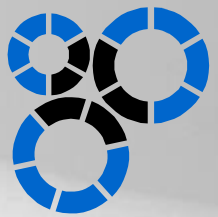
Machine Learning
CSE - 465

Lecture - 04

Outline

- Inductive Learning
- Concept Learning
- Hypothesis
- Hypothesis Space
- Null Hypothesis
- Alternative Hypothesis
- Null Hypothesis Testing
- Find-S Algorithm



Inductive Learning

- Inductive learning involves using evidence to determine the outcome.
- It means the process of learning by example -- where a system tries to induce a general rule from a set of observed instances.
- On the basis of past experience, formulating a generalized concept.
- Most machine learning models learn using a type of inductive inference or inductive reasoning where general rules (the model) are learned from specific historical examples (the training data).
- Any hypothesis found approximate the target function well over a sufficiently large set of training examples will also approximate the target function well over other unobserved examples.

Concept Learning

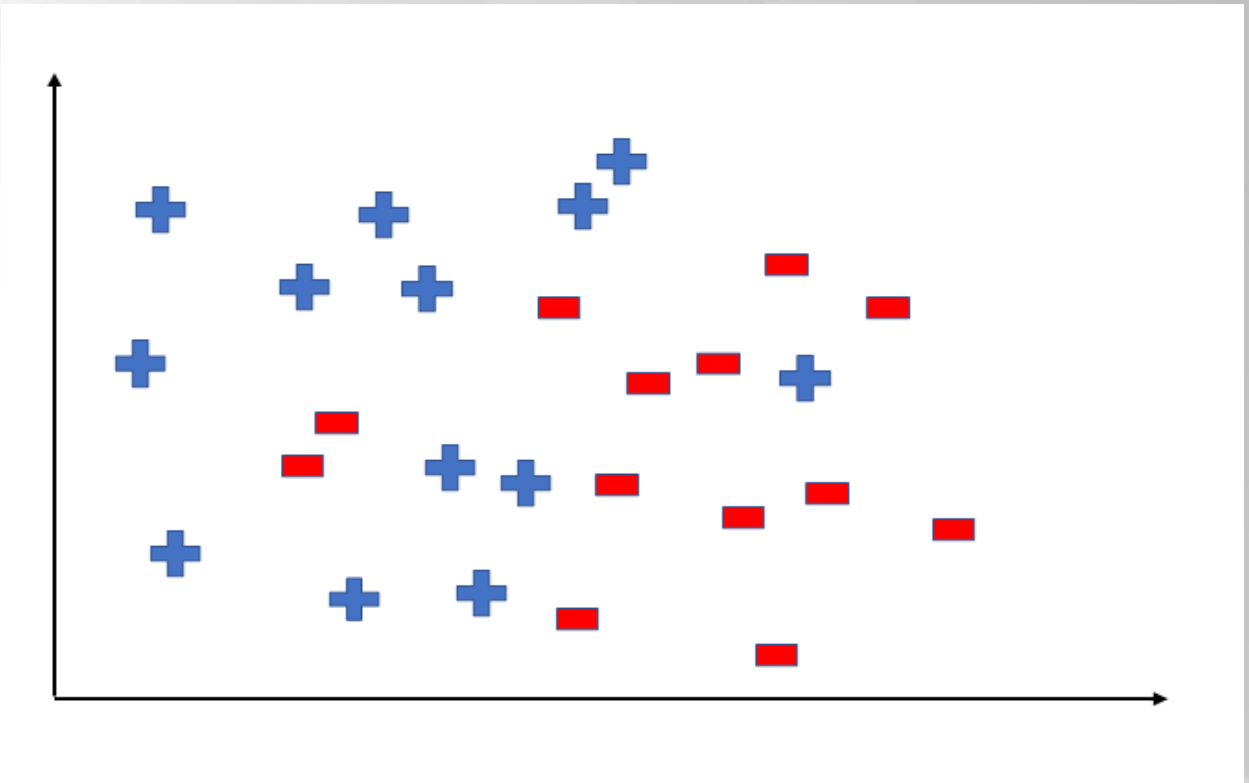
- The problem of searching through a predefined space of potential hypotheses for the hypothesis that best fits the training examples.

What is a Hypothesis?

- In most supervised machine learning algorithm, our main goal is to find out a possible hypothesis from the hypothesis space that could possibly map out the inputs to the proper outputs.
- A hypothesis is a candidate model that approximates a target function for mapping examples of inputs to outputs
- A hypothesis is a function that best describes the target in supervised machine learning.
- The hypothesis that an algorithm would come up depends upon the data and also depends upon the restrictions and bias that we have imposed on the data.

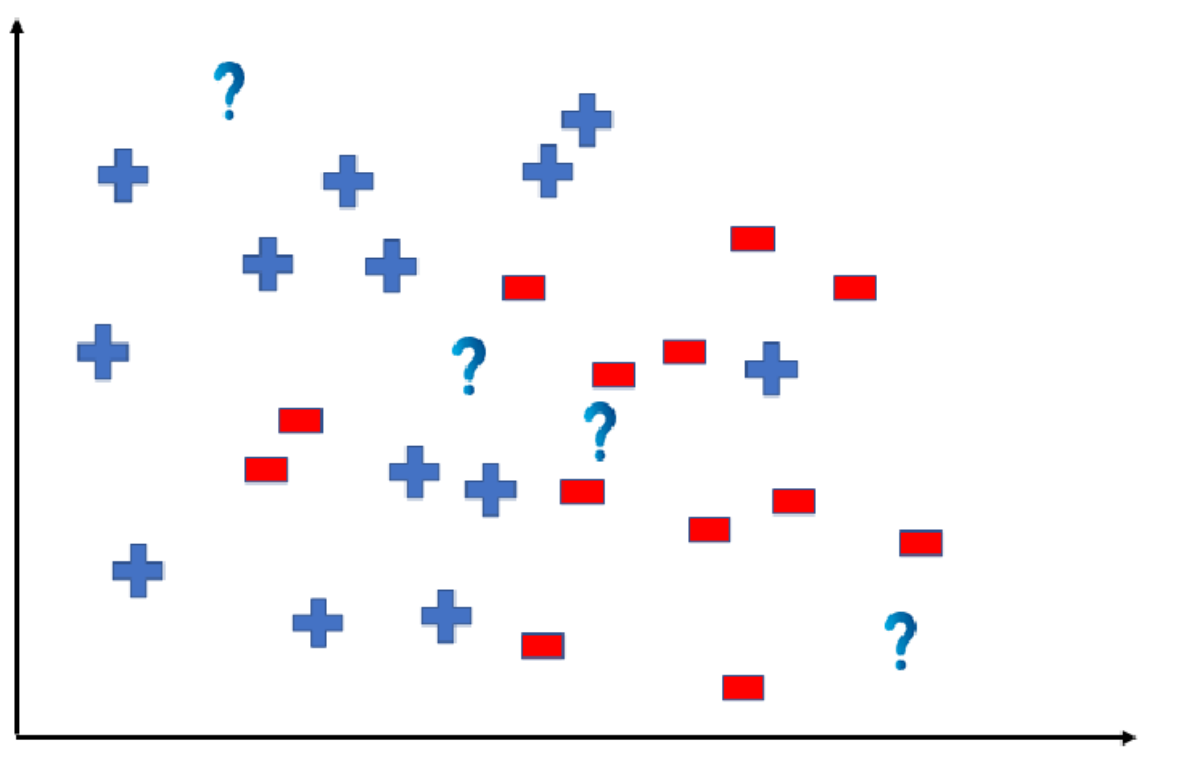
What is a Hypothesis?

- To better understand the Hypothesis Space and Hypothesis consider the following coordinate that shows the distribution of some data:



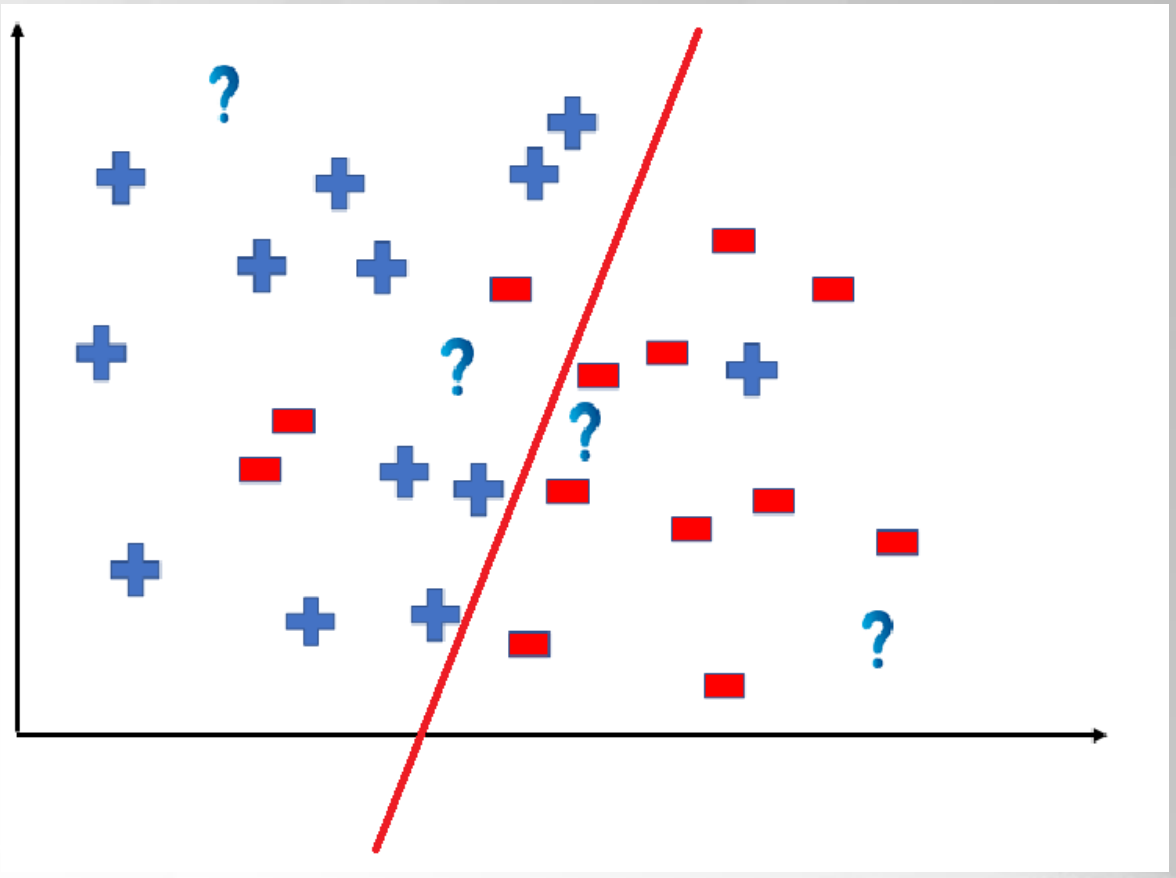
What is a Hypothesis?

- Suppose we have test data for which we have to determine the outputs or results. The test data is as shown below:



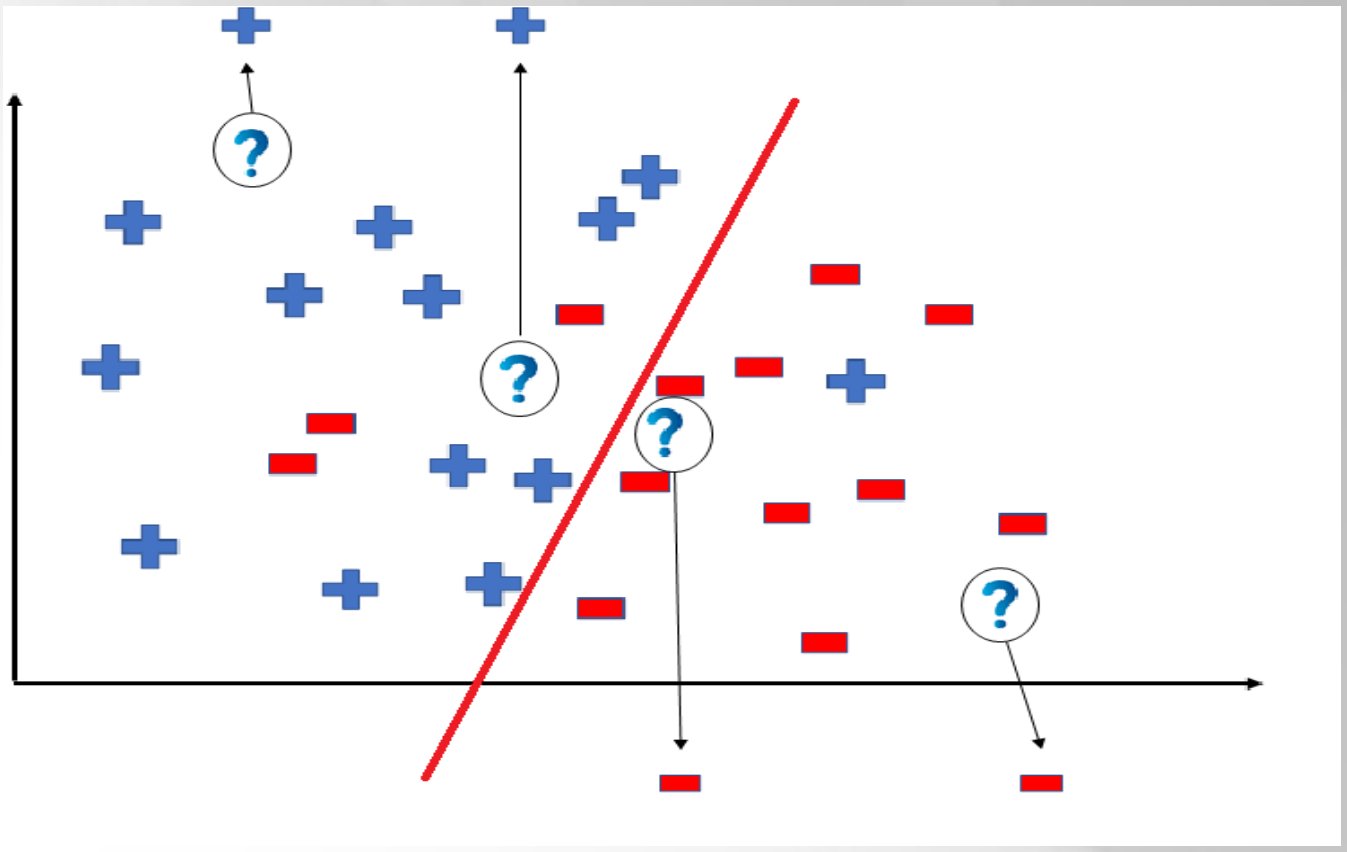
What is a Hypothesis?

- We can predict the outcomes by dividing the coordinate as shown below:



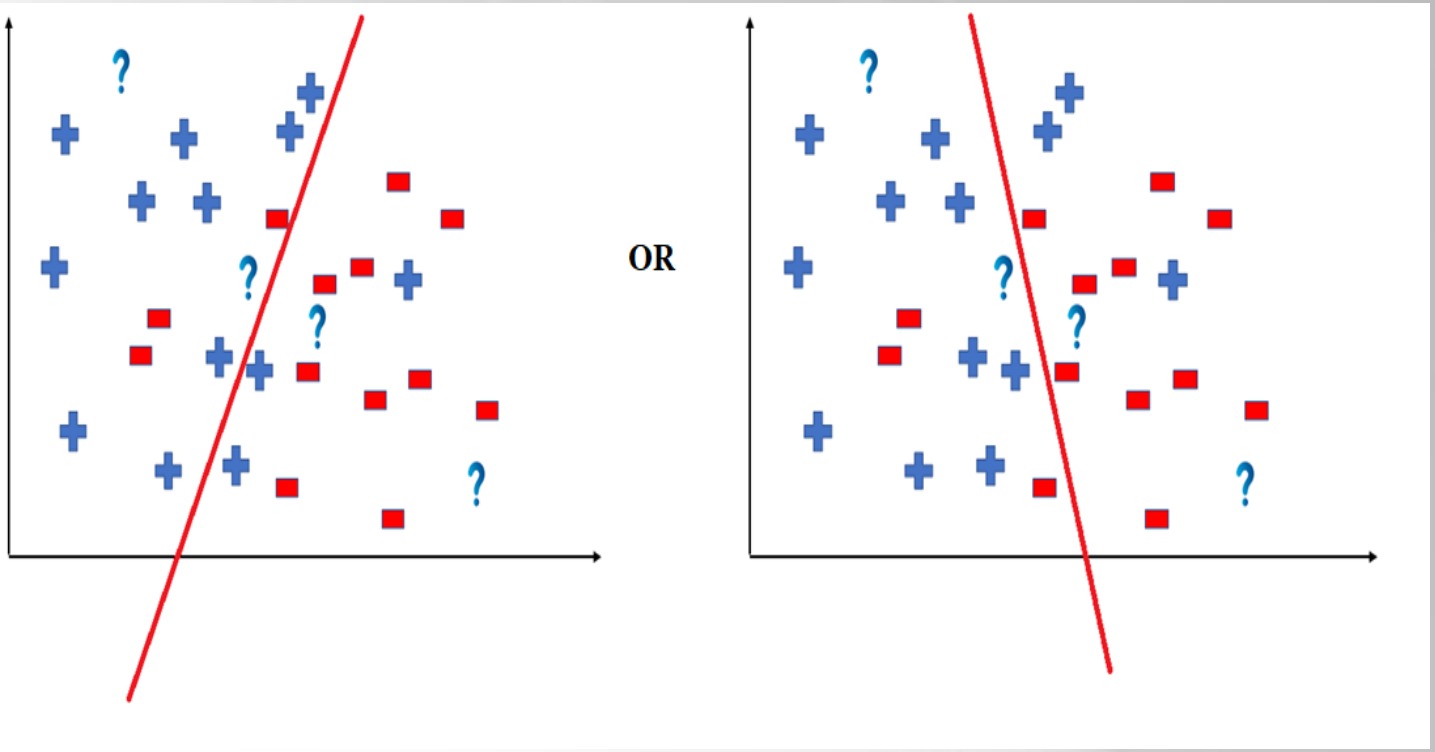
What is a Hypothesis?

- So the test data would yield the following result:



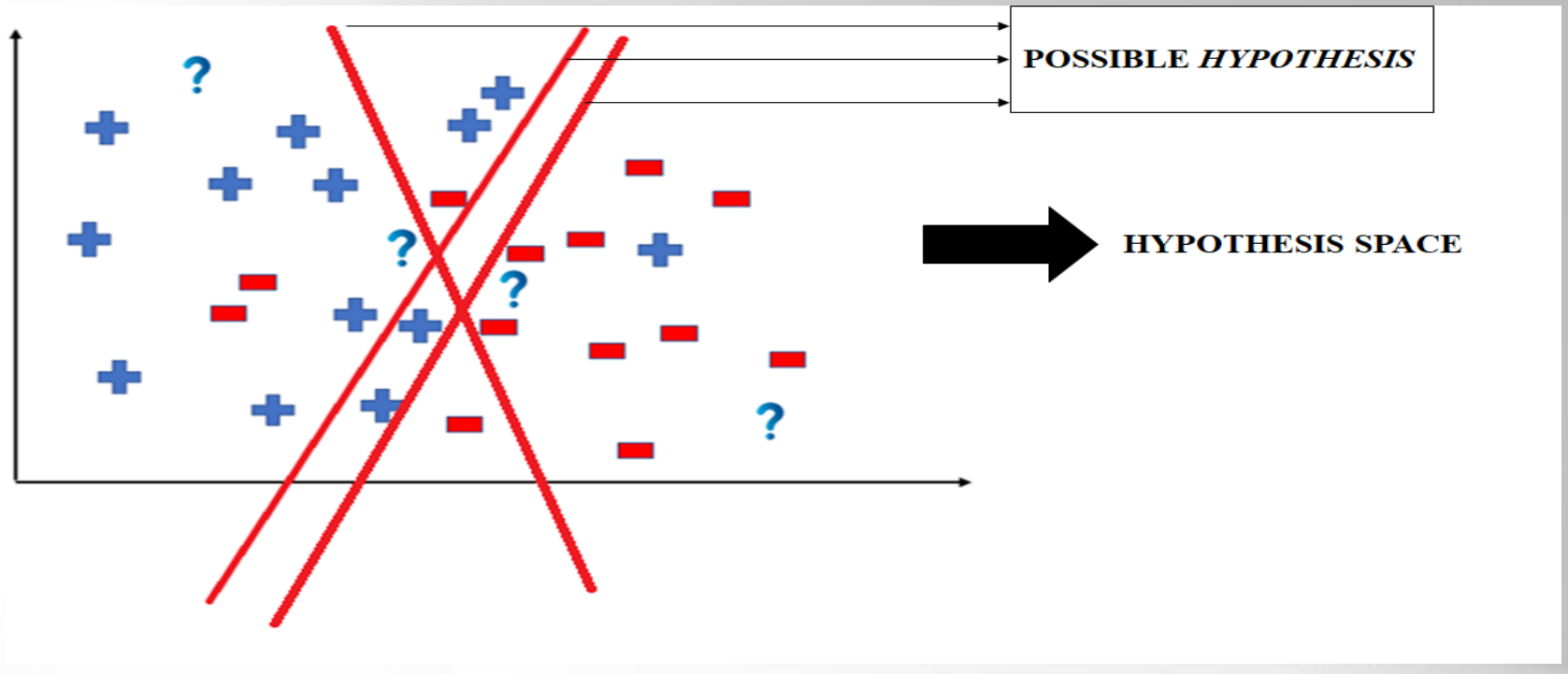
What is a Hypothesis?

- But note here that we could have divided the coordinate plane as:



What is a Hypothesis?

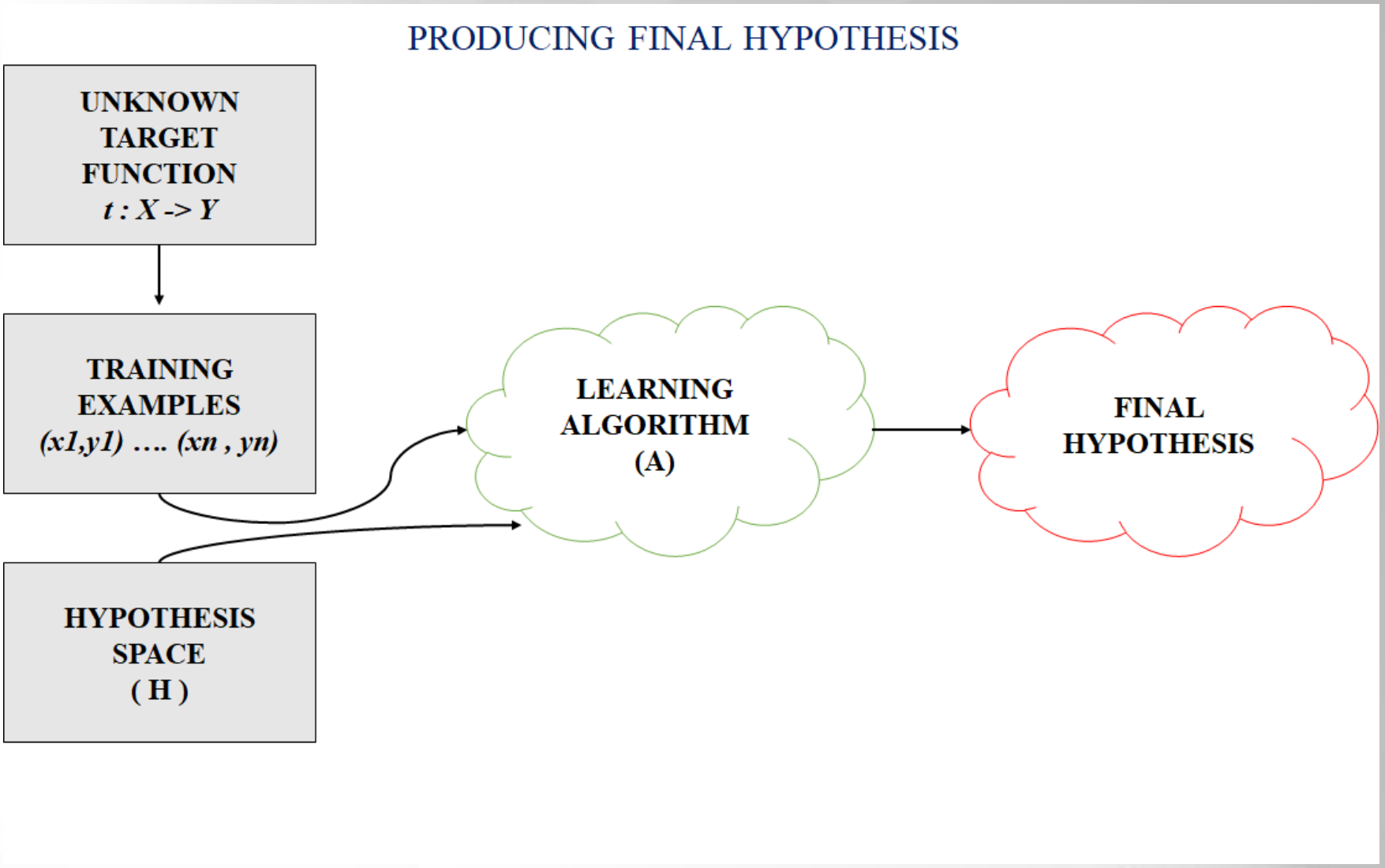
- The way in which the coordinate would be divided depends on the data, algorithm and constraints.
- All these legal possible ways in which we can divide the coordinate plane to predict the outcome of the test data composes of the Hypothesis Space. Each individual possible way is known as the hypothesis.



Hypothesis Space

- Hypothesis space is the set of all the possible legal hypothesis.
- This is the set from which the machine learning algorithm would determine the best possible (only one) which would best describe the target function or the outputs.

Final Hypothesis



Null Hypothesis

- A null hypothesis is a hypothesis that says there is no statistical significance between the two variables in the hypothesis.
- It is the hypothesis that the researcher is trying to disprove.
- An example can be something like this: There is no statistically significant relationship between the type of water I feed the flowers and growth of the flowers. A researcher is challenged by the null hypothesis and usually wants to disprove it, to demonstrate that there is a statistically-significant relationship between the two variables in the hypothesis.

Alternative Hypothesis

- An alternative hypothesis simply is the inverse, or opposite, of the null hypothesis. So, if we continue with the previous example, the alternative hypothesis would be that there is indeed a statistically-significant relationship between what type of water the flower plant is fed and growth. More specifically, here would be the null and alternative hypotheses for the example:

- **Null**: If one plant is fed club soda for one month and another plant is fed plain water, there will be no difference in growth between the two plants.

- **Alternative**: If one plant is fed club soda for one month and another plant is fed plain water, the plant that is fed club soda will grow better than the plant that is fed plain water.

Null Hypothesis Testing

- There are considered to be two methods for null hypothesis testing.

- Significance testing approach
  - the null hypothesis is rejected if the resulting data is significantly unlikely to have occurred if the null hypothesis were true.

- Testing the null hypothesis through contrast
  - The null hypothesis and the alternative hypotheses are compared, and the differences in the data help inform and construct the scientist's understandings of the phenomena.

General-to-Specific Learning

Most General Hypothesis: h = <?, ?, ?, ?, ?, ?>

Most Specific Hypothesis: h = < **Ø, Ø, Ø, Ø, Ø, Ø**>

General-to-Specific Learning

Example	Sky	AirTemp	Humidity	Wind	Water	Forecast	EnjoySport
1	Sunny	Warm	Normal	Strong	Warm	Same	Yes
2	Sunny	Warm	High	Strong	Warm	Same	Yes
3	Rainy	Cold	High	Strong	Warm	Change	No
4	Sunny	Warm	High	Strong	Cool	Change	Yes

$$h_1 = \langle Sunny, ?, ?, Strong, ?, ? \rangle$$

$$h_2 = \langle Sunny, ?, ?, ?, ?, ? \rangle$$

h_2 is more general than h_1

h_2 imposes fewer constraints on the instance than **h_1**

FIND-S: Finding a Maximally Specific Hypothesis

1. Initialize h as the most specific hypothesis in the hypothesis space H

2. For each positive training example x
   - For each attribute constraint a_i in h:
     - If the constraint a_i is satisfied by x → Do Nothing with the constraint a_i
     - Else if not satisfied, then replace a_i in h by the **next immediate** more general constraint that can be satisfied by x

3. When reached to the end of the training examples, output the obtained hypothesis h that has been found

Step 1: FIND-S

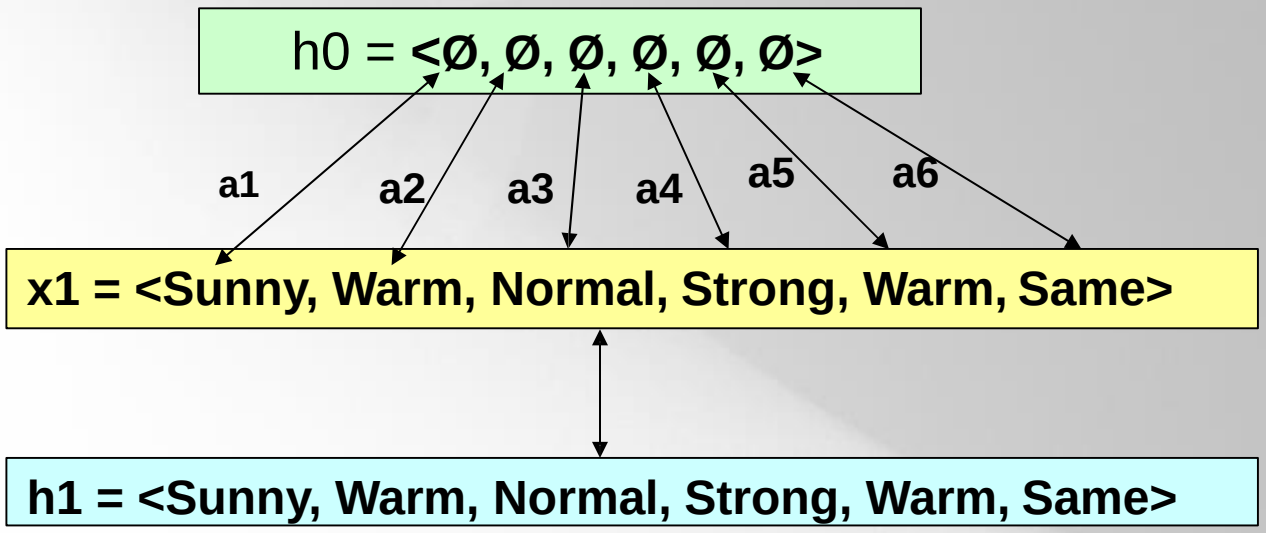
Example	Sky	AirTemp	Humidity	Wind	Water	Forecast	EnjoySport
1	Sunny	Warm	Normal	Strong	Warm	Same	Yes
2	Sunny	Warm	High	Strong	Warm	Same	Yes
3	Rainy	Cold	High	Strong	Warm	Change	No
4	Sunny	Warm	High	Strong	Cool	Change	Yes

1. Initialize h to the most specific hypothesis in H

h0 = **<Ø, Ø, Ø, Ø, Ø, Ø>**

Step 2: FIND-S (Iteration-01)

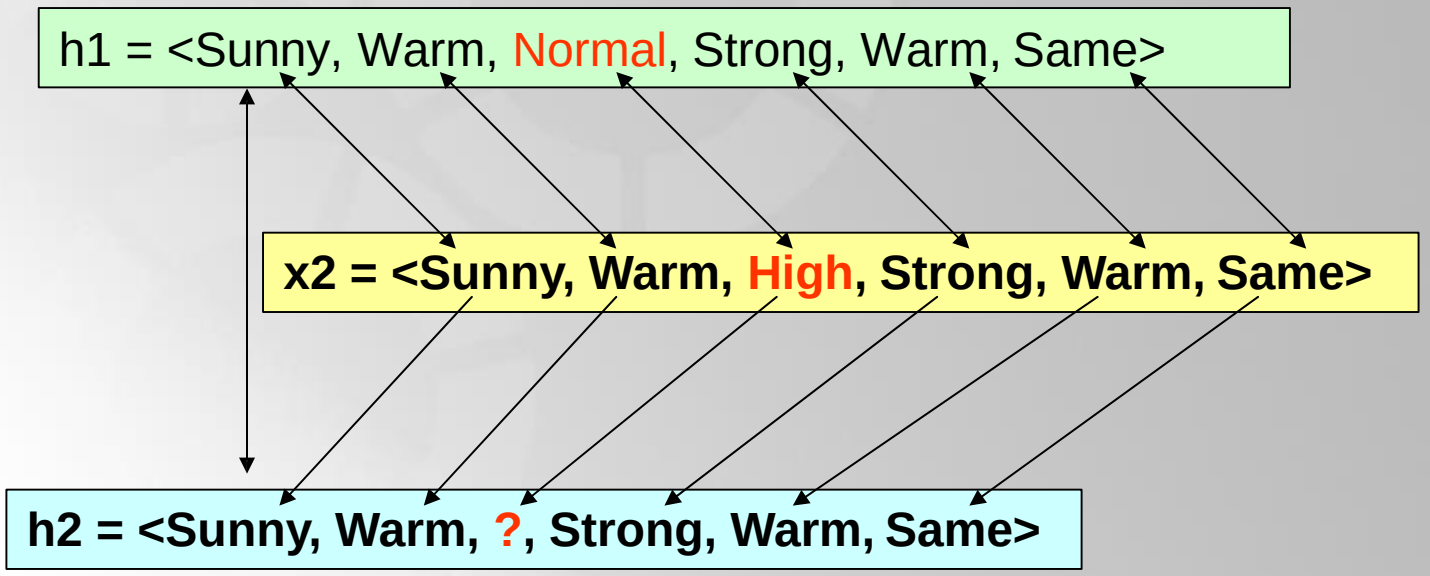
2. For each positive training instance x
   - For each attribute constraint a_i in h
     If the constraint a_i is satisfied by x
     Then do nothing
     Else replace a_i in h by the next more general constraint that is satisfied by x



Iteration 1

Step 2: FIND-S (Iteration-02)

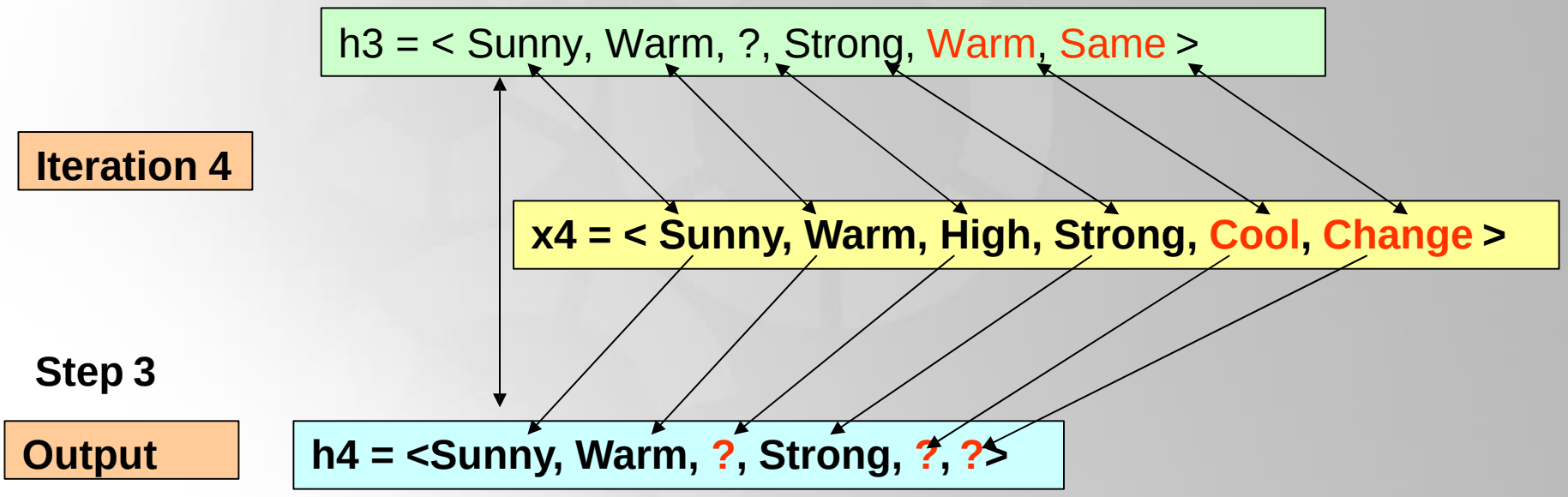
Iteration 2



Step 2: FIND-S (Iteration-03)

Iteration 3 **Ignore** **h3 = <Sunny, Warm, ?, Strong, Warm, Same>**

Step 2: FIND-S (Iteration-04)



Limitation of Find-S

- There's no way to determine if the only final hypothesis (found by Find-S) is consistent with the data or kf there are more hypotheses that are consistent with data.
- Inconsistent sets of training examples can mislead the Find-S algorithm, as it ignores negative data samples. An algorithm that can detect inconsistency of training data is better.
- A good concept learning algorithm should be able to backtrack the choice of hypothesis found so that the resulting hypothesis can be improved over time. Unfortunately, Find-S provides no such method.

Thank You