Machine Learning

Course synopsis

The course analyzes the general task of extracting information from noisy data pertaining to a physical system, which is viewed as a machine learning problem. In particular, the main focus is centered on supervised learning, where the input-output function of a completely unknown system (black box) has to be reconstructed.

Starting from a proper theoretical analysis of the optimal solution for pattern recognition, classification and regression problems, main approaches proposed in literature are presented, pointing out their characteristics, both in terms of reliability and generality. Only techniques with high practical relevance, whose validity has been extensively verified, are taken into account.

Specifically, besides classical statistical parametric (discriminant analysis) and non parametric (Parzen's windows and nearest neighbor) methods, most promising machine learning techniques, such as neural networks and support vector machines, are examined. Particular attention is devoted to rule generation techniques, capable of expressing the input-output function to be determined as a collection of intelligible rules.

Course Contents

Parte I: Formalization of the machine learning problem

1. **Introduction to general machine learning problem**
    - Scope of machine learning
    - Deductive and inductive reasoning
    - Learning as information extraction from examples
    - White, gray and black box
    - Optimal solution to machine learning problem

2. **Different kinds of machine learning problems**
    - Supervised and unsupervised learning
    - Pattern recognition, classification and regression
    - Formalization of supervised learning problem

3. **Optimal solutions for supervised learning problems**
    - Pattern recognition problem: Bayes classifier
    - Classification problem: generalized Bayes classifier
    - Regression problem: regression function

Parte II: Black-box methods for pattern recognition problems

1. **Classical statistical parametric methods**

    - General principles
    - Linear Discriminant Analysis
    - Quadratic Discriminant Analysis
    - Regularized Discriminant Analysis

2. **Classical statistical nonparametric methods**

    - General principles
    - Parzen windows
    - Nearest-neighbor and case-based reasoning
    - Linear separators: perceptron

3. **Methods based on series expansion: neural networks**

    - General principles
    - Ridge and radial construction
    - Generator function
    - Sigmoidal neural networks and radial basis functions
    - Training a multilayer neural networks

4. **Methods based on series expansion: support vector machines**

    - Optimal hyperplane: primary and dual problem
    - Generalized optimal hyperplane
    - Support vector machines
    - Training support vector machines through linear programming

Parte III: Rule induction methods

1. **Rule extraction methods**

    - Characterization of intelligible rules
    - General principles
    - Taxonomy of rule extraction methods

2. **Rule generation methods: decision trees**

    - General principles
    - Procedure adopted to create a node

- Pruning a decision tree
- Rule set construction

3. **Rule generation methods: Boolean function synthesis**

    - General principles
    - Mapping the input space
    - Boolean function synthesis
    - Rule set construction