T1: Introduction to Machine Learning

Fundamentos del Aprendizaje Automático

Curso 2025/2026

Structure

Outline

What is Machine Learning?

- Trending term nowadays

What is Machine Learning?

- Trending term nowadays
- Nevertheless, the field dates back to the 80s

What is Machine Learning?

- Trending term nowadays
- Nevertheless, the field dates back to the 80s
  - Grounded on statistical reasoning

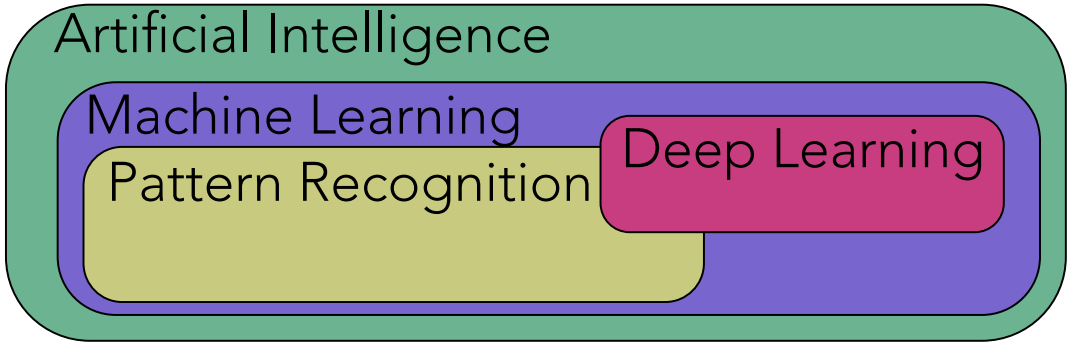
What is Machine Learning?

- Trending term nowadays
- Nevertheless, the field dates back to the 80s
  - Grounded on statistical reasoning
- **Premise**: Infer knowledge from data by computational means

What is Machine Learning?

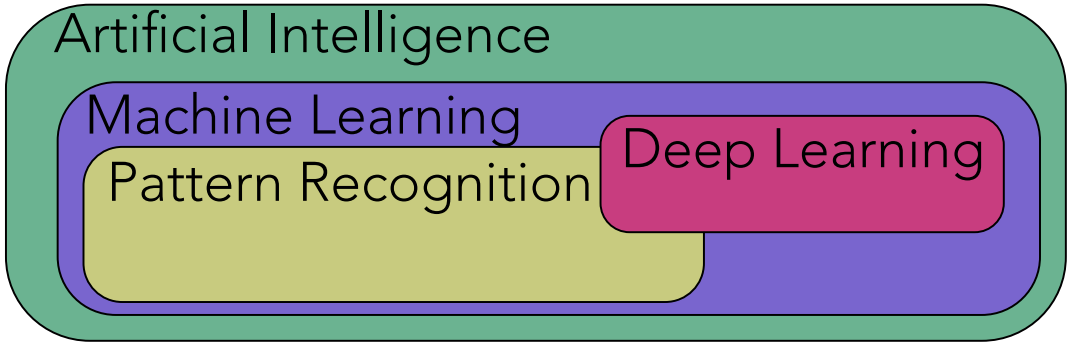
- Trending term nowadays
- Nevertheless, the field dates back to the 80s
  - Grounded on statistical reasoning
- **Premise**: Infer knowledge from data by computational means
- How does it relate to other terms such as Artificial Intelligence or Pattern Recognition?

What is Machine Learning?



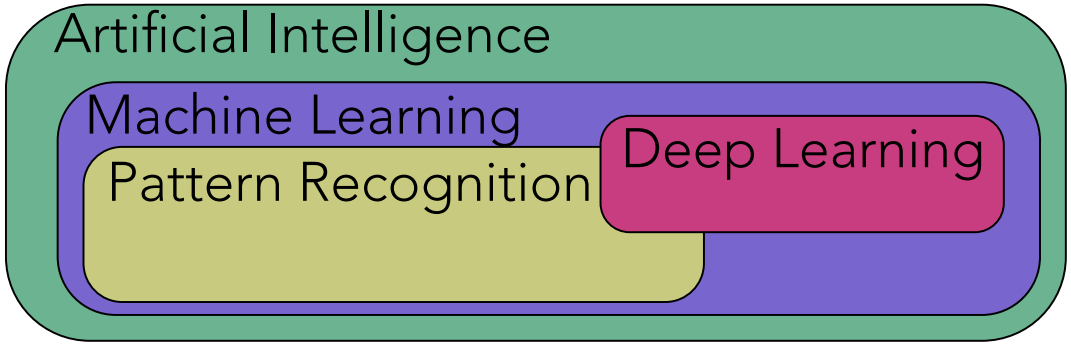
- **Artificial Intelligence**: Mimic human intelligence/intelligent behaviour
  - Could be hand-crafted rules by a programmer
- **Machine Learning**: AI subfield focused on the design of algorithms capable of inferring knowledge from data
- **Pattern Recognition**: ML subfield that mainly focuses on classification tasks with hand-crafted features
- **Deep Learning**: ML subfield that focuses on deep neural models for both feature extraction and knowledge inference

What is Machine Learning?



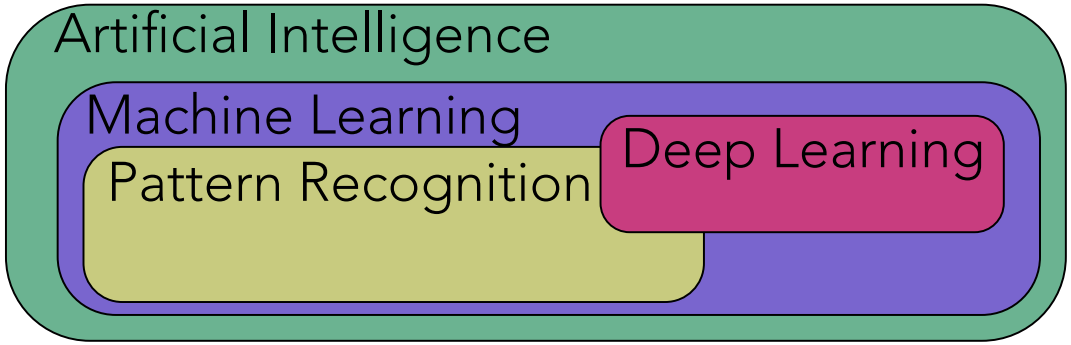
- **Artificial Intelligence**: Mimic human intelligence/intelligent behaviour
  - Could be hand-crafted rules by a programmer
- **Machine Learning**: AI subfield focused on the design of algorithms capable of inferring knowledge from data
- **Pattern Recognition**: ML subfield that mainly focuses on classification tasks with hand-crafted features
- **Deep Learning**: ML subfield that focuses on deep neural models for both feature extraction and knowledge inference

What is Machine Learning?



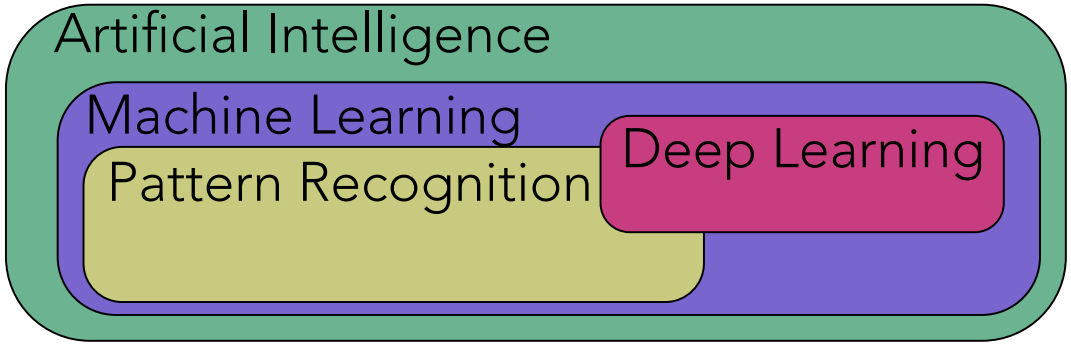
- **Artificial Intelligence**: Mimic human intelligence/intelligent behaviour
  - Could be hand-crafted rules by a programmer
- **Machine Learning**: AI subfield focused on the design of algorithms capable of inferring knowledge from data
- **Pattern Recognition**: ML subfield that mainly focuses on classification tasks with hand-crafted features
- **Deep Learning**: ML subfield that focuses on deep neural models for both feature extraction and knowledge inference

What is Machine Learning?



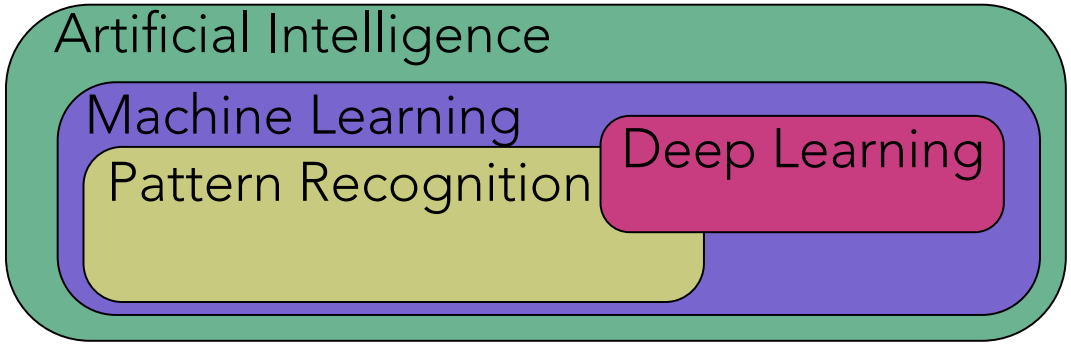
- **Artificial Intelligence**: Mimic human intelligence/intelligent behaviour
  - Could be hand-crafted rules by a programmer
- **Machine Learning**: AI subfield focused on the design of algorithms capable of inferring knowledge from data
- **Pattern Recognition**: ML subfield that mainly focuses on classification tasks with hand-crafted features
- **Deep Learning**: ML subfield that focuses on deep neural models for both feature extraction and knowledge inference

What is Machine Learning?



- **Artificial Intelligence**: Mimic human intelligence/intelligent behaviour
  - Could be hand-crafted rules by a programmer
- **Machine Learning**: AI subfield focused on the design of algorithms capable of inferring knowledge from data
- **Pattern Recognition**: ML subfield that mainly focuses on classification tasks with hand-crafted features
- **Deep Learning**: ML subfield that focuses on deep neural models for both feature extraction and knowledge inference

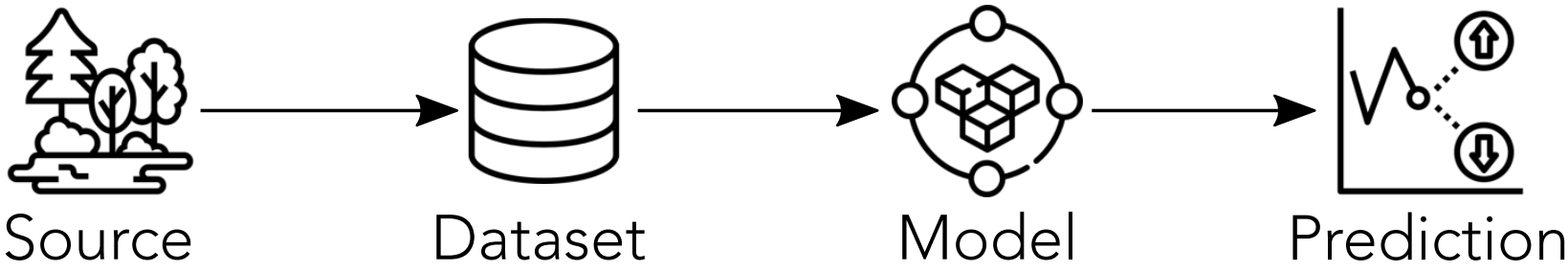
What is Machine Learning?



Field	Goal	Representative tasks	Models
Pattern Recognition	Automaticall detect and categorize patterns	Classification	k-Nearest Neighbor Logistic Regression Gaussian Mixture Models
Machine Learning	Infer knowledge	Classification, regression, clustering, sequence labelling	Same as ML + Decision Trees, Neural models, Support Vector Machine
Deep Learning	Infer knowledge with deep models	Classification, regression, clustering, sequence labelling	Deep neural networks
Artificial Intelligence	Mimic (human) intelligence	All previous + automated planning + multi-agent systems + ...	All previous

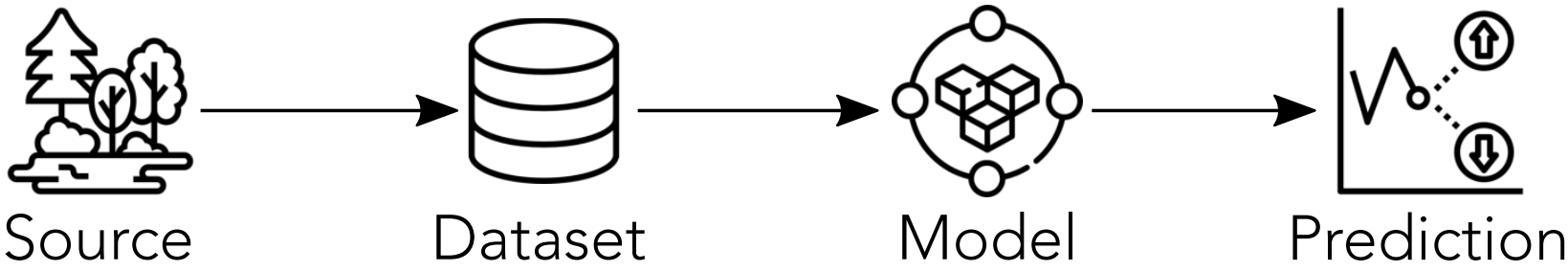
Outline

Conceptual stages



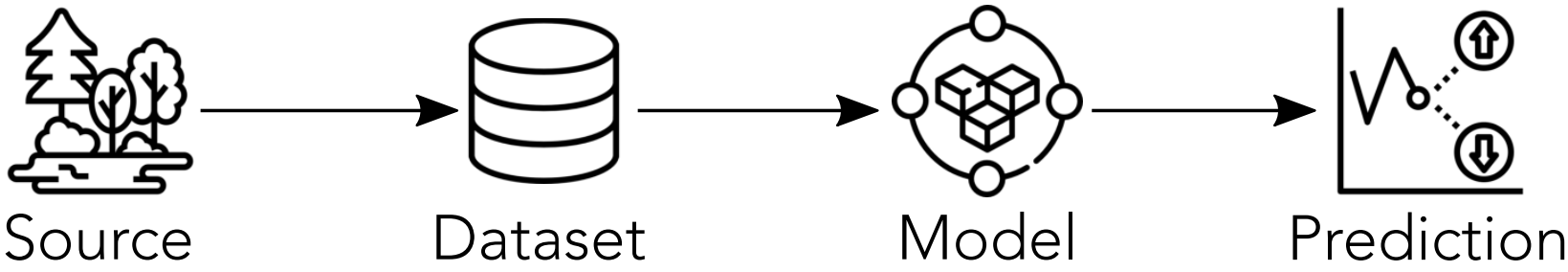
- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

Conceptual stages



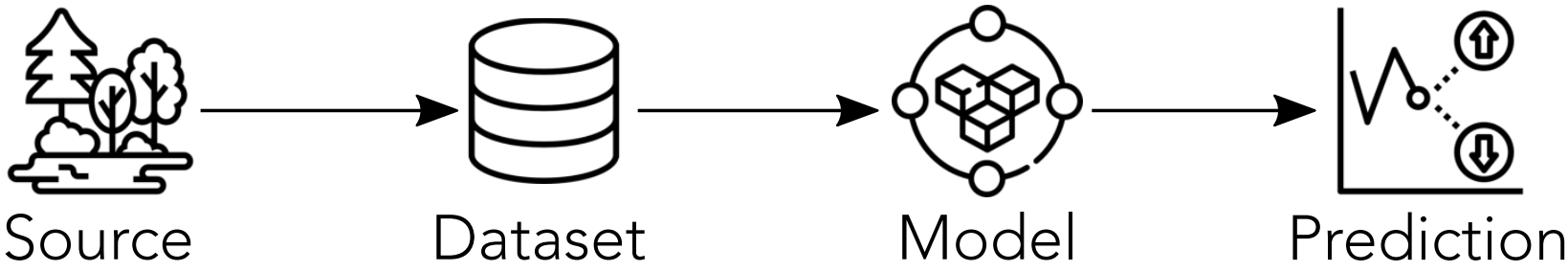
- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

Conceptual stages



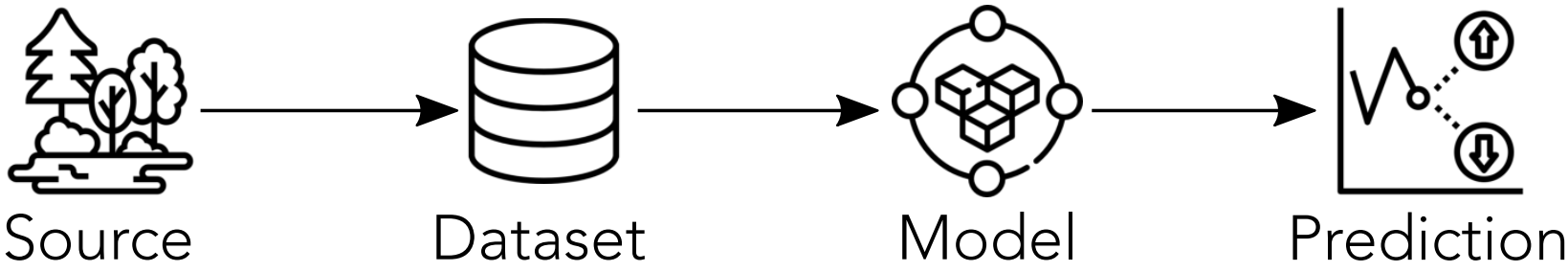
- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

Conceptual stages



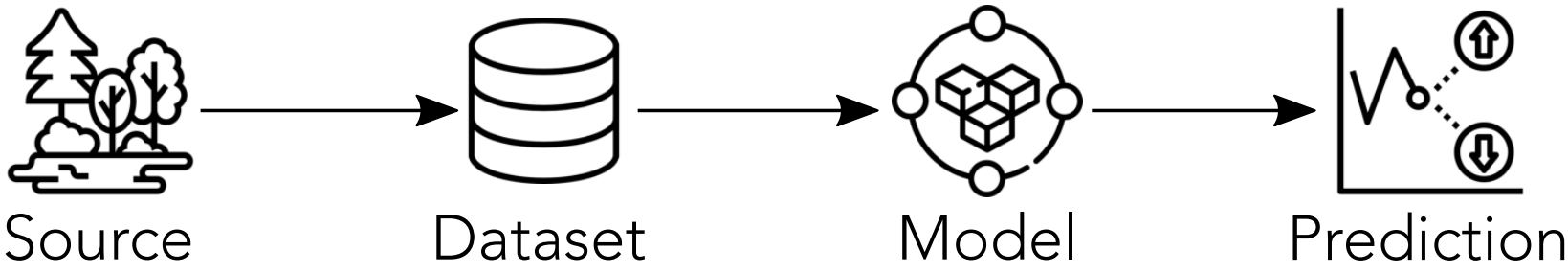
- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

Conceptual stages



- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

Conceptual stages



- **Source**: Data captured by sensors (photographs, recordings, scanned documents...)
  - **Feature extraction**: Obtaining adequate descriptors for the task at hand
- **Dataset**: Collection of elements from *Source* represented as descriptors
- **Model**: Knowledge extracted from the *Dataset* using an ML algorithm
- **Prediction**: Estimation on novel data unseen in the previous stages

From (conceptual) stages to (practical) scheme

ML comprises two main processes:

1. **Train** process: The knowledge is extracted from known data
2. **Test** process: The knowledge is exploited for new data

From (conceptual) stages to (practical) scheme

ML comprises two main processes:

1. **Train** process: The knowledge is extracted from known data
2. **Test** process: The knowledge is exploited for new data

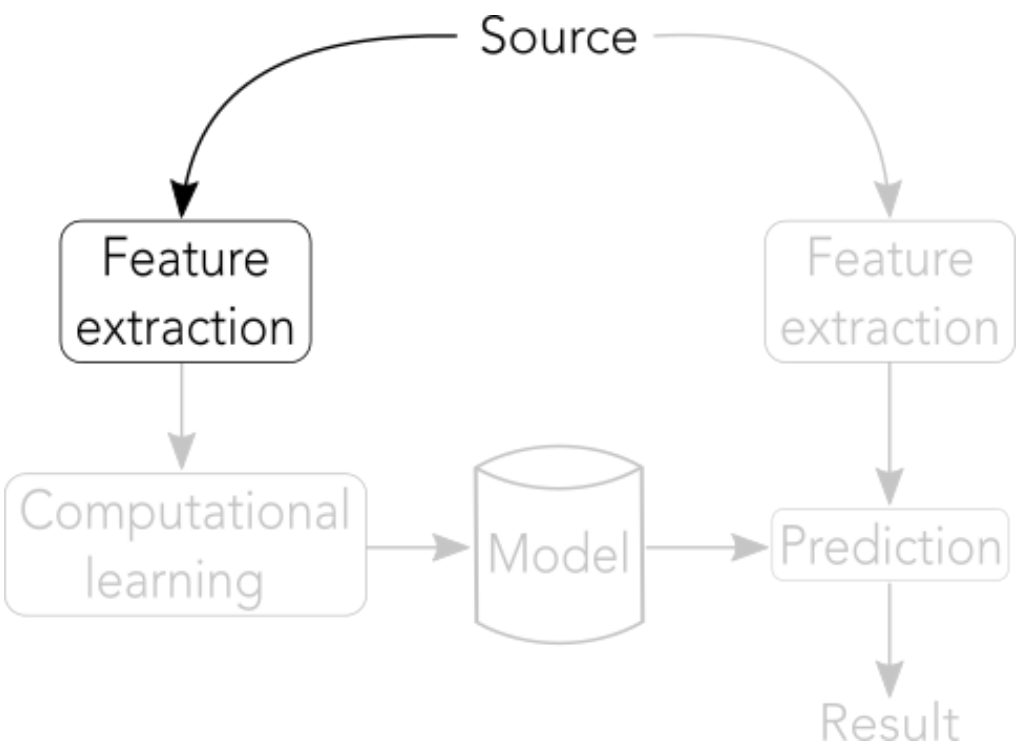
From (conceptual) stages to (practical) scheme

ML comprises two main processes:

1. **Train** process: The knowledge is extracted from known data
2. **Test** process: The knowledge is exploited for new data

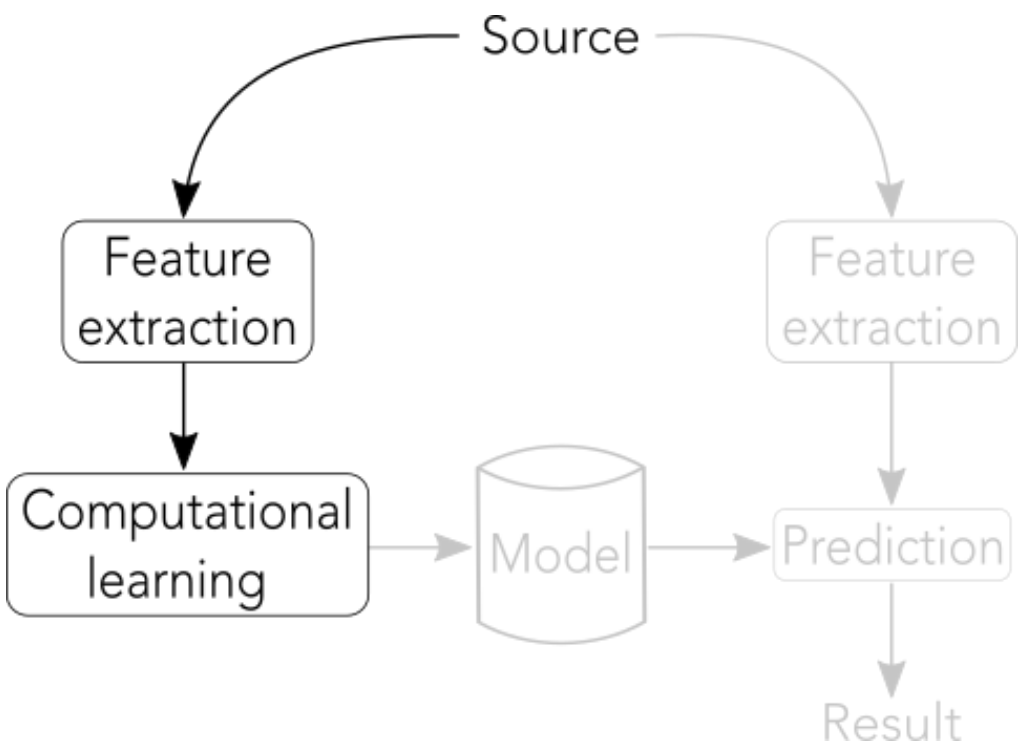
From (conceptual) stages to (practical) scheme

Train process



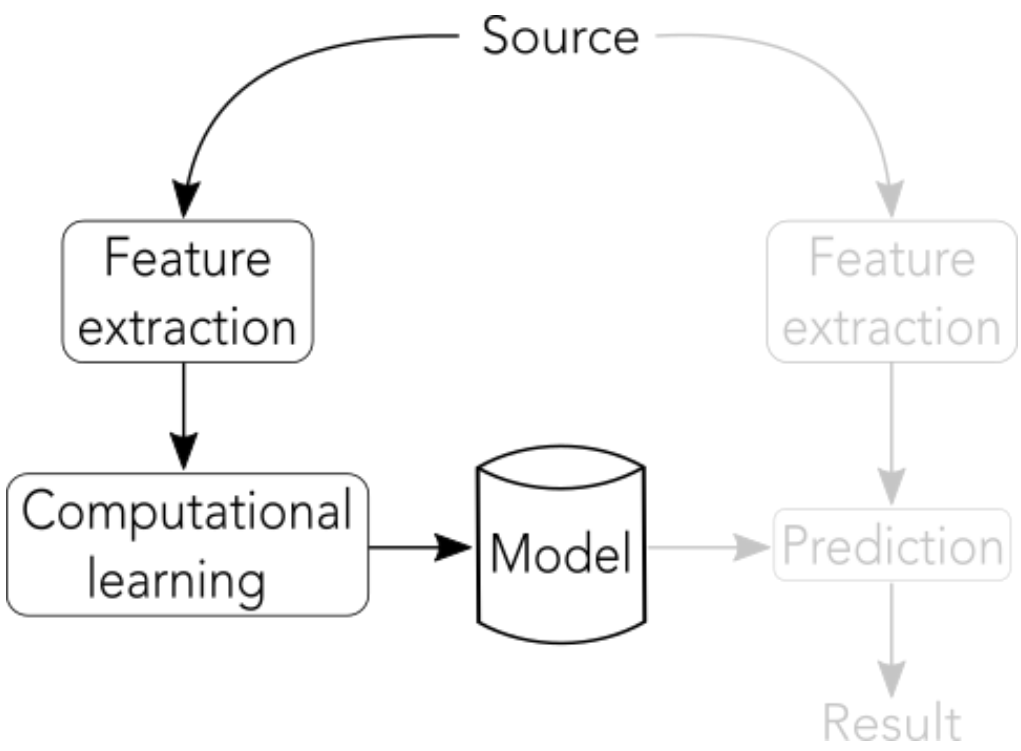
From (conceptual) stages to (practical) scheme

Train process



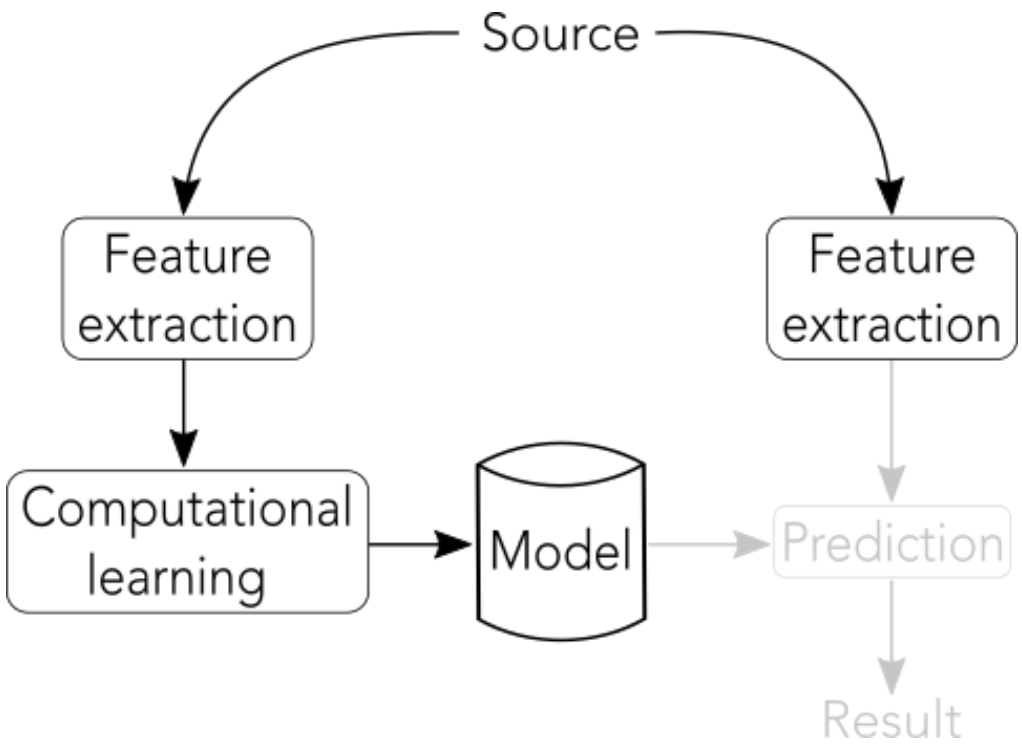
From (conceptual) stages to (practical) scheme

Train process



From (conceptual) stages to (practical) scheme

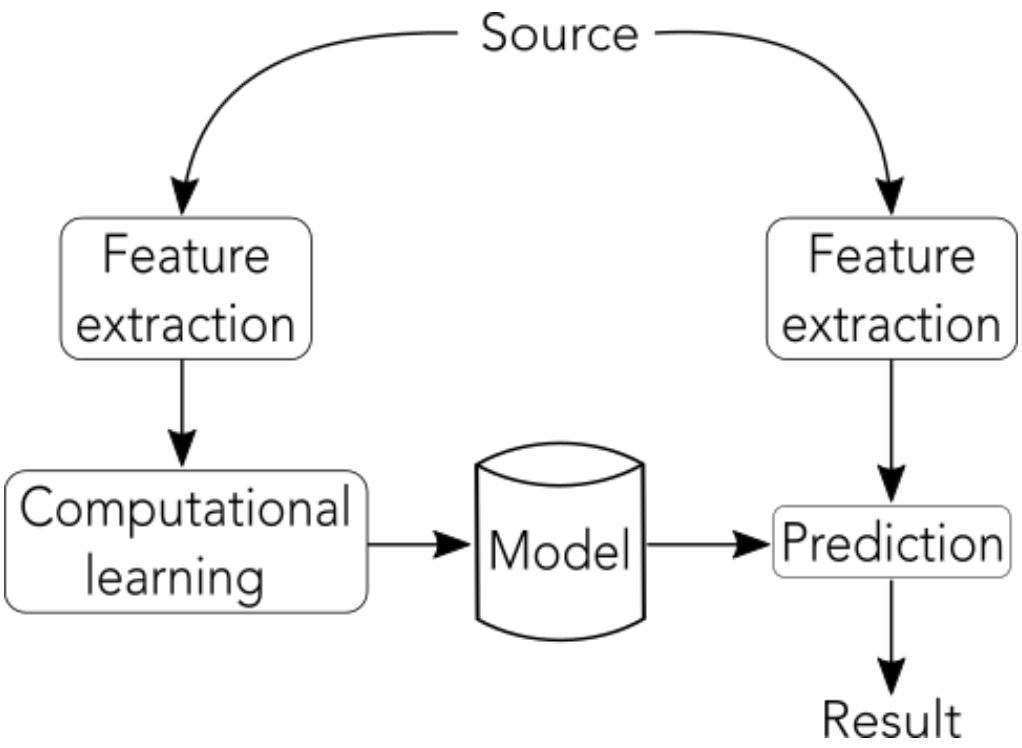
Train process



Test process

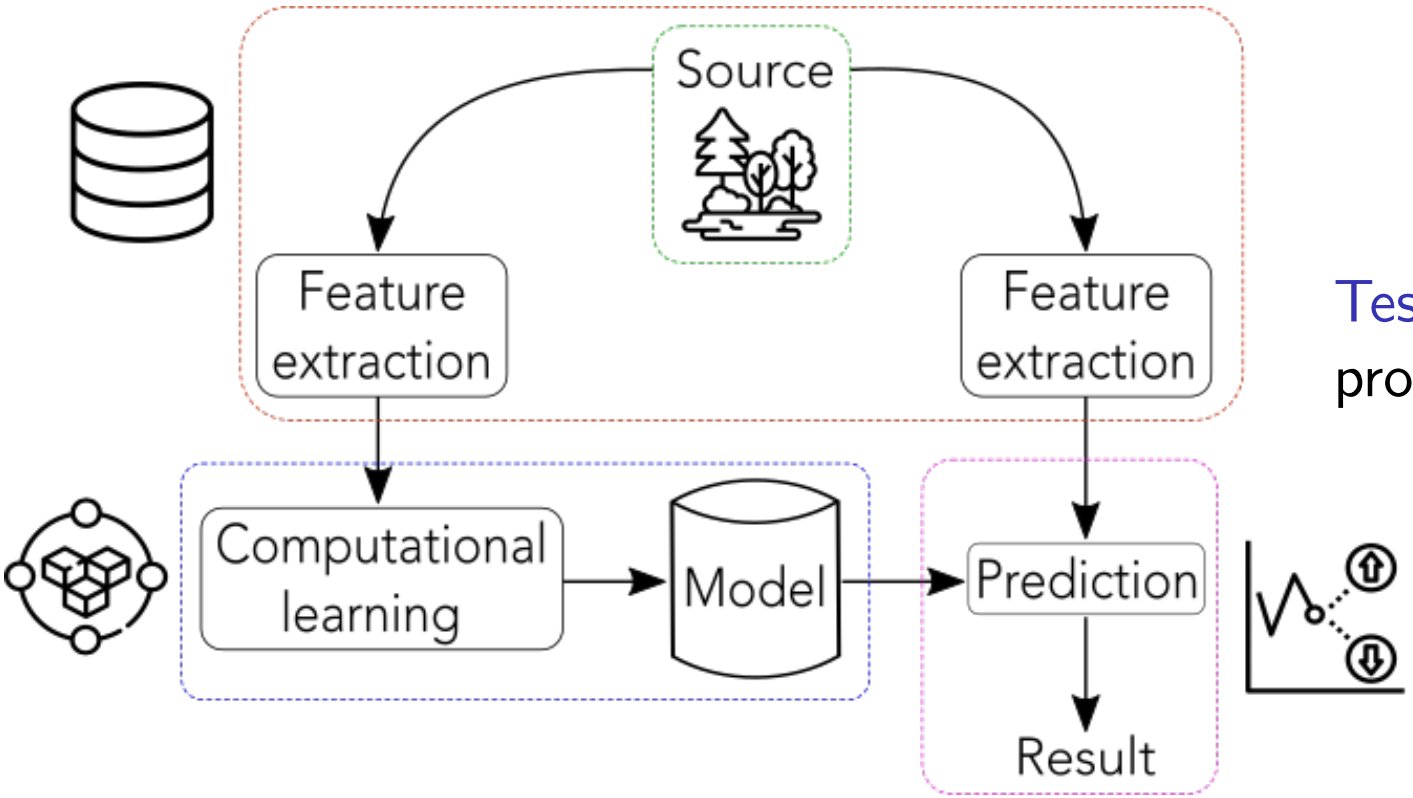
From (conceptual) stages to (practical) scheme

Train process



Test process

From (conceptual) stages to (practical) scheme



Feature extraction

- Encode the elements from *Source* as a set of descriptors
- The set must be adequate for the task being modeled

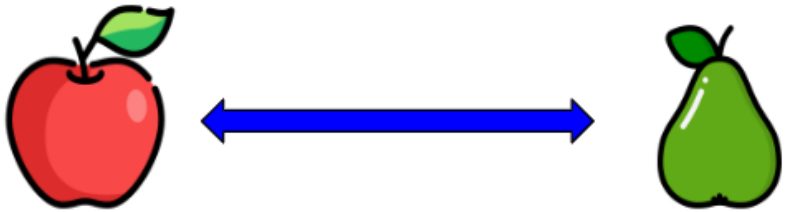
Feature extraction

- Encode the elements from *Source* as a set of descriptors
- The set must be adequate for the task being modeled

Feature extraction

- Encode the elements from *Source* as a set of descriptors
- The set must be adequate for the task being modeled

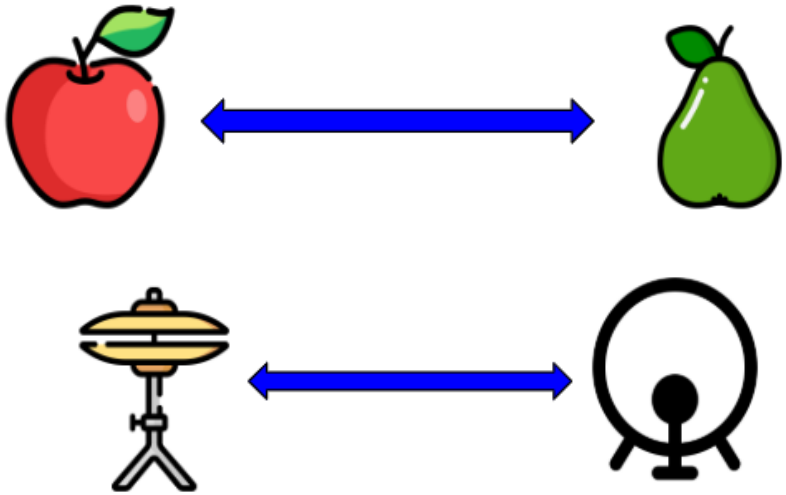
Example: How could you differentiate these two elements?



Feature extraction

- Encode the elements from *Source* as a set of descriptors
- The set must be adequate for the task being modeled

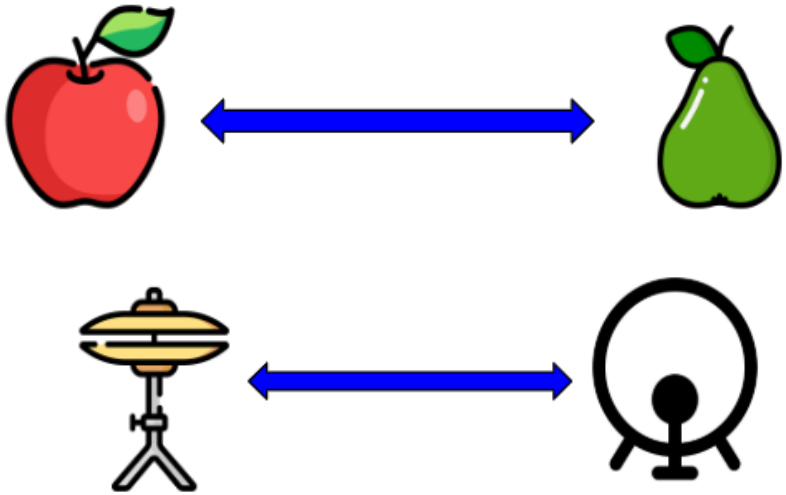
Example: How could you differentiate these two elements?



Feature extraction

- Encode the elements from *Source* as a set of descriptors
- The set must be adequate for the task being modeled

Example: How could you differentiate these two elements?



Must be derived by a computer!

Feature extraction

Representation strategies:

Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation

Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)

Feature extraction

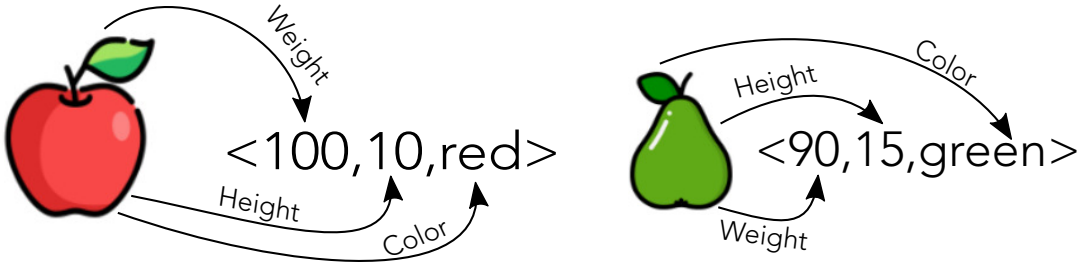
Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features

Feature extraction

Representation strategies:

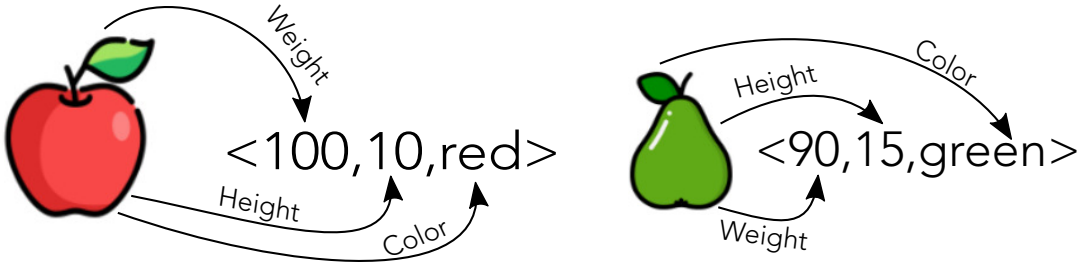
- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features



Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features

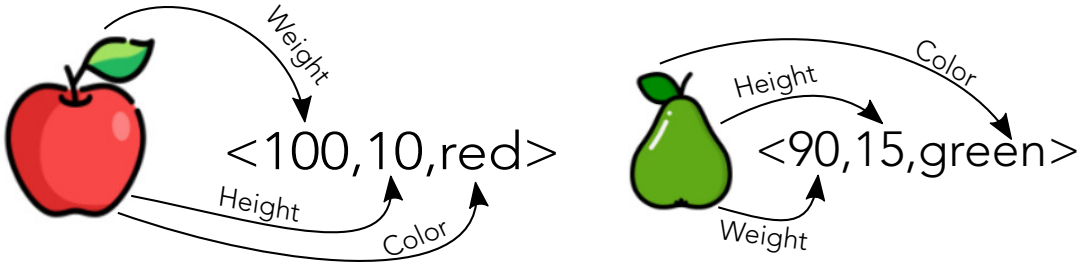


- **Structural** representation

Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features

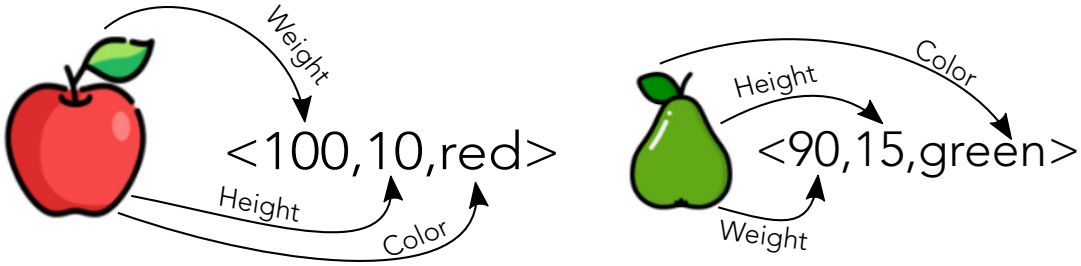


- **Structural** representation
  - Encoding the structure (shape) of the object

Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features

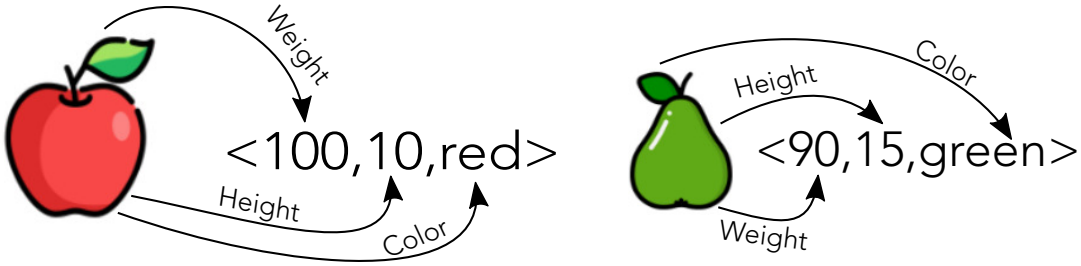


- **Structural** representation
  - Encoding the structure (shape) of the object
  - The *size* of the structure depends on the object

Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features

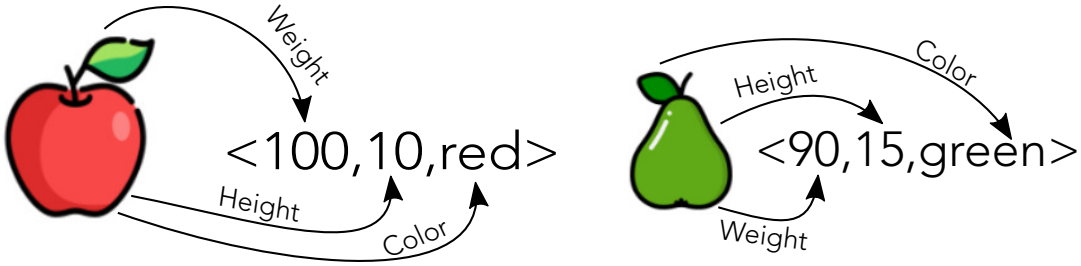


- **Structural** representation
  - Encoding the structure (shape) of the object
  - The *size* of the structure depends on the object
  - Strings, trees, graphs

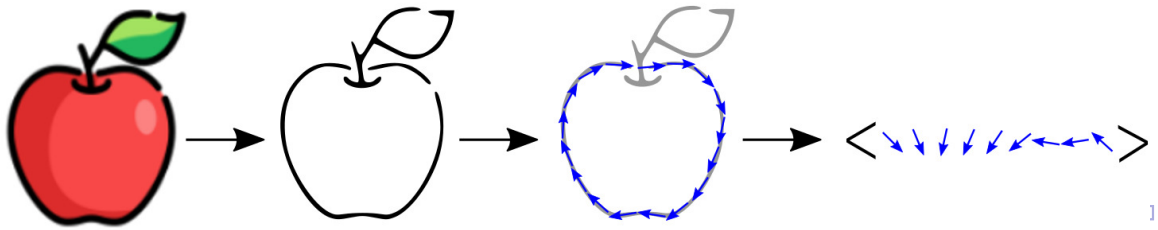
Feature extraction

Representation strategies:

- **Statistical (feature-based)** representation
  - Vector of characteristics (features)
  - All elements have the same number of features



- **Structural** representation
  - Encoding the structure (shape) of the object
  - The *size* of the structure depends on the object
  - Strings, trees, graphs



Feature extraction

Representation strategies:

Strategy	**Representation capabilities**	**Flexibility**
Statistical (feature-based)	Limited	Addressable by (almost) all existing algorithms
Structural	Usually achieve superior performance rates	Limited number of algorithms to process them

Computational learning

How does the model infer knowledge from the (extracted) representations?

Computational learning

How does the model infer knowledge from the (extracted) representations?

Collection of train data

<100,10,red>
<120,12,red>
<110,9,red>
<95,11,red>

<90,15,green>
<80,17,green>
<85,16,green>
<87,15,green>

Computational learning

How does the model infer knowledge from the (extracted) representations?

Collection of train data

<100,10,red>
<120,12,red>
<110,9,red>
<95,11,red>

<90,15,green>
<80,17,green>
<85,16,green>
<87,15,green>

Rule-based approach

If "color" = "red" → 

else → 

Computational learning

How does the model infer knowledge from the (extracted) representations?

Collection of train data

<100,10,red>
<120,12,red>
<110,9,red>
<95,11,red>

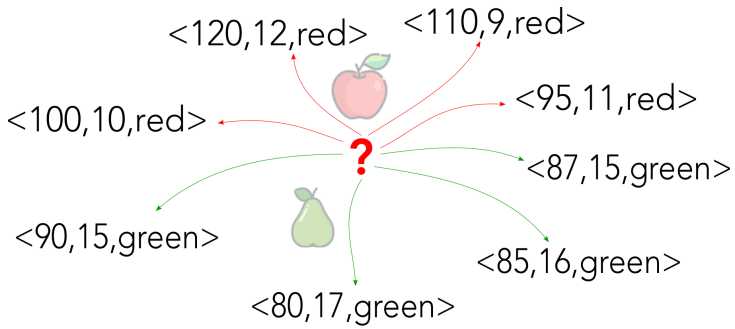
<90,15,green>
<80,17,green>
<85,16,green>
<87,15,green>

Rule-based approach

If "color" = "red" → 

else → 

Distance-based approach



Computational learning

How does the model infer knowledge from the (extracted) representations?

Collection of train data

<100,10,red>
<120,12,red>
<110,9,red>
<95,11,red>

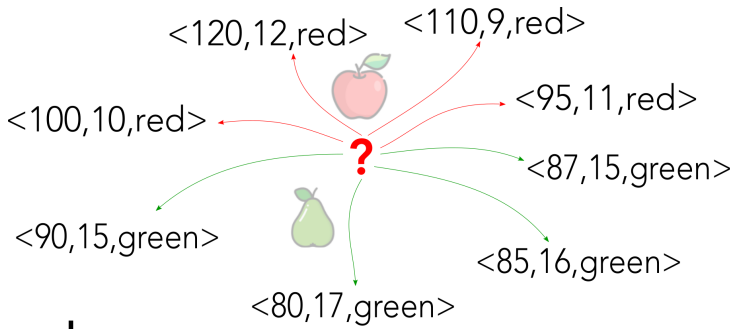
<90,15,green>
<80,17,green>
<85,16,green>
<87,15,green>

Rule-based approach

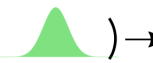
If "color" = "red" → 

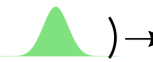
else → 

Distance-based approach



Probabilistic approach

P(?, ) >P(?, ) → 

P(?, ) <P(?, ) → 

Model

What is the model in each case?

Model

What is the model in each case?

- Distance-based approach: Collection of samples stored in a database

Model

What is the model in each case?

- Distance-based approach: Collection of samples stored in a database
- Rule-based approach: Set of rules

Model

What is the model in each case?

- Distance-based approach: Collection of samples stored in a database
- Rule-based approach: Set of rules
- Probabilistic approach: Parameters of a probabilistic distribution