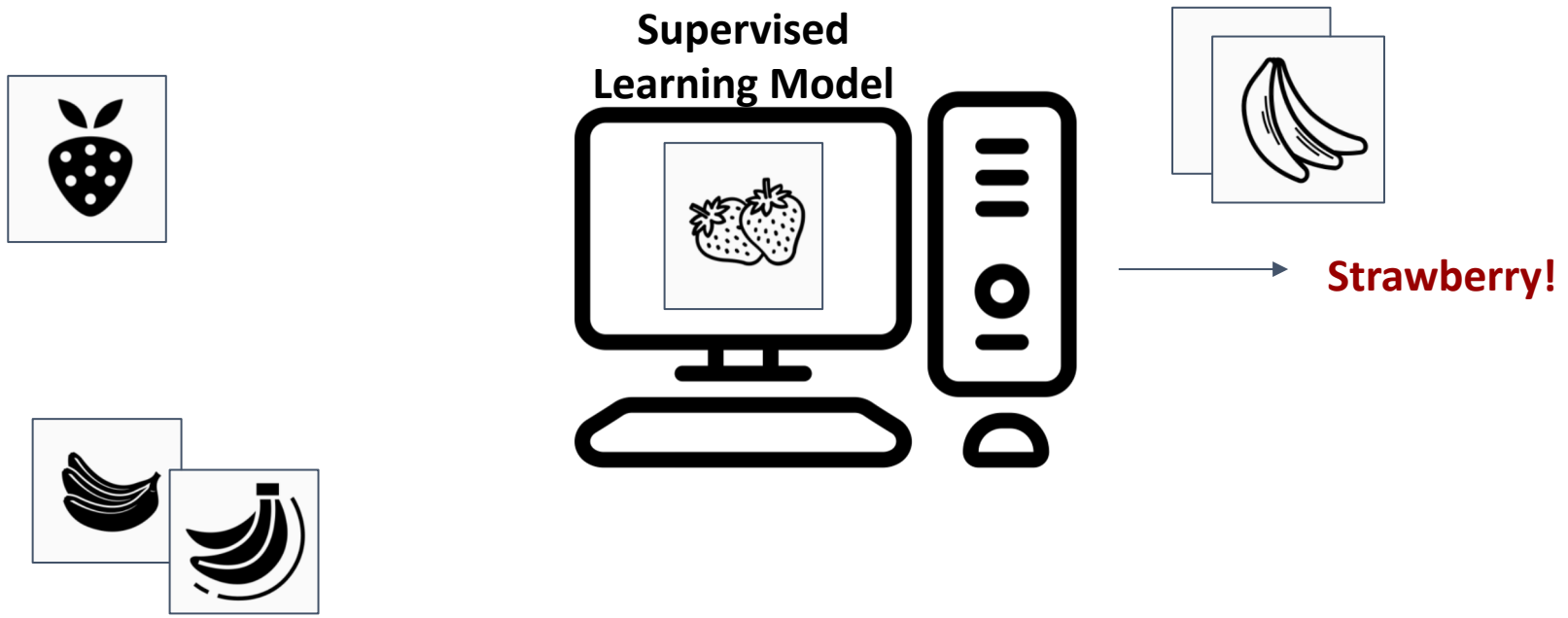

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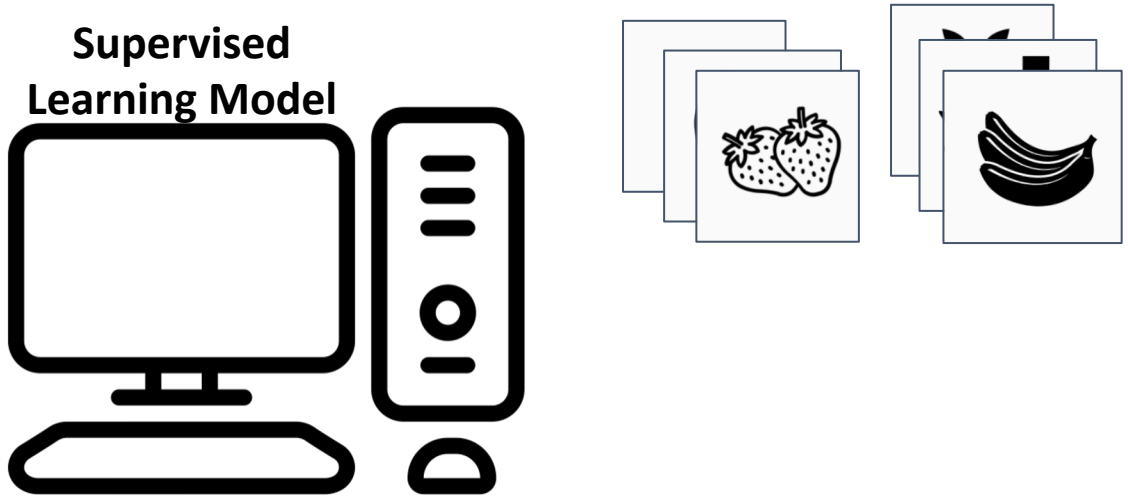

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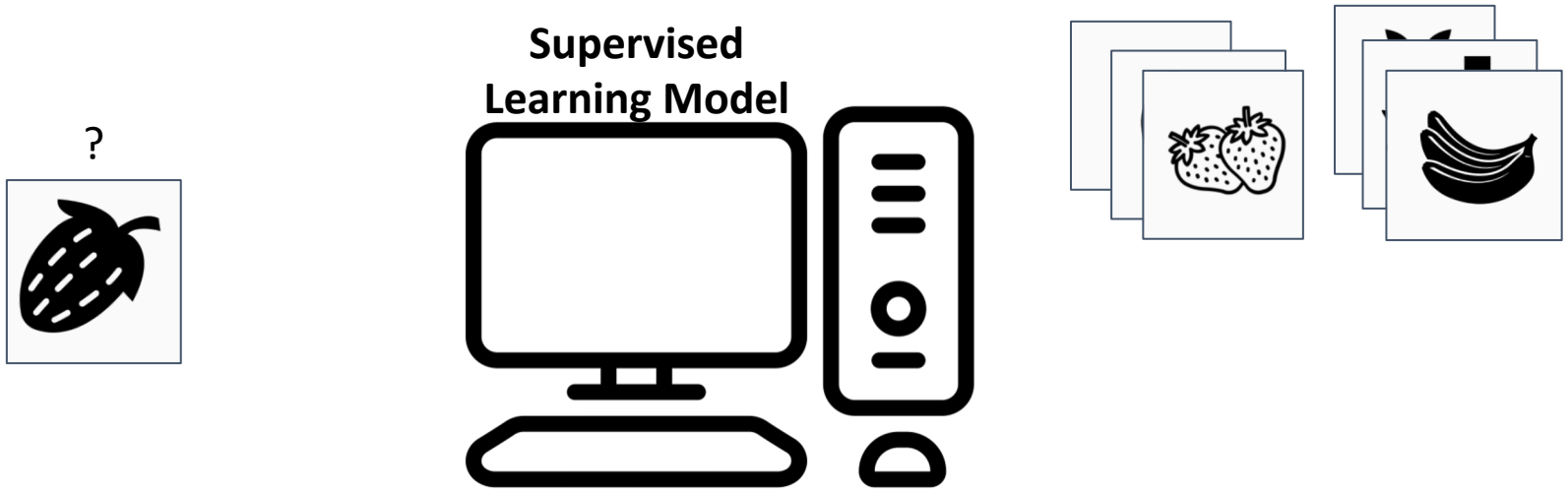

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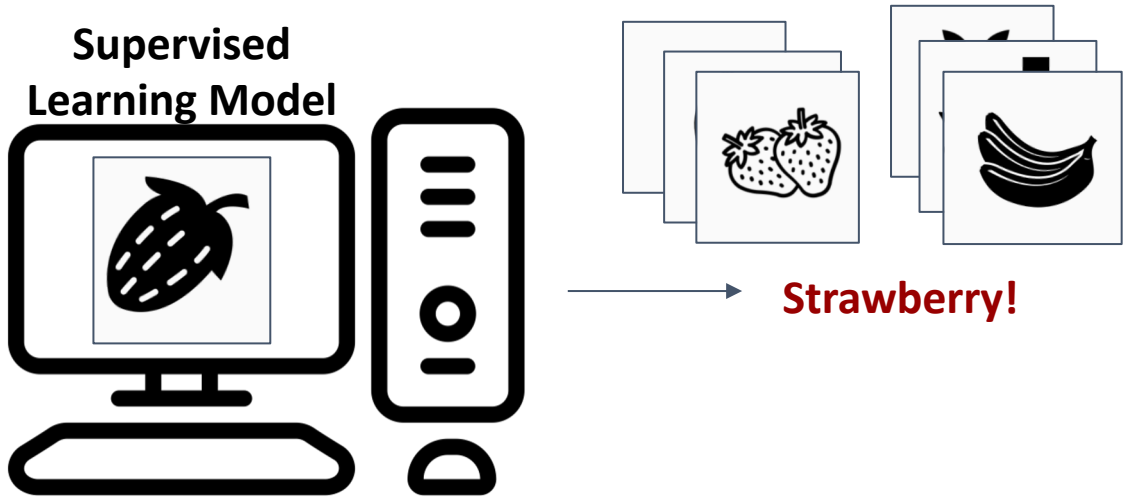

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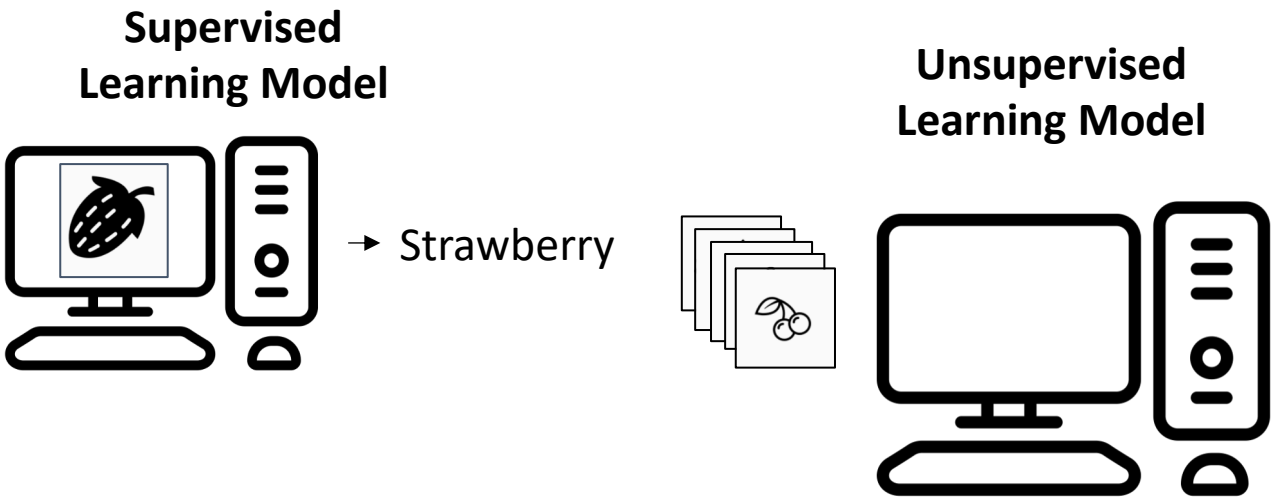

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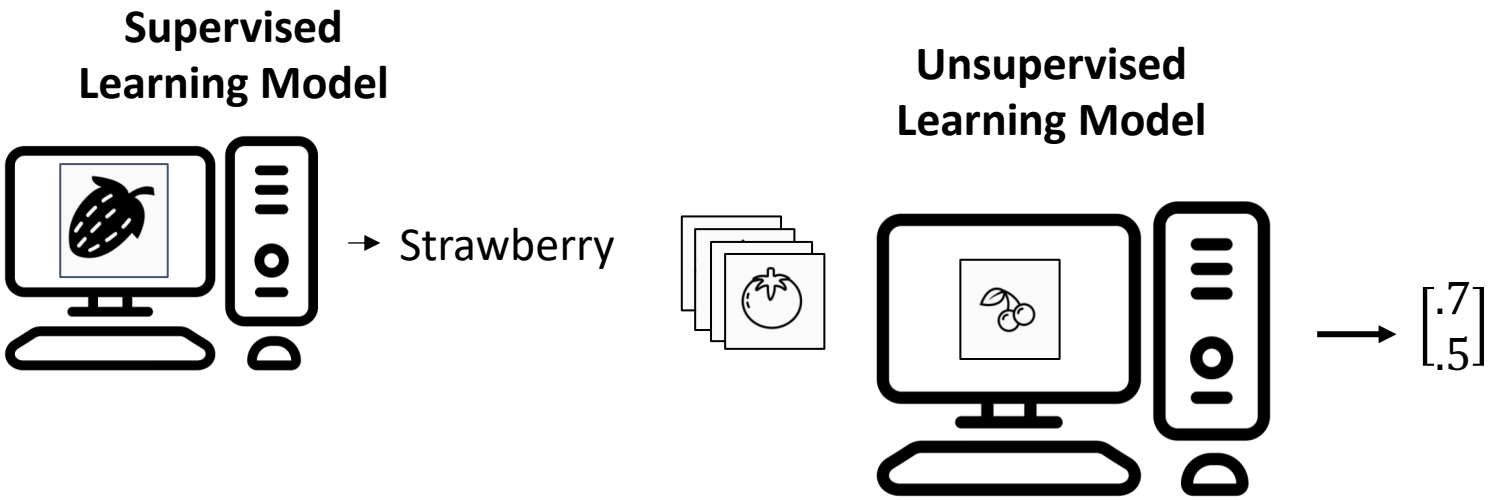

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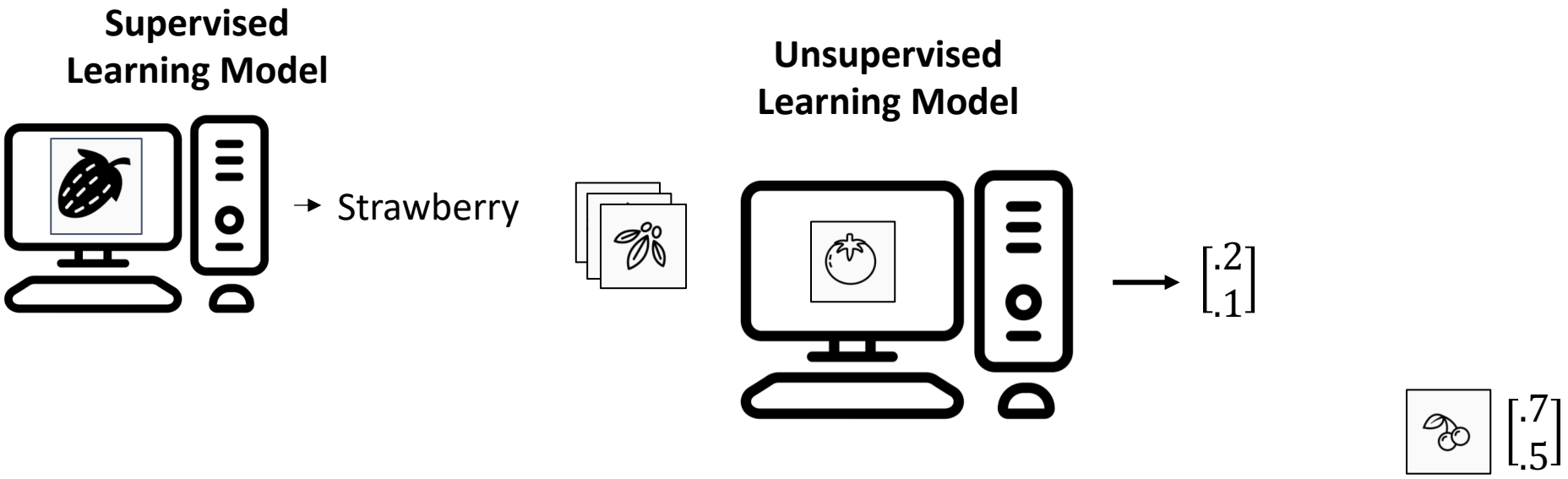

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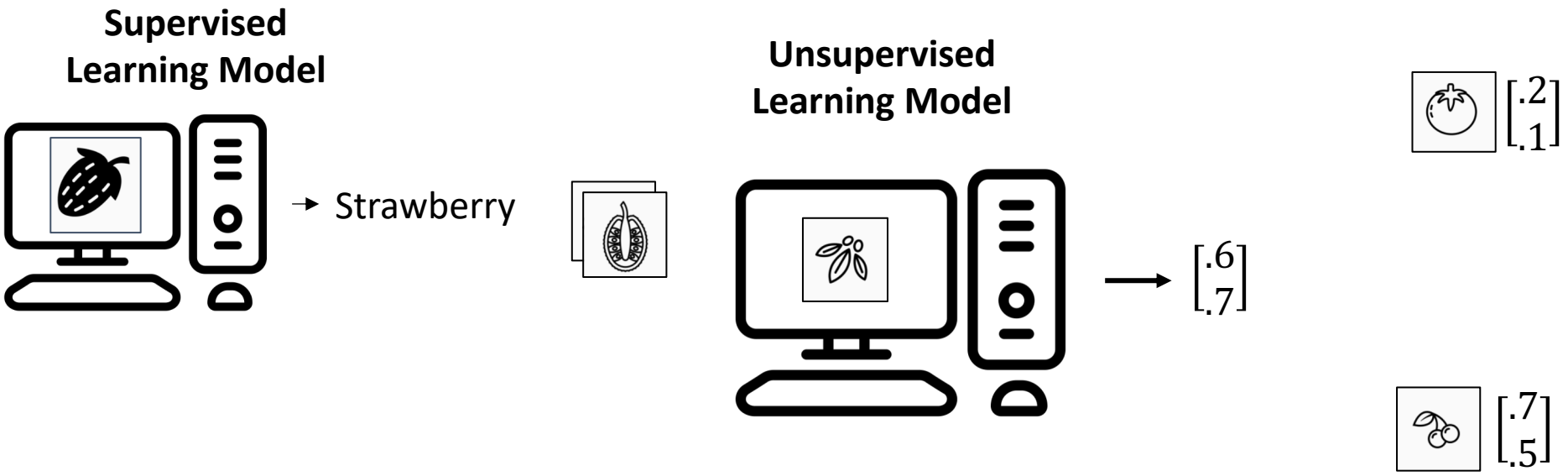

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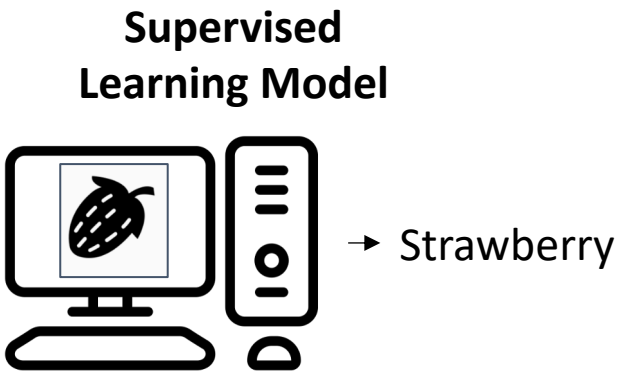
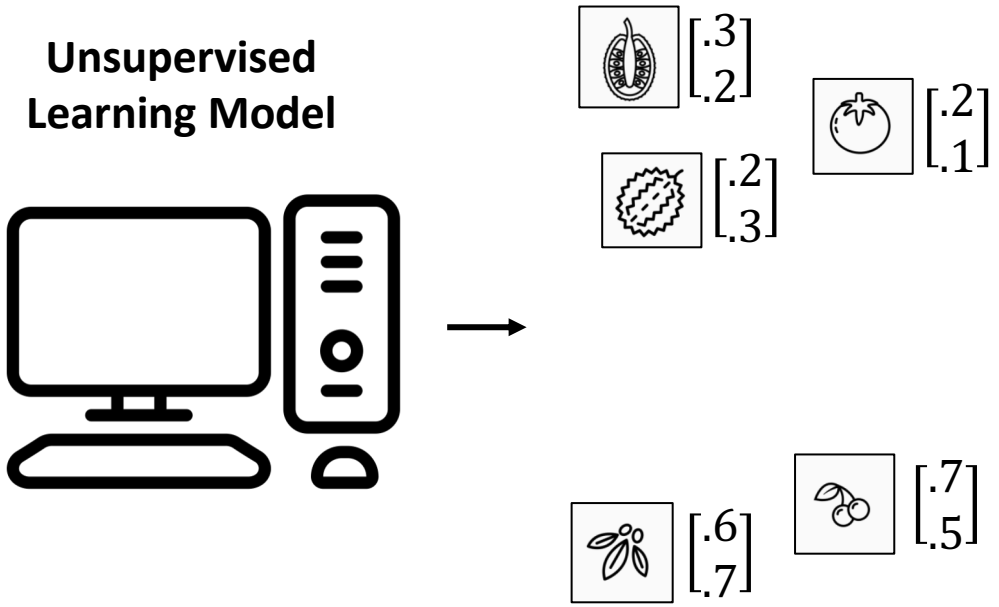




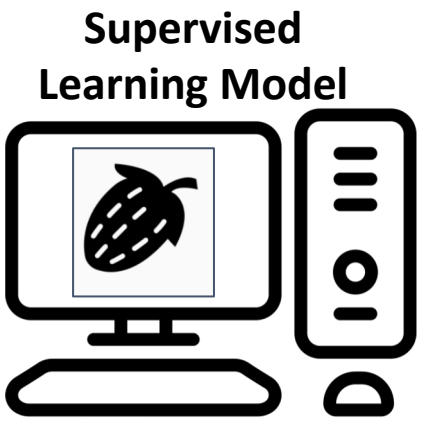
Two kinds of machine learning

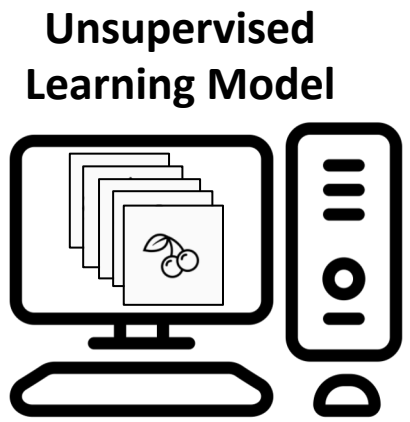
Supervised learning

- Have a bunch of labelled data, want to label new data
- Learn a function $f(X) \rightarrow Y$ where all values of Y are known for some samples of X

Unsupervised learning

- Have a bunch of unlabeled data, want to organize it
- Learn an embedding $f(X) \rightarrow Y, X \in \mathbb{R}^n, Y \in \mathbb{R}^m, n \gg m$
- Lower dimensional, easier to interpret (e.g. as clusters)



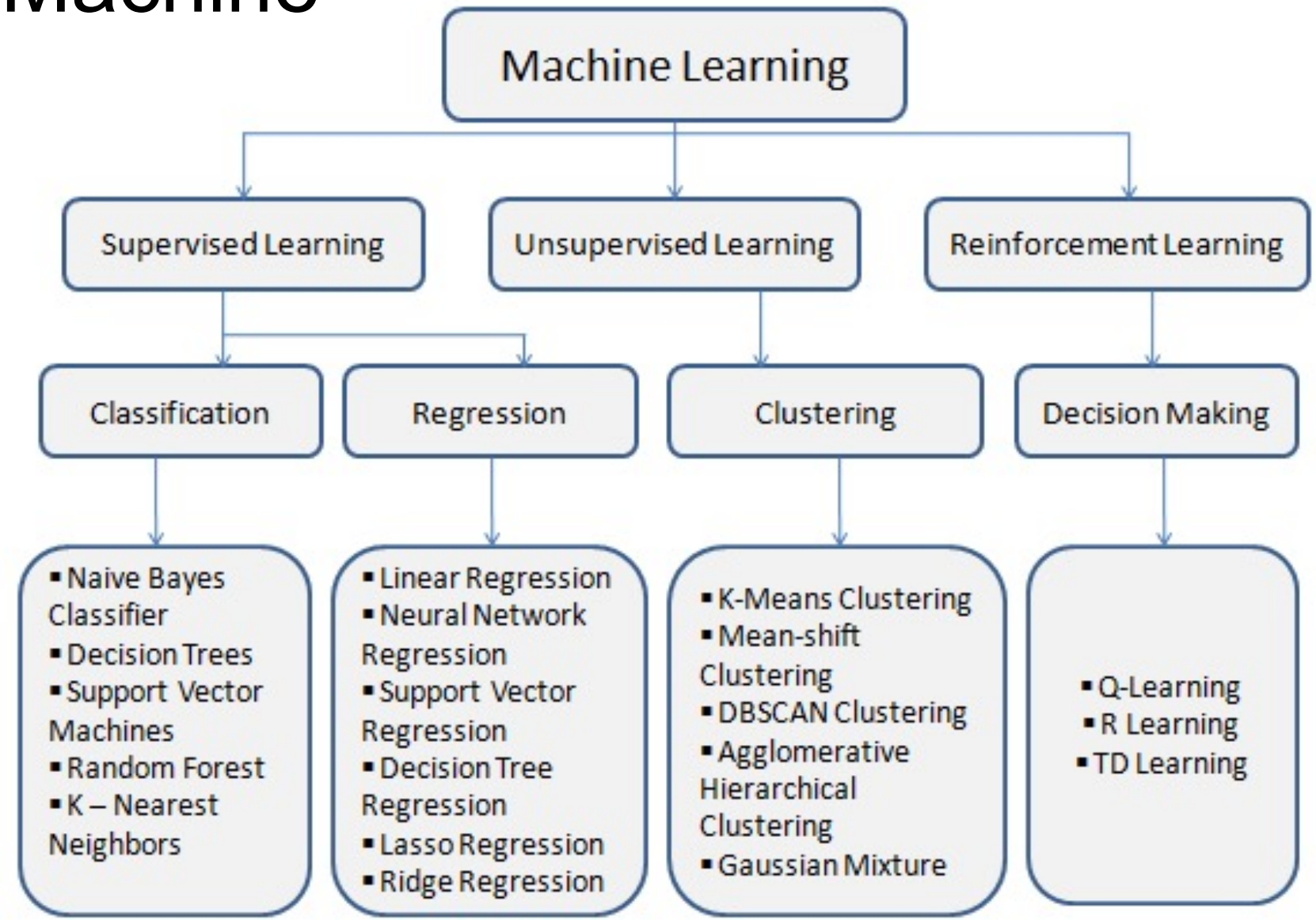


Learning algorithms

"A computer program is said to learn from experience **E** with respect to some class of tasks **T** and performance measure **P** , if its performance at tasks in **T** , as measured by **P** , improves with experience **E**."

Tasks (T)	**Performance (P)**	**Experience (E)**
Transcription Machine Translation Classification Anomaly detection Synthesis and sampling ⋮ Regression	Accuracy rate Adjusted R^2 RMSE/MSE/MAE	Supervised Learning Unsupervised Learning Reinforcement Learning

Types of Machine Learning



Putting these frameworks in perspective

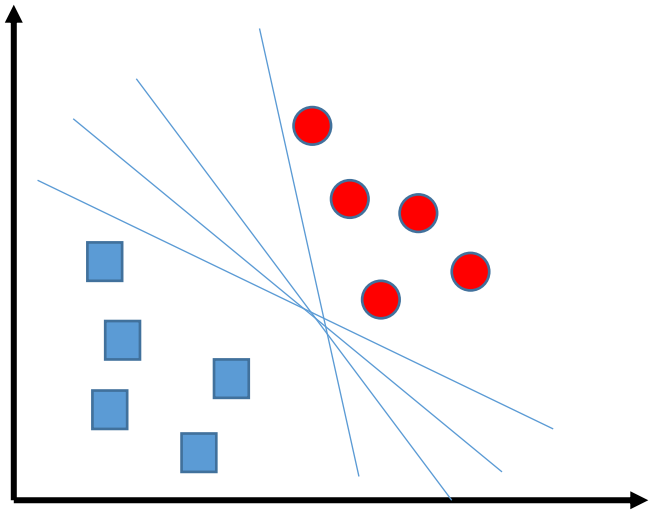
- **"Pure" Reinforcement Learning (cherry)**
  - The machine predicts a scalar reward given once in a while.
  - **A few bits for some samples**
- **Supervised Learning (icing)**
  - The machine predicts a category or a few numbers for each input
  - Predicting human-supplied data
  - **10→10,000 bits per sample**
- **Unsupervised/Predictive Learning (cake)**
  - The machine predicts any part of its input for any observed part.
  - Predicts future frames in videos
  - **Millions of bits per sample**

- **(Yes, I know, this picture is slightly offensive to RL folks. But I'll make it up)**

Original LeCun cake analogy slide presented at NIPS 2016

Decision Boundaries

Find a hyperplane in an N-dimensional space that distinctly classifies the data points.

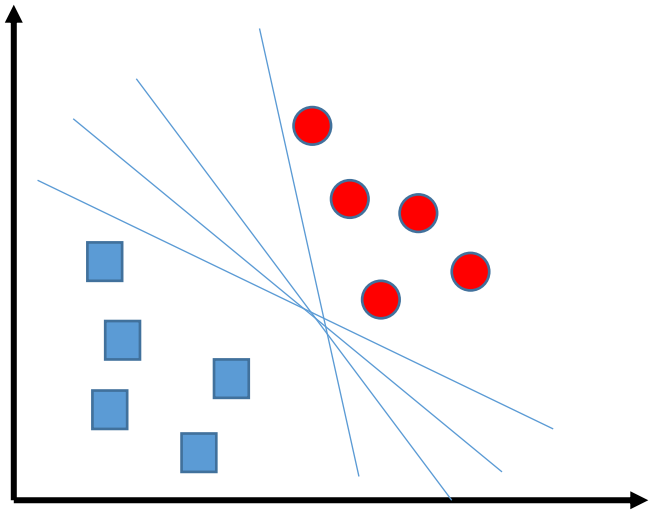


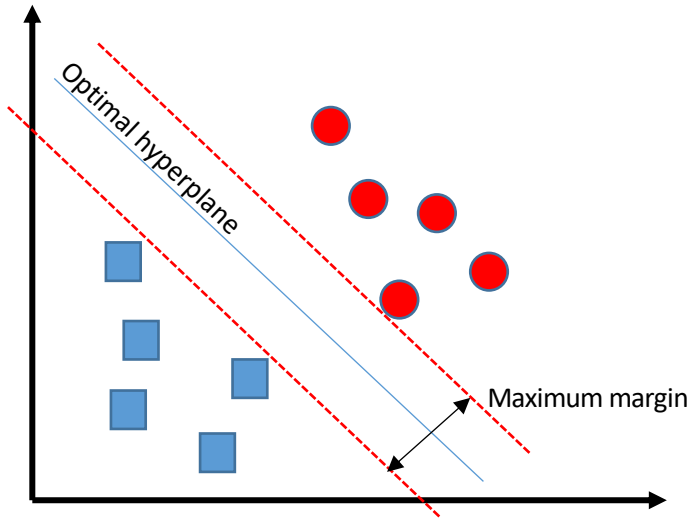
What is the correct decision boundary for this problem?

Tell me what you think
PollEv.com/antoniooliveirafonseca958

Support Vector Machine

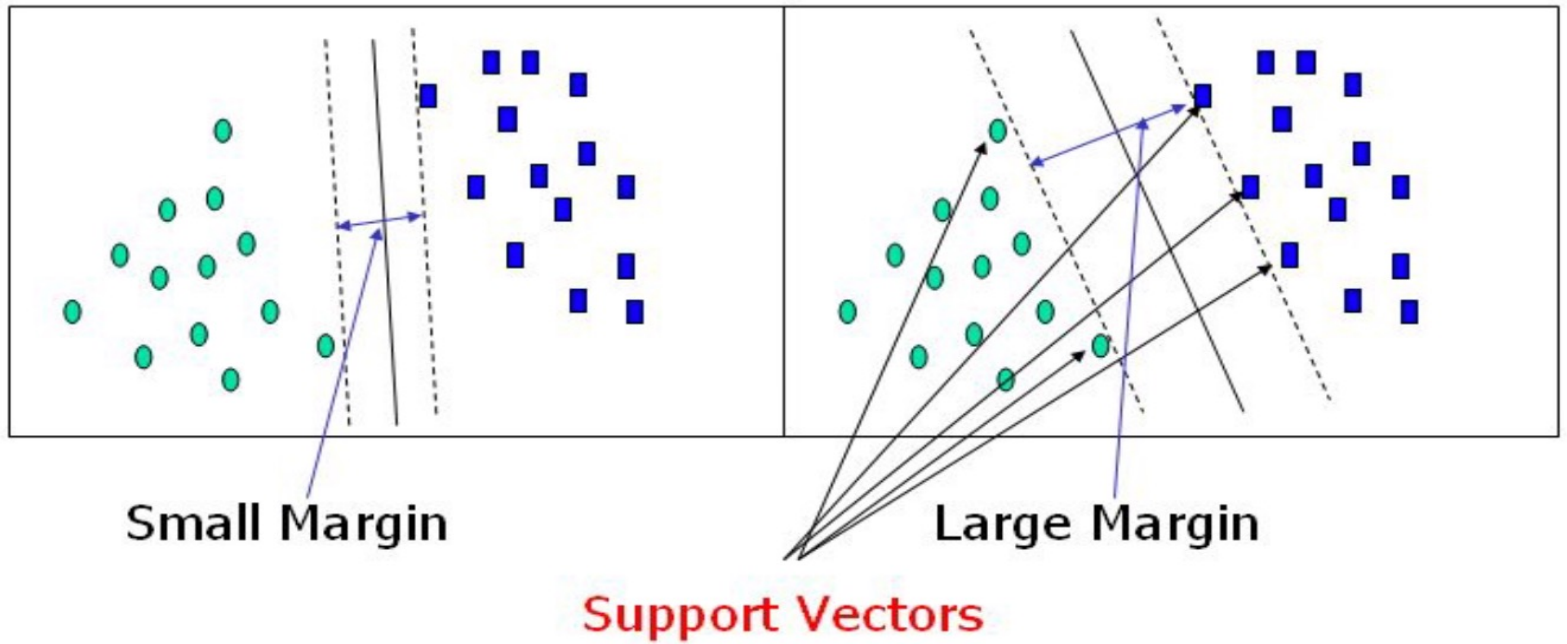
Find the optimal hyperplane in an N-dimensional space that distinctly classifies the data points.





Support Vector Machine

Maximize the margin of the classifier



Support Vectors

SVM Optimization

Hinge loss function

$$c(x, y, f(x)) = \begin{cases} 0, & \text{if } y * f(x) \geq 1 \\ 1 - y * f(x), & \text{else} \end{cases}$$

Loss function for the SVM

$$min_w \lambda \parallel w \parallel^2 + \sum_{i=1}^{n} (1 - y_i \langle x_i, w \rangle)_+$$

Gradients

$$\frac{\delta}{\delta w_k} \lambda \parallel w \parallel^2 = 2\lambda w_k$$

$$\frac{\delta}{\delta w_k} \left(1 - y_i \langle x_i, w \rangle\right)_+ = \begin{cases} 0, & \text{if } y_i \langle x_i, w \rangle \geq 1 \\ -y_i x_{ik}, & \text{else} \end{cases}$$

Updating the weights:

No misclassification

$$w = w - \alpha \cdot (2\lambda w)$$

Misclassification

$$w = w + \alpha \cdot (y_i \cdot x_i - 2\lambda w)$$

Support Vector Machine for Regression

- The best fit line is the hyperplane that has the maximum number of points.
- Limitations
  - The fit time complexity of SVR is more than quadratic with the number of samples
  - SVR scales poorly with number of samples (e.g., >10k samples). For large datasets, **Linear SVR** or **SGD Regressor**
  - Underperforms in cases where the number of features for each data point exceeds the number of training data samples
  - Underperforms when the data set has more noise, i.e. target classes are overlapping.