Introduction to Data Science

(Lecture 2)

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Review: What is Data Science?

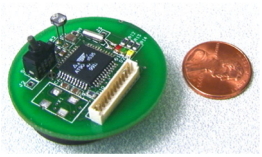
What is Data Science?

- **Data Science** is an interdisciplinary field of research that aims to design and develop automated or semi-automated techniques to **extract knowledge (information) from large-scale data** and use it for **future purposes** such as **prediction, decision making,** or **recommendation**.

- It can be an integration of statistics, machine learning, big data processing, predictive analytics, and computing.






Only Some of the Applications!

Stock Market Prediction

Zillow®

REDFIN™

Real State Prediction

amazon

facebook

Online Shopping
and Advertisements

Recommendation Systems

Self-Driving Cars

Healthcare

Ingredients

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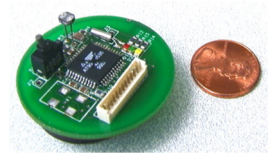
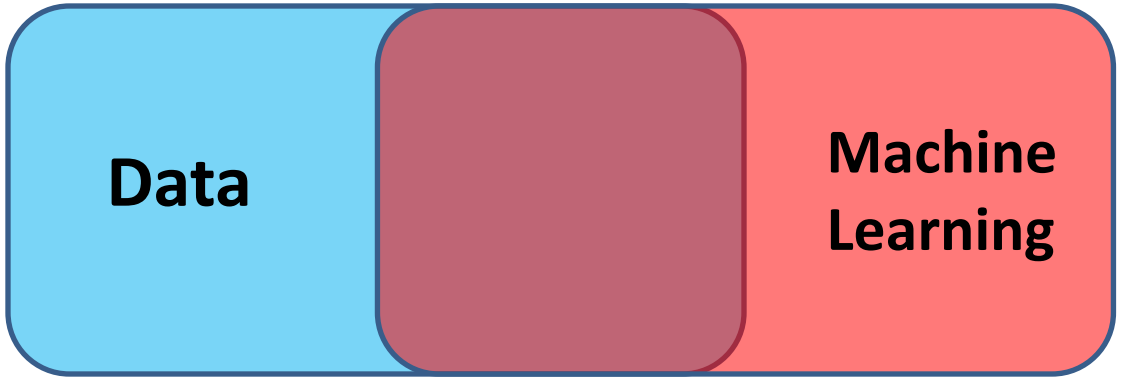
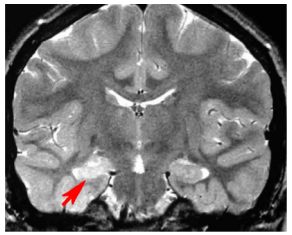
- **Data:** Rapid growth of massive datasets
  - E.g. WWW, Social Networks, Online Activities, Smart Phone, Wearables, Sensor networks, Science, …

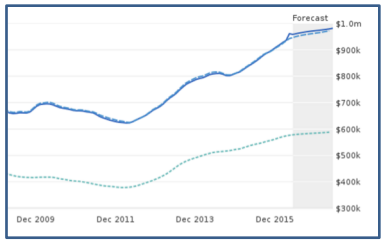


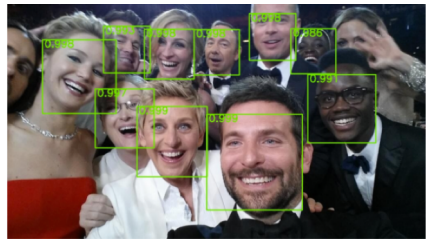
Ingredients

- **Machine Learning:** It is applied Everywhere:
  - E.g., recommendation system, market prediction, speech recognition, Face detection, Fraud detection, Spam filtering, vehicle control, Medical diagnosis, ...



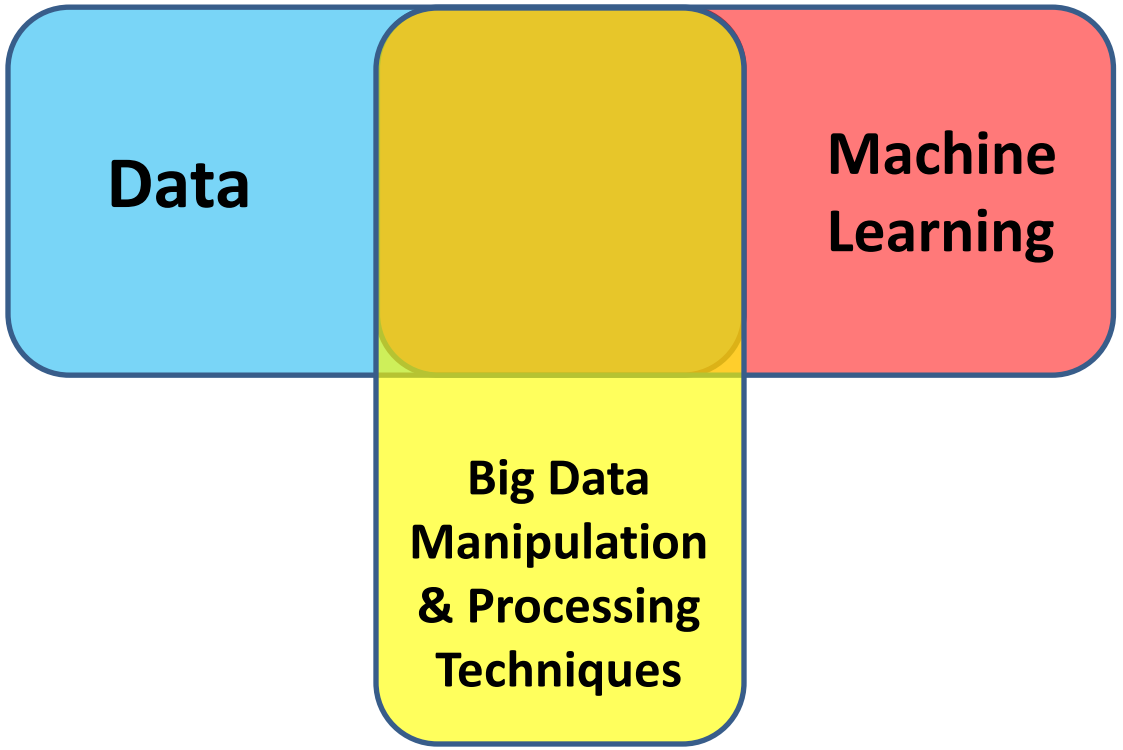






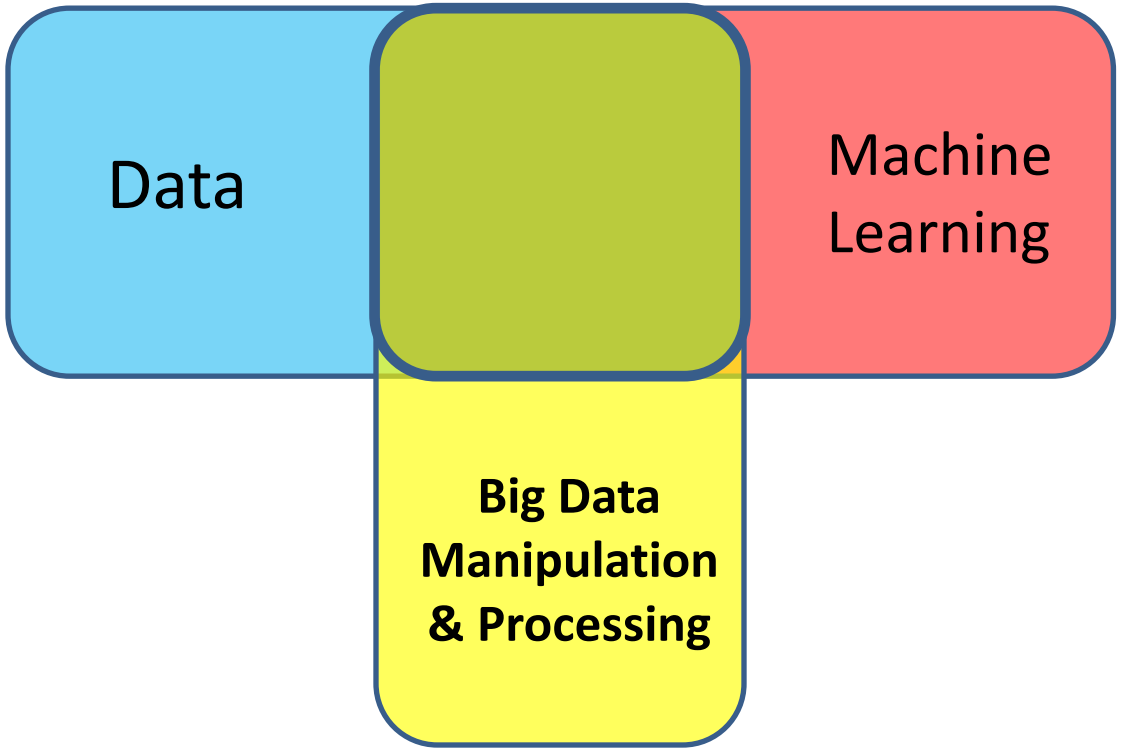
Ingredients

- **Big Data Manipulation & Processing:**
  - Large-Scale Data Processing, Distributed Computing, Cloud Computing



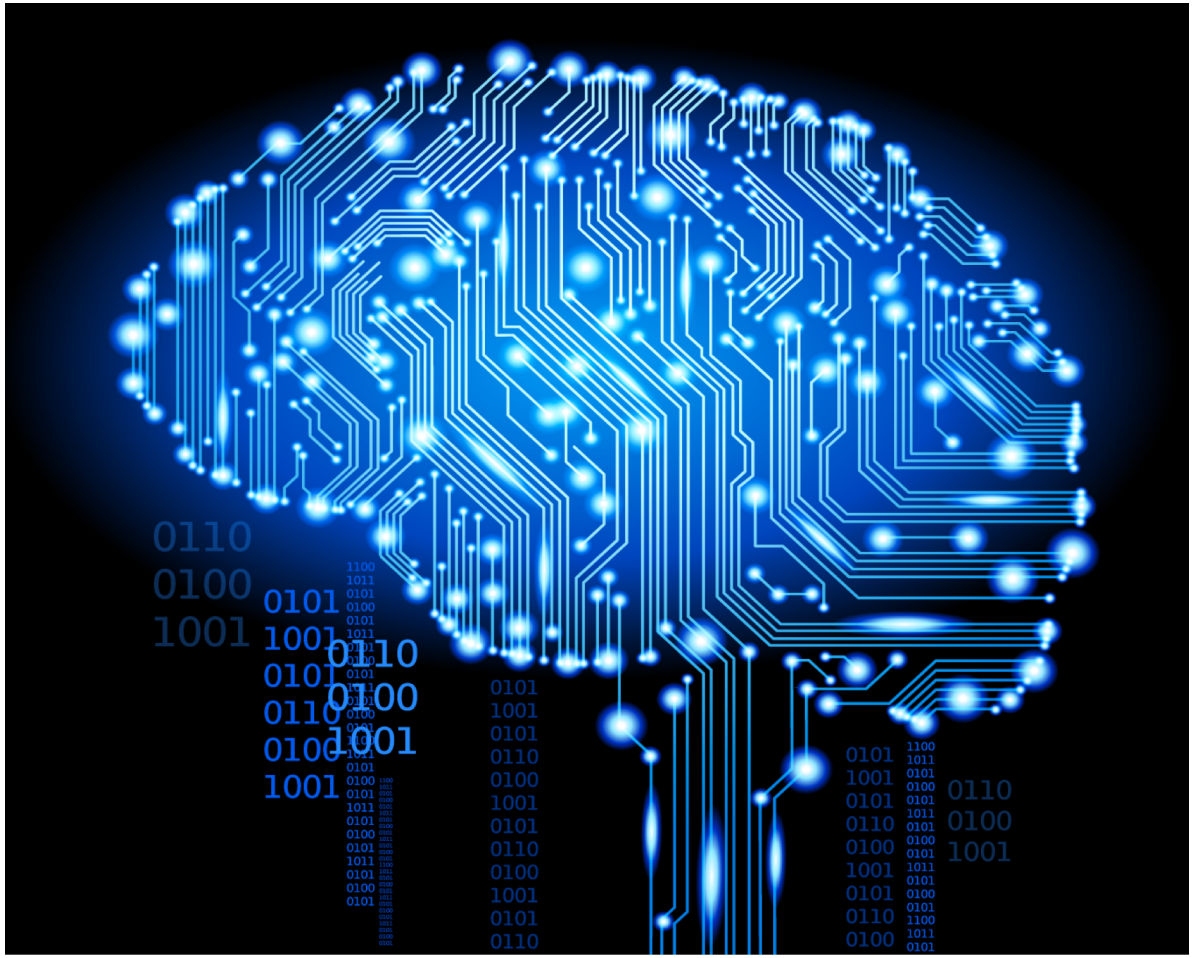
Ingredients

- Data, Machine Learning Algorithms, Big Data Manipulation Techniques



Data Analytics and Machine Learning

What is Machine Learning?



What is Machine Learning?

- **A Definition:** Designing and constructing algorithms or methods that give computers the ability to learn from past data, without being explicitly programmed, and then make predictions on future data.

- **Another Definition:** A set of algorithms that can automatically detect and extract patterns in past data, and then use the extracted patterns to predict on future data, or to perform other kinds of decision making.

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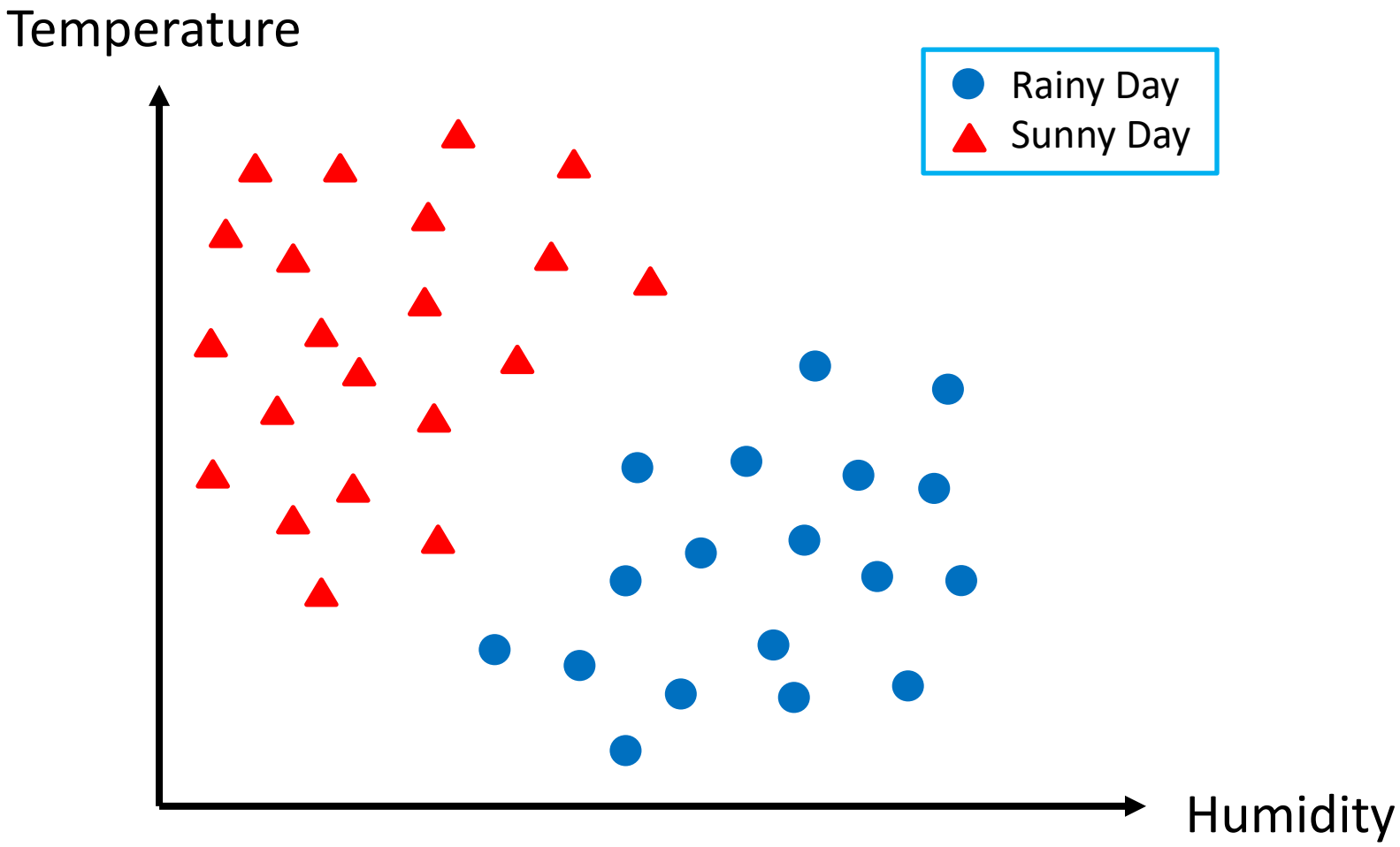
Example: Weather Forecasting

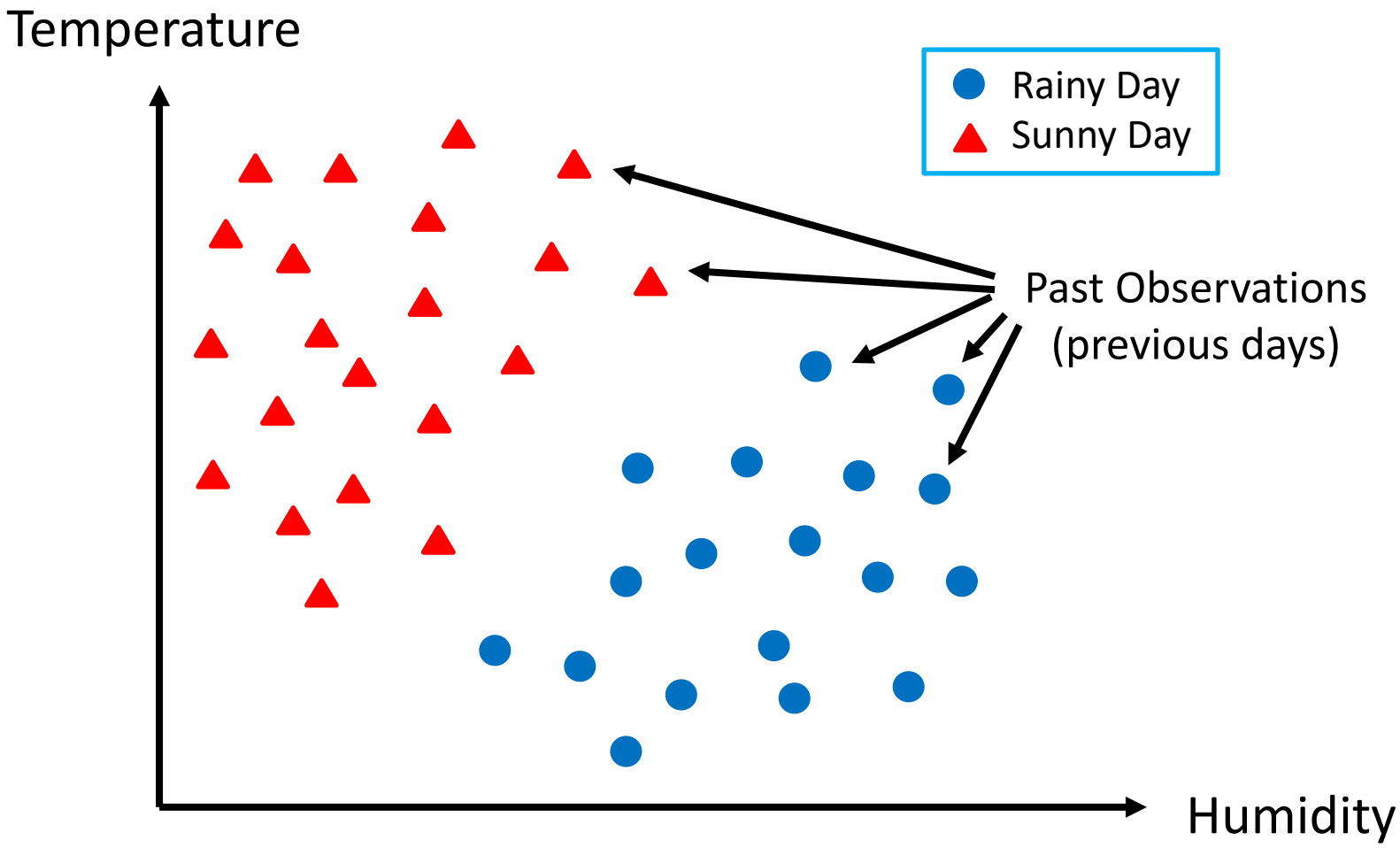
- Suppose that we have the **Temperature** and **Humidity** of the **past 30 days**.
- We also know whether those days were **Sunny** or **Rainy**.

- **Questions**: Now, If we know the **Temperature** and **Humidity** of **tomorrow**, can we **predict** tomorrow's outlook (predict whether tomorrow is rainy or sunny)?

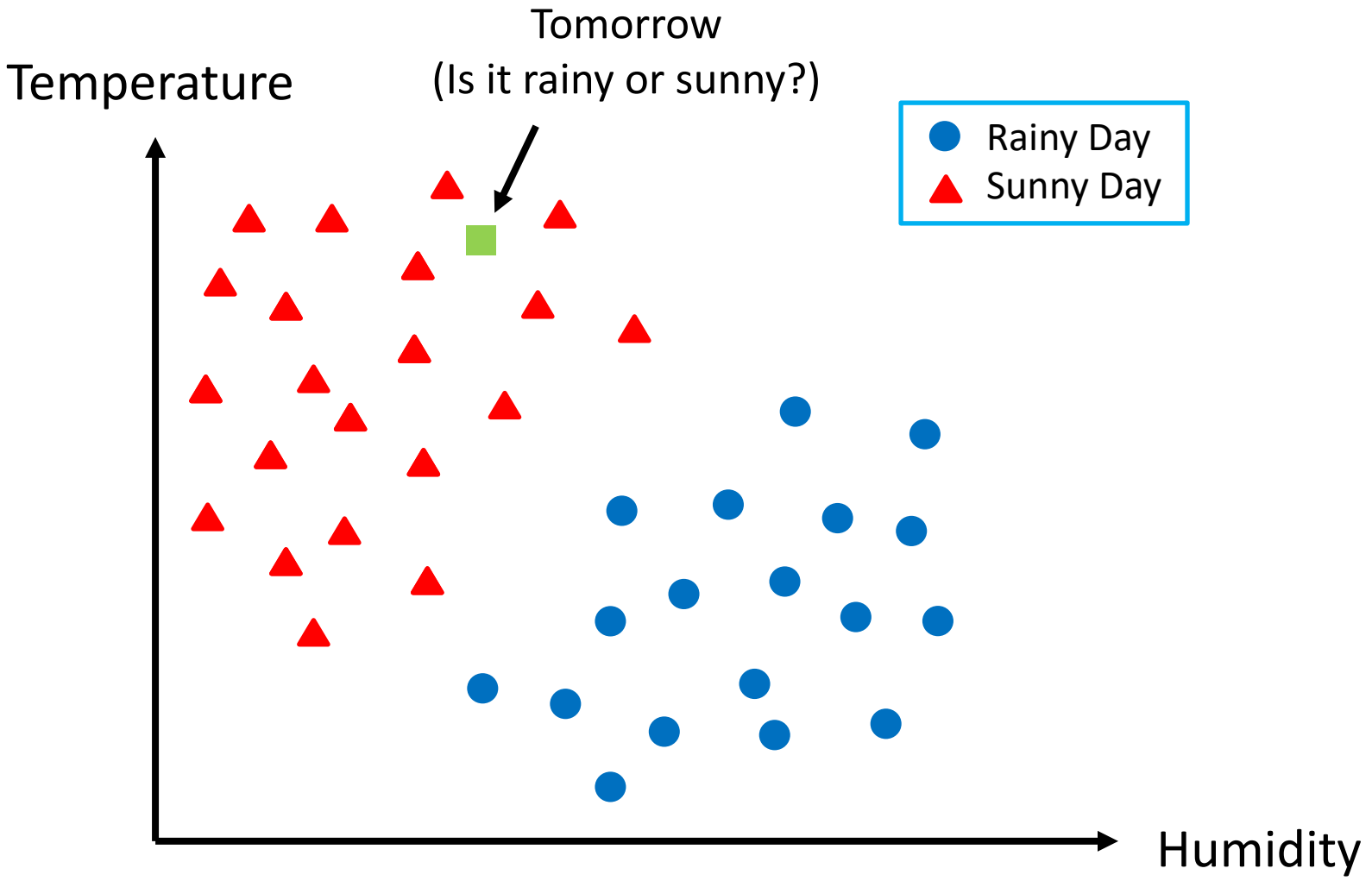
Example: Weather Forecasting



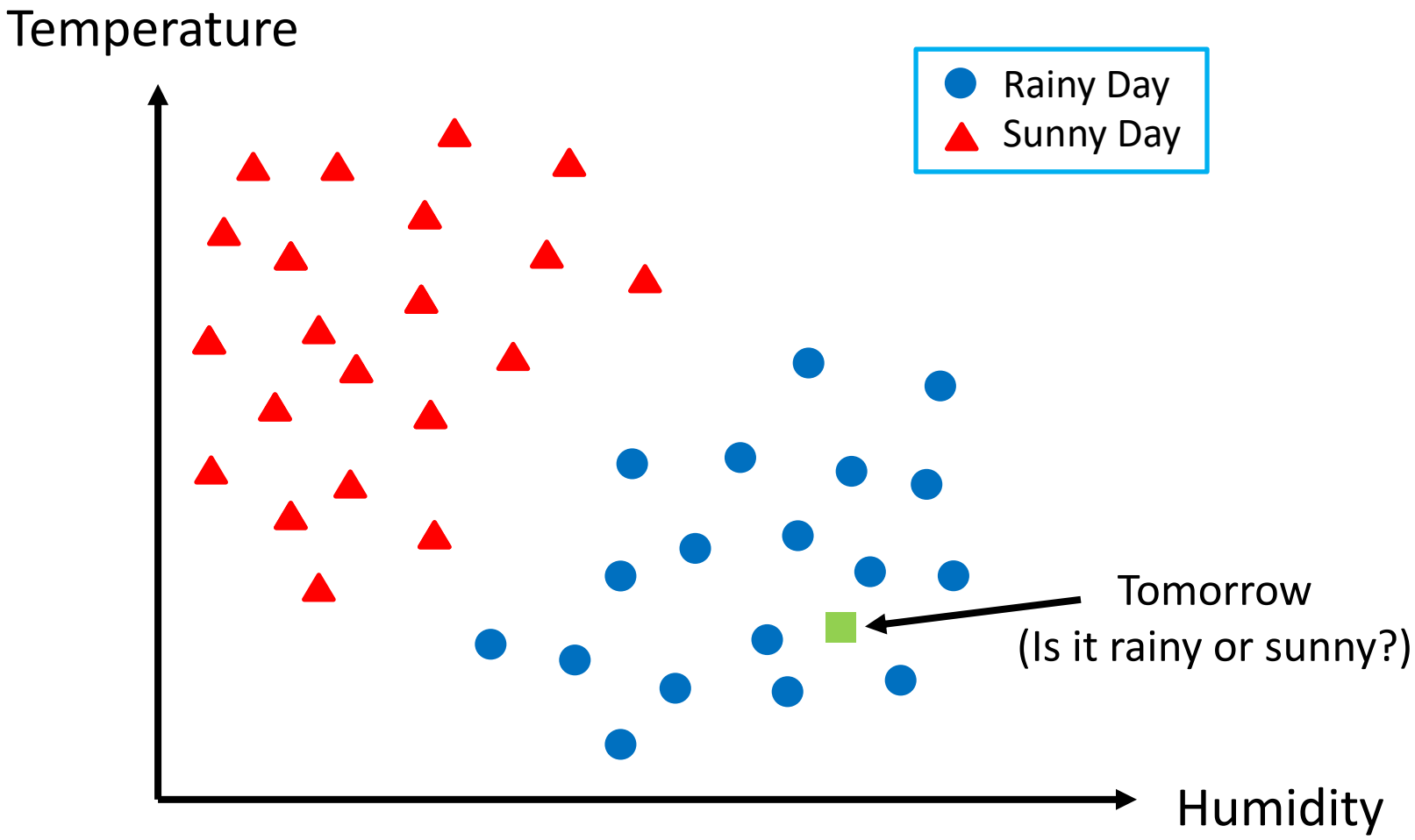
Example: Weather Forecasting



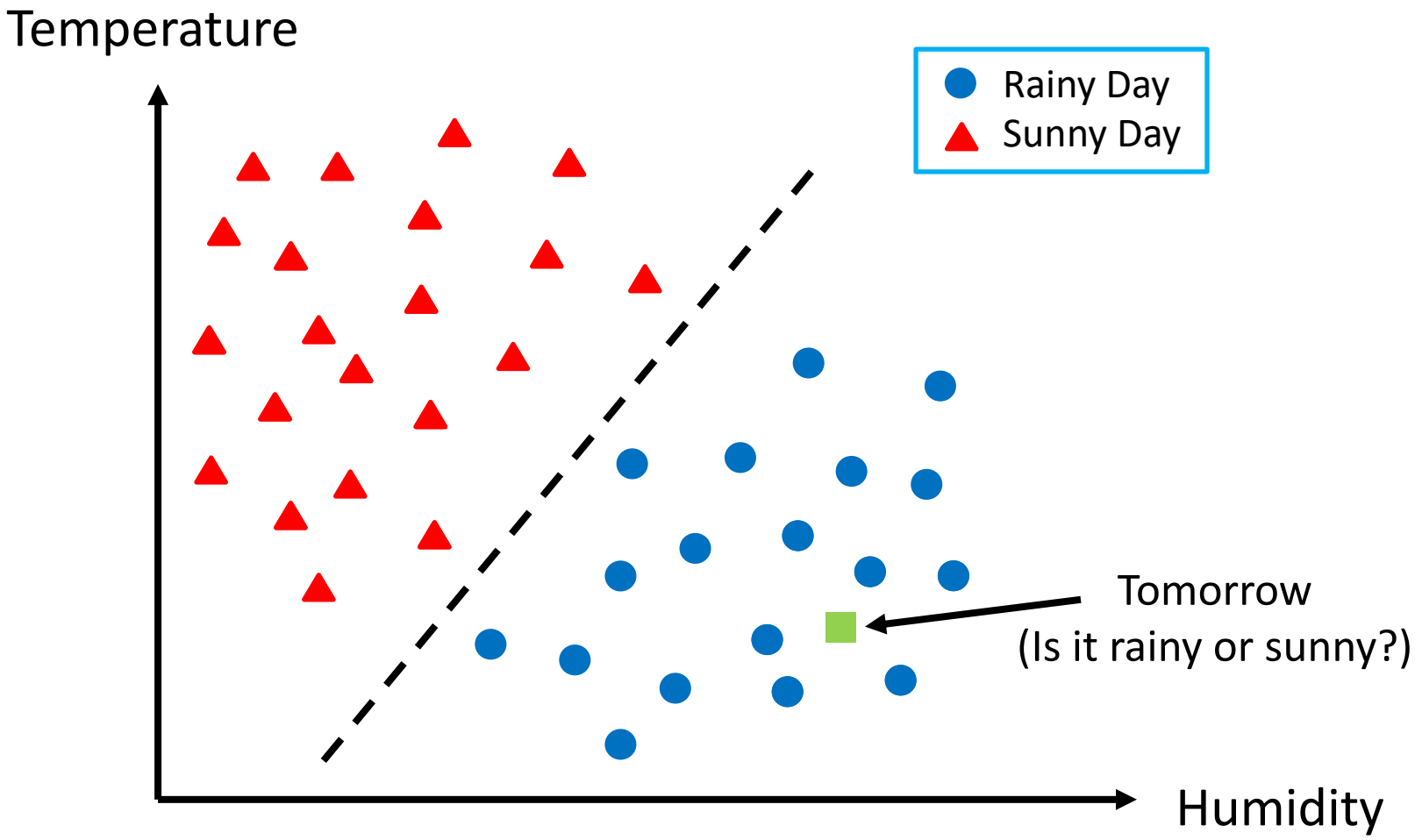
Example: Weather Forecasting



Example: Weather Forecasting

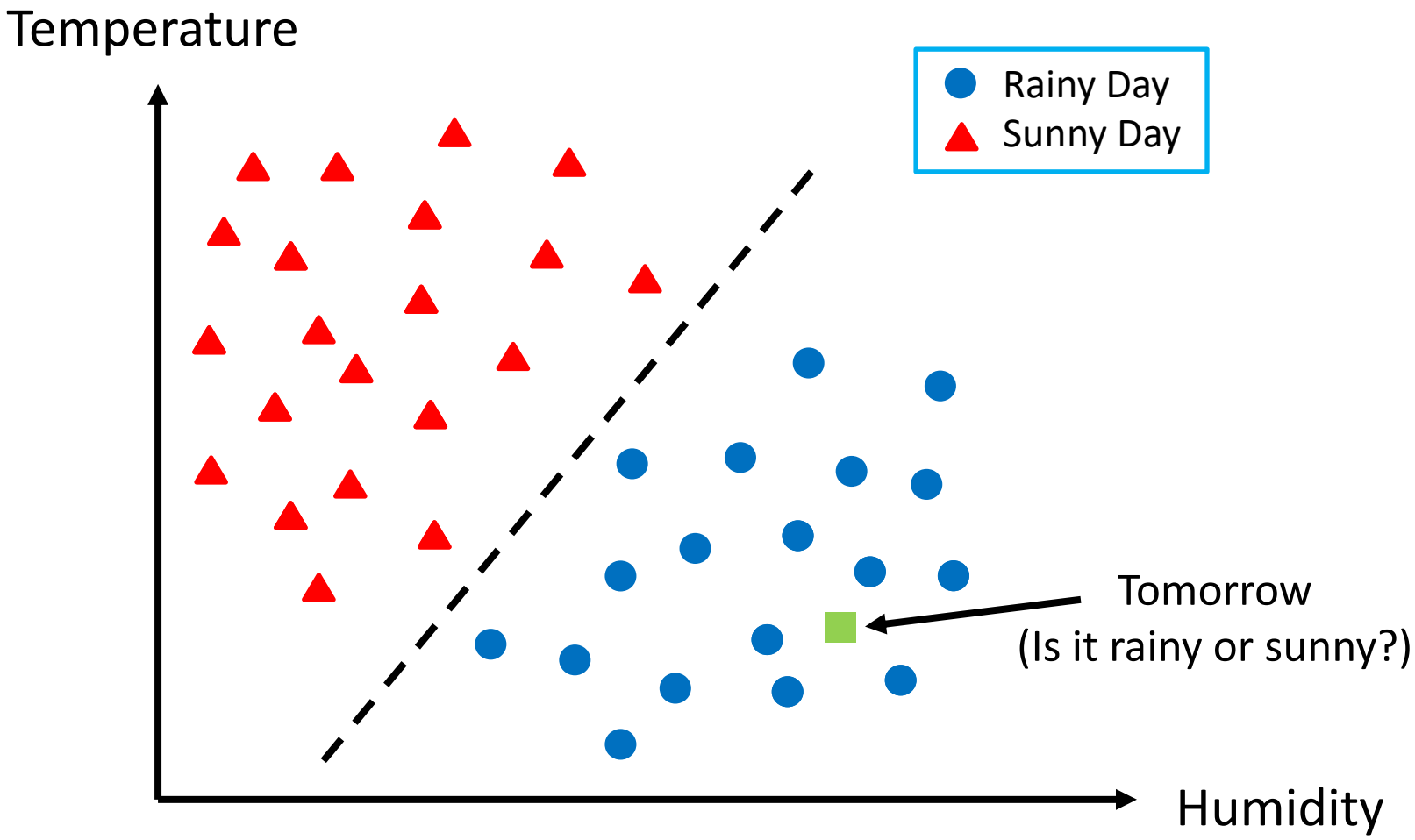


Example: Weather Forecasting



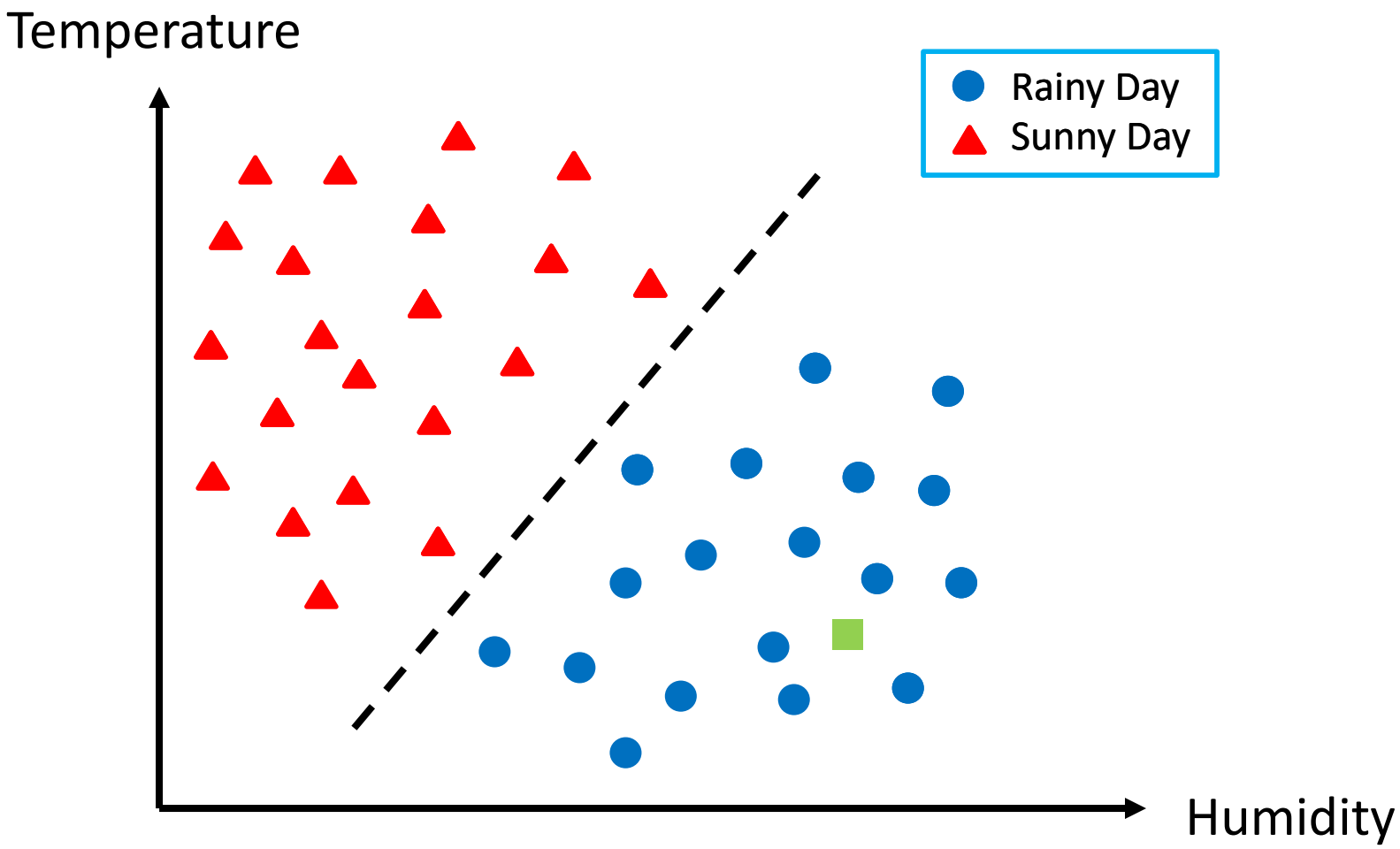
Example: Weather Forecasting

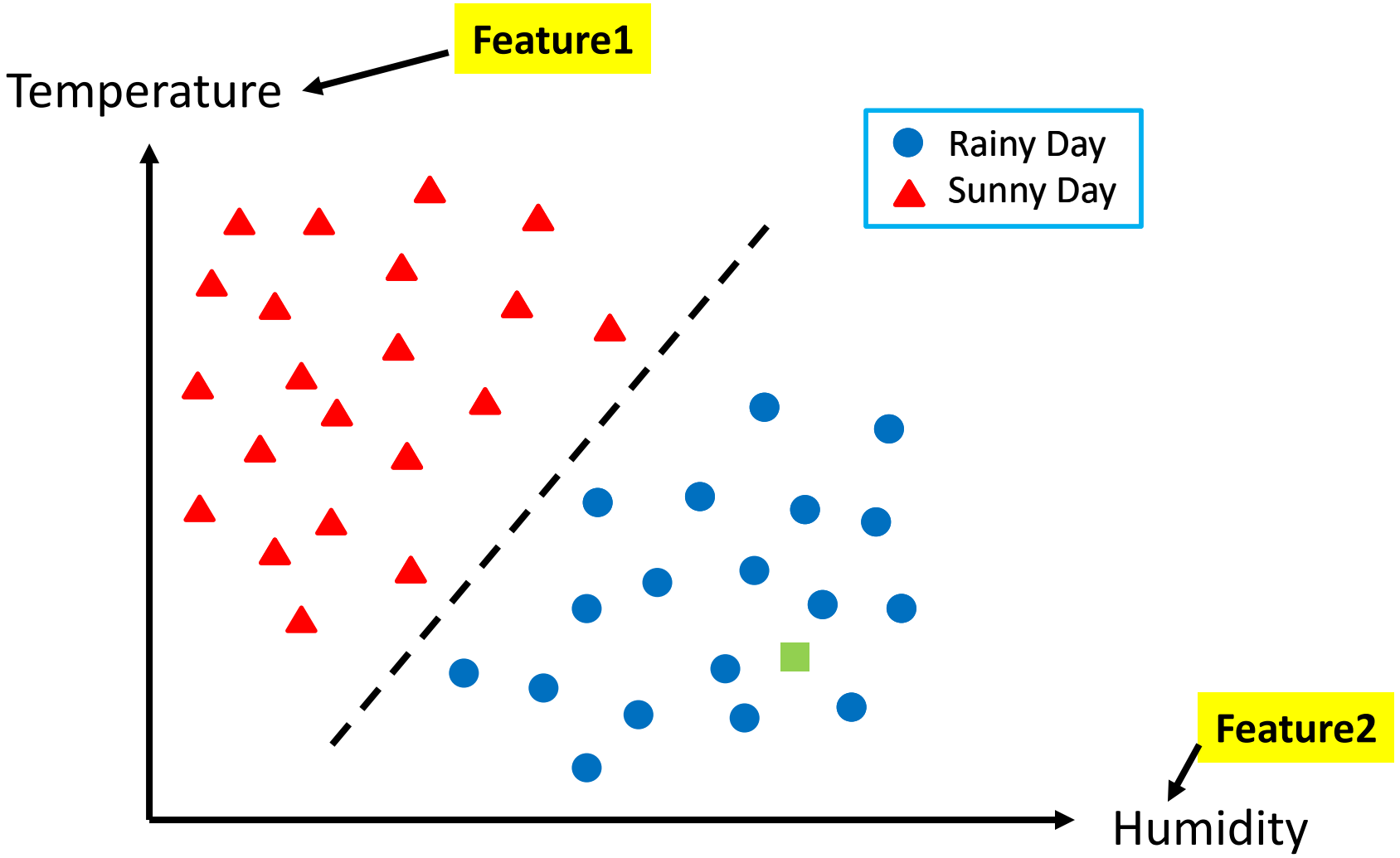
This is a super simple and very idealistic example, but did you get the idea?

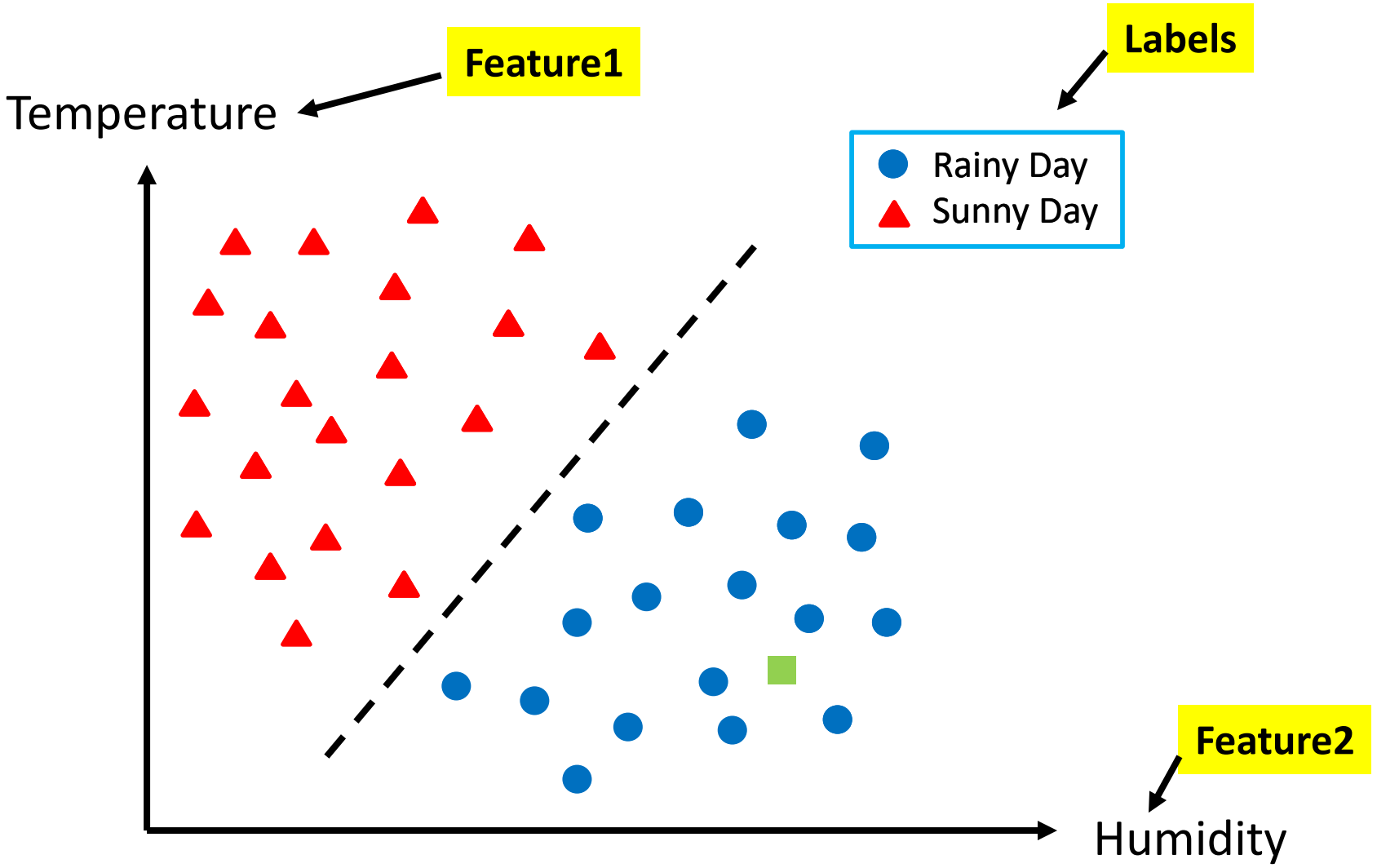


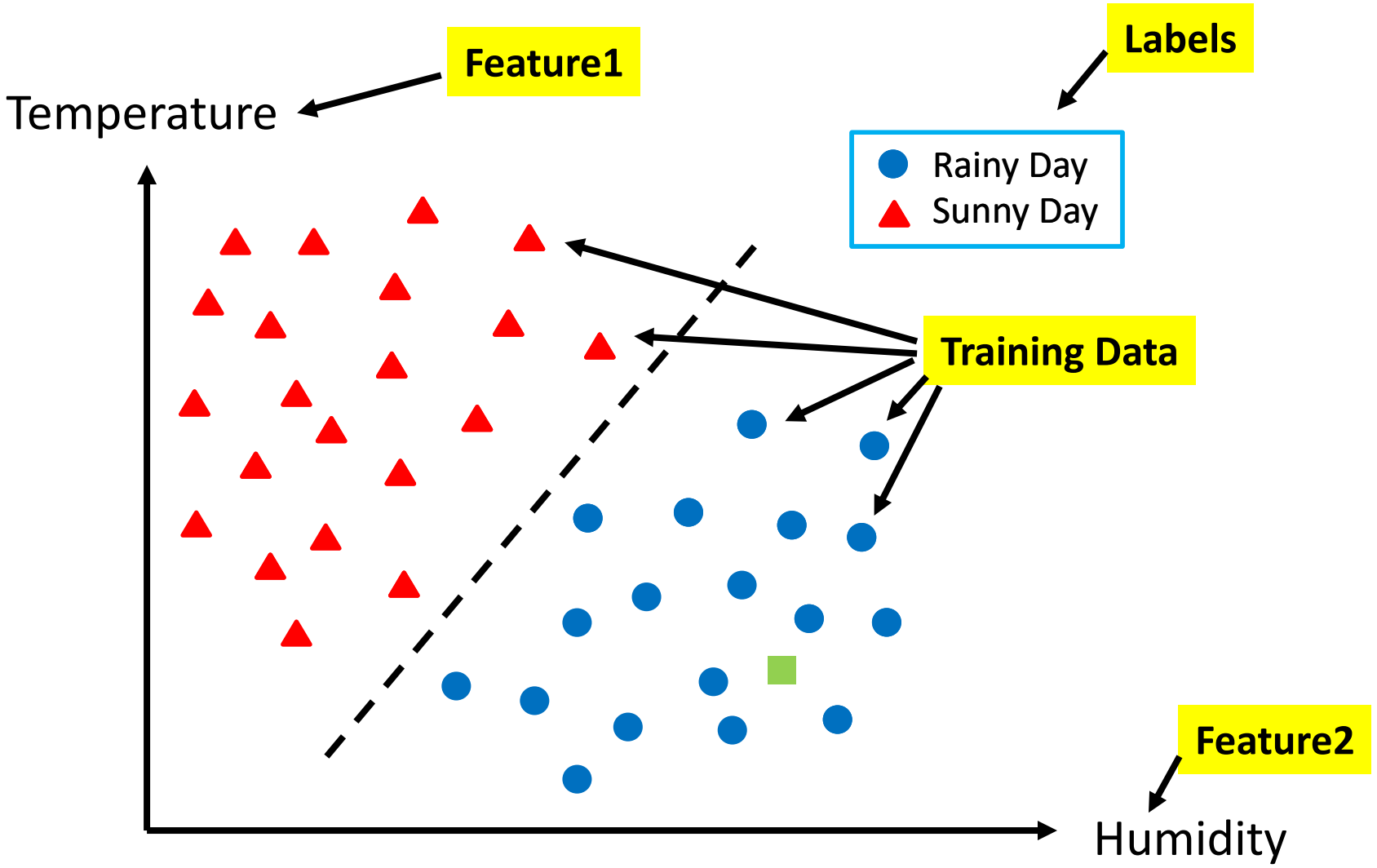
Terminology

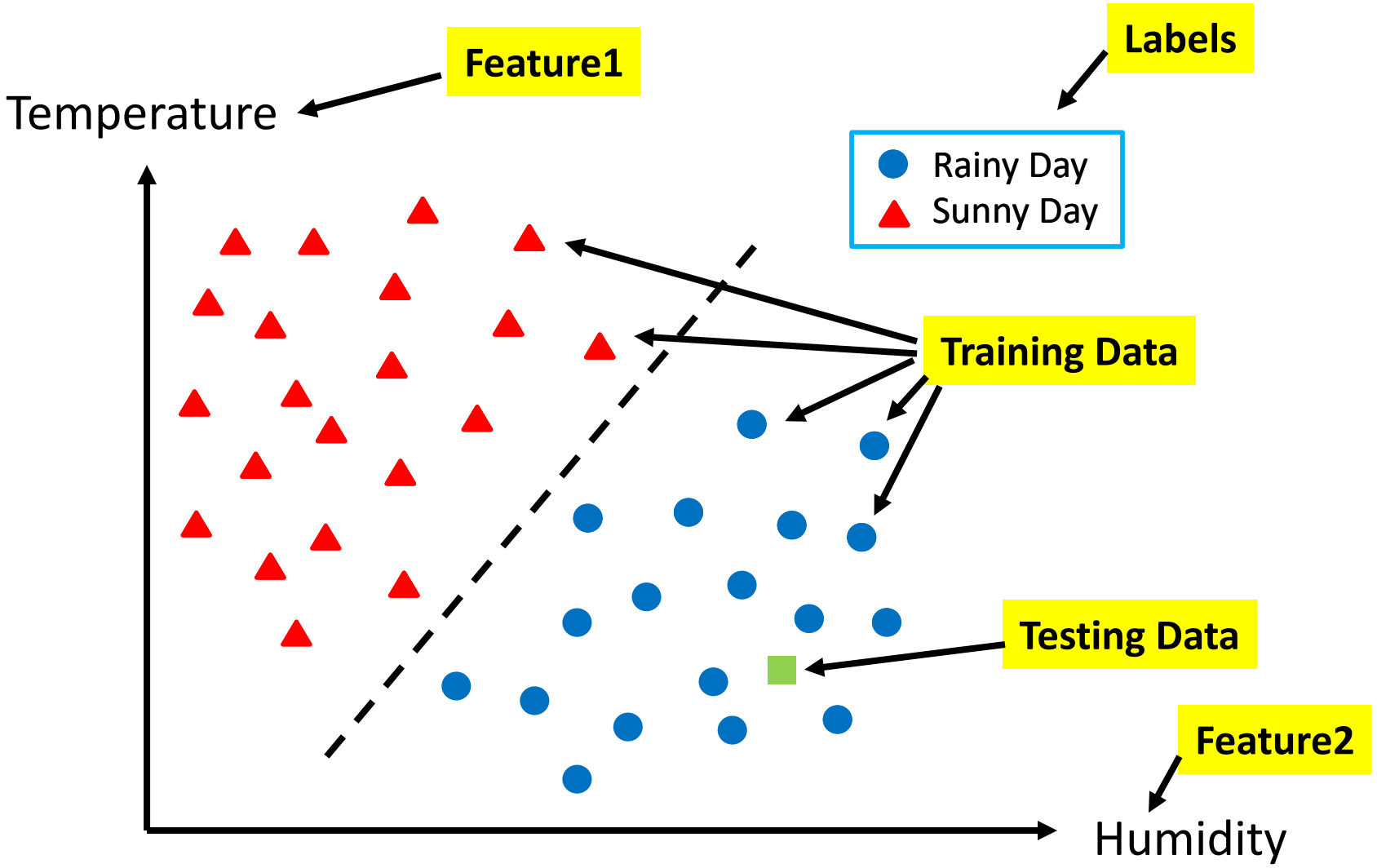
- **Observations**: Data Samples (Data Examples).
- **Features (inputs)**: Attributes that represent an observation, e.g., temperature, humidity
- **Labels (outputs):** Values assigned to observations (also called **class**, **target**), e.g., rainy/sunny
- **Training Data:** Past observations given to the Machine Learning algorithm for training. E.g. temperature and humidity of the past 30 days, along with the label for each day.
- **Testing/Prediction Data:** Observations given to a "predictive model" for prediction.

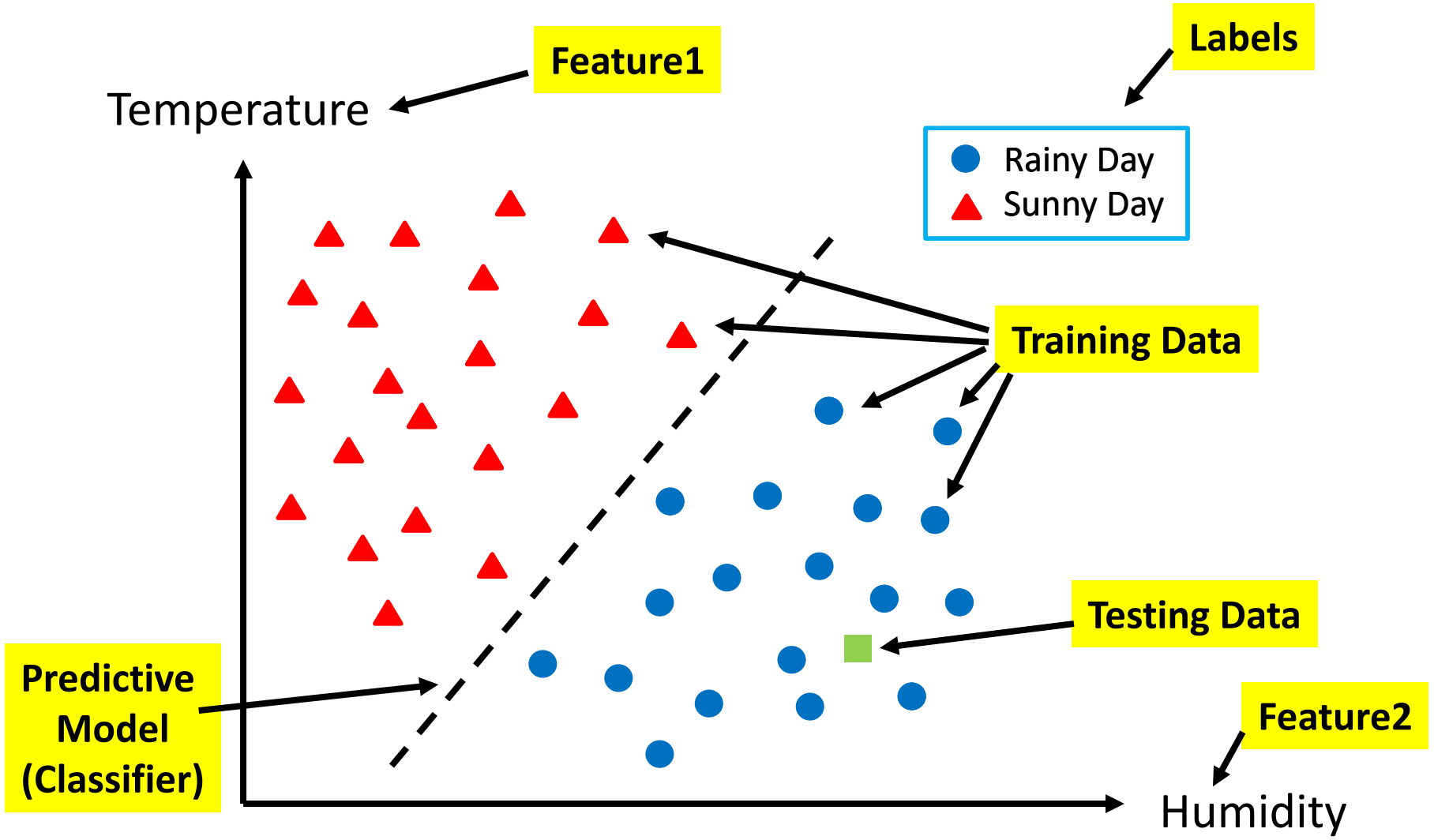

Temperature
Rainy Day
Sunny Day
Humidity


Feature1
Temperature
Rainy Day
Sunny Day
Feature2
Humidity


Feature1
Temperature
Labels
Rainy Day
Sunny Day
Feature2
Humidity


Feature1
Temperature
Labels
Rainy Day
Sunny Day
Training Data
Feature2
Humidity


Feature1
Temperature
Labels
Rainy Day
Sunny Day
Training Data
Testing Data
Feature2
Humidity

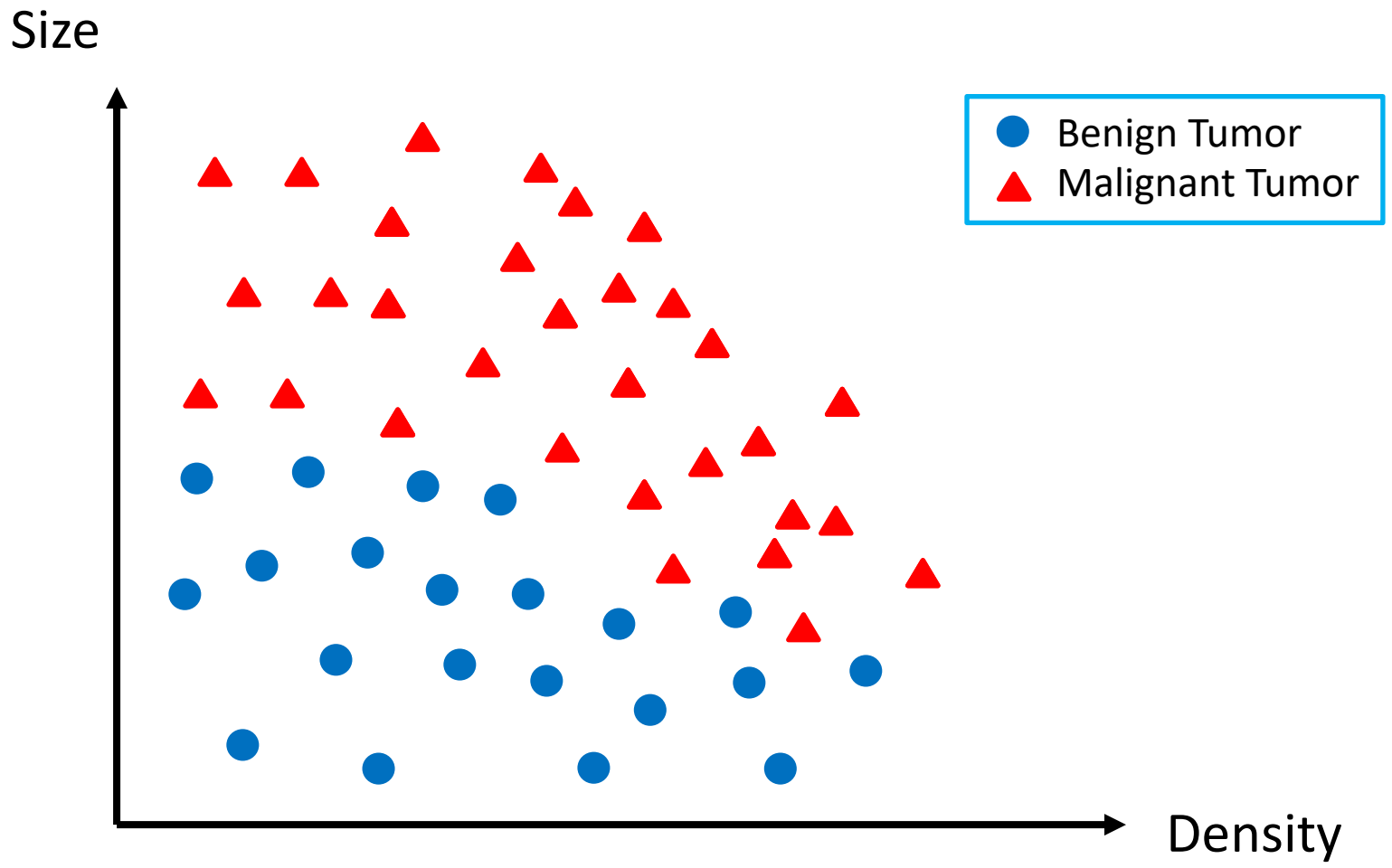

Feature1
Temperature
Labels
Rainy Day
Sunny Day
Training Data
Testing Data
Predictive Model (Classifier)
Feature2
Humidity

Another Example: Predicting Cancer

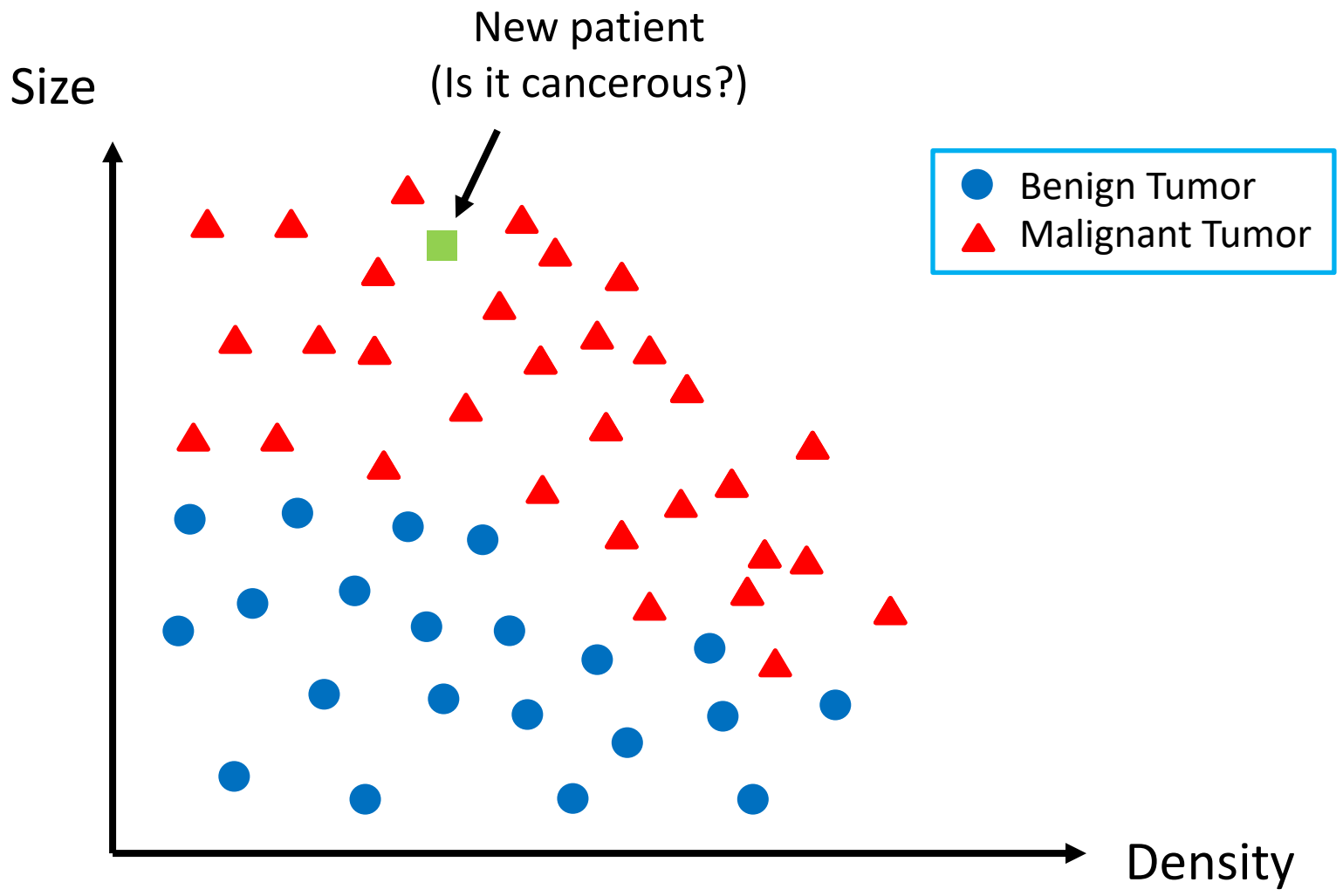
- Data: Suppose that we have the **Size** and **Density** of 100 tumors observed in 100 patients in the **past**.
- We also know whether those tumors were **Malignant** or **Benign**.

- **Questions**: Now, If we know the **Size** and **Softness** of a tumor in a **new** patient, can we **predict** if it is **Malignant** or **Benign**?

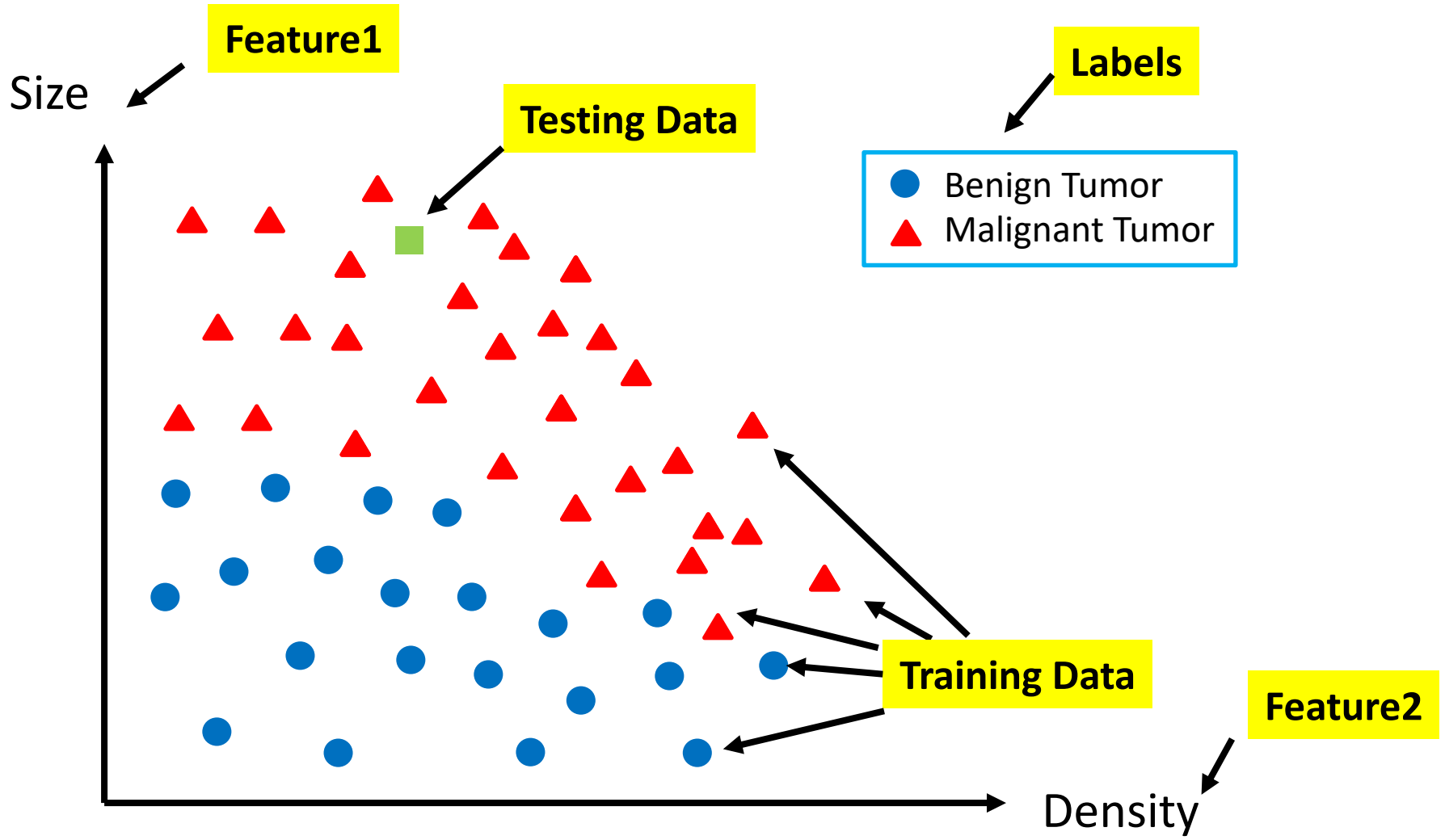
Example: Predicting Cancer



Example: Predicting Cancer



Example: Predicting Cancer



Example

- Suppose that we have medical data of **100 patients** diagnosed with a tumor in their body. We know the **age** and **gender** of patients. For each patient, we also know the **size** and **density** of tumors. After Biopsy examination, we know which one of these patients has **malignant** tumor and which one has **benign** tumors.

- Now, for **5 new patients** with tumor, having the **size** and **density** of tumors, and **age** and **gender** of patients, we would like to predict the type of tumor **without biopsy procedure**.

- Can you define **training data**, **testing data**, **features**, and **labels** for this problem?

More Terminology

- **Training Stage (Modeling):** Building a predictive model based on the training dataset (past data).
  - The model does not have to be perfect. As long as it is close, it is useful.
  - We should tolerate randomness and mistakes.

- **Testing Stage (Prediction):** Applying the trained model to forecast what is going to happen in future (on future testing data)

Machine Learning Settings

Common Learning Settings

- Supervised learning
- Unsupervised learning
- Semi-supervised learning
- Reinforcement learning
- Transfer learning
- Active learning

- **Supervised learning:** Learning from **labeled** observations.
  - In training stage, the algorithm is presented with **features and their known labels**, and the goal is to train a model that maps future inputs to new labels.
  - E.g. Neural Networks (ANN), K-Nearest Neighbors classifier (KNN), Decision Tree classifier, Linear Regression, Logistic Regression, Polynomial Regression, Random Forest, …
- **Unsupervised learning:** Learning from **unlabeled** observations.
  - The algorithm is presented **Only** with **features!** The goal is to **Discover hidden patterns and structure** from features alone. It is like a Data Exploration to find hidden patterns.
- **Semi-supervised learning:** Labels are provided only for a part of the training data. The remaining data is unlabeled.
- **Reinforcement learning:** Learning from an ***agent*** taking ***actions*** in an ***environment*** so as to maximize a long-term ***reward***. E.g. Game Theory, Control Theory.
- **Transfer learning:** Learning from a dataset while solving a problem, and then applying the **extracted knowledge** to a different but related dataset/problem.
- **Active learning:** Similar to Semi-Supervised Learning, but the algorithm is able to interactively query the user or some other information source to obtain the labels as needed.

Common Learning Settings

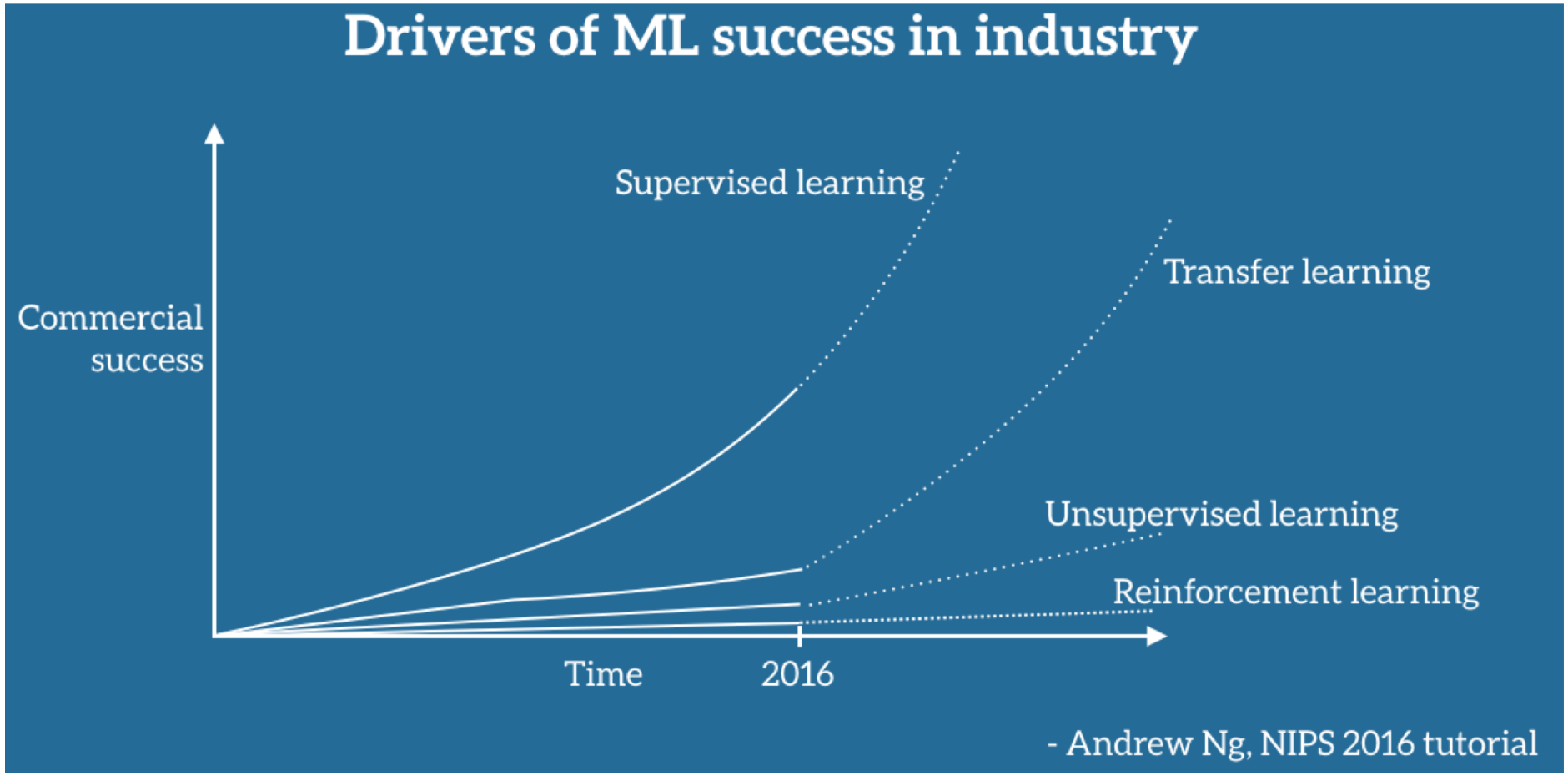


Figure Reference: Andrew Ng

Thank You!

Questions?