LEARNING

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01/09/2019

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Contents

Learning Agent

What is the Learning Problem?

- Learning is essential for unknown environments, i.e., when designer lacks omniscience
- Learning is useful as a system construction method, i.e., expose the agent to reality rather than trying to write it down
- Learning modifies the agent's decision mechanisms to improve performance

Concept 1 (Mitchell (1997))

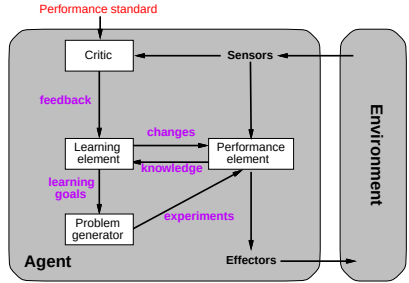
Learning $\equiv$ Improving with experience at some task

- Improve over task T,
- with respect to performance measure P,
- based on experience E.

Forms of Learning

Any component of an agent can be improved by learning from data. The improvements, and the techniques used to make them, depend on four major factors:

- Which *component* is to be improved.
- What *prior knowledge* the agent already has.
- What *representation* is used for the data and the component.
- What *feedback* is available to learn from.



Components to be learned

The components of these agents include:

1. A direct mapping from conditions on the current state to actions.
2. A means to infer relevant properties of the world from the percept sequence.
3. Information about the way the world evolves and about the results of possible actions the agent can take.
4. Utility information indicating the desirability of world states.
5. Action-value information indicating the desirability of actions.
6. Goals that describe classes of states whose achievement maximizes the agent's utility.

Each of these components can be learned.

Representation and prior knowledge

- Representations can be
  - Functions with inputs, a vector of attribute values, and outputs, either a continuous numerical value or a discrete value
  - Functions and prior knowledge composed of first-order logic sentences
  - Bayesian networks

Note

- Deductive learning/teaching:

  General (rule) $\rightarrow$ Specific examples or activities

- Inductive learning/teaching:

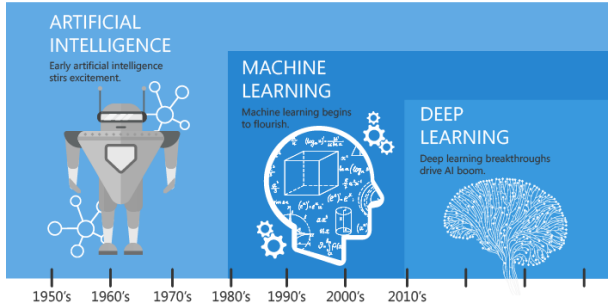
  Specific examples or activities $\rightarrow$ General (rule)

Feedback to learn from

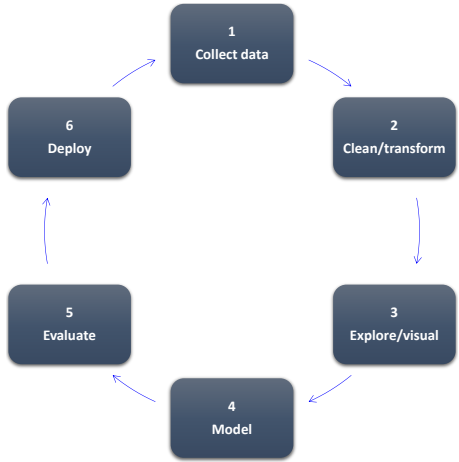
There are three *types of feedback* that determine the three main types of learning:

- In **unsupervised learning** the agent learns patterns in the input even though no explicit feedback is supplied.
- In **reinforcement learning** the agent learns from a series of reinforcements—rewards or punishments.
- In **supervised learning** the agent observes some example input–output pairs and learns a function that maps from input to output.
  - In **semi-supervised learning** we are given a few labeled examples and must make what we can of a large collection of unlabeled examples.

State of The Art



Machine Learning Workflow



Machine Learning Workflow (cont.)

1. Collect available data.
2. Clean and transform that data. If you're collecting data that is missing values, then you need to clean and transform that data until it's in the form machine learning requires.
3. Explore and visualize the data to make sure it is encoding what you expect it to encode.
4. Build a model on training data.
5. Evaluate the model test data.
6. Deploy the model on un-seen data.

Data Objects and Attribute Types

Types of Data Sets

- **Record**
  - Relational records
  - Data matrix: numerical matrix, crosstabs
  - Document data: text documents
  - Transaction data
- **Graph and network**
  - World Wide Web
  - Social or information networks
  - Molecular Structures

Types of Data Sets (cont.)

- **Ordered**
  - Video data: sequence of images
  - Temporal data: time-series
  - Sequential Data: transaction sequences
  - Genetic sequence data
- **Spatial, image and multimedia**
  - Spatial data: maps
  - Image data
  - Video data

Data Objects

Concept 2

- Data sets are made up of data objects.
- **A data object** represents an **entity**, also called samples, examples, instances, data points, objects, tuples.
- Data objects are described by **attributes**.
- Database rows $\rightarrow$ data objects; columns $\rightarrow$ attributes.

Example 1

- sales database: customers, store items, sales
- medical database: patients, treatments
- university database: students, professors, courses

Attributes

Concept 3

Attribute (or dimensions, features, variables): a data field, representing a characteristic or feature of a data object.

Concept 4

Types:

- Nominal
- Binary
- Numeric: quantitative
  - Interval-scaled
  - Ratio-scaled

Attribute Types

- **Nominal**: categories, states, or "names of things"
  - Hair_color = {auburn, black, blond, brown, grey, red, white}
  - marital status, occupation, ID numbers, zip codes
- **Binary**: nominal attribute with only 2 states (0 and 1)
  - Symmetric binary: both outcomes equally important→ e.g., gender
  - Asymmetric binary: outcomes not equally important → e.g., medical test (positive vs. negative)
  - Convention: assign 1 to most important outcome (e.g., HIV positive)
- **Ordinal**: values have a meaningful order (ranking) but magnitude between successive values is not known.
  - Size = {small, medium, large}, grades, army rankings

Numeric Attribute Types

- Quantity (integer or real-valued)
- **Interval**
  - Measured on a scale of equal-sized units
  - Values have order $\rightarrow$ e.g., temperature in C$^\circ$or F$^\circ$, calendar dates
  - No true zero-point
- **Ratio**
  - Inherent zero-point
  - We can speak of values as being an order of magnitude larger than the unit of measurement (10 K$^\circ$ is twice as high as 5 K$^\circ$) $\rightarrow$ e.g., temperature in Kelvin, length, counts, monetary quantities

Discrete vs. Continuous Attributes

- **Discrete Attribute**
  - Has only a finite or countably infinite set of values $\rightarrow$ e.g., zip codes, profession, or the set of words in a collection of documents
  - Sometimes, represented as integer variables
  - Note: Binary attributes are a special case of discrete attributes
- **Continuous Attribute**
  - Has real numbers as attribute values $\rightarrow$ e.g., temperature, height, or weight
  - Practically, real values can only be measured and represented using a finite number of digits
  - Continuous attributes are typically represented as floating-point variables

Pandas

```
import pandas as pd
data = [{'a': 1, 'b': 2},{'a': 5, 'b': 10, 'c': 20}]
df = pd.DataFrame(data, index=['first', 'second'])
print(df)
```

```
        a   b     c
first   1   2   NaN
second  5  10  20.0
```

Data Visualisation

Learning From Examples

Supervised learning

- Given a **training set** of N example input–output pairs

$$D = \{(x_1, y_1), (x_2, y_2) \ldots (x_n, y_n)\}$$

*where each y_j was generated by an unknown function $y = f(x)$, discover a function h that **approximates** the true function f.*

Statistical Learning

Reinforcement Learning

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