The goal of this course is to provide a brief introduction to the theory of artificial neural networks (ANN) and their applications. We review the history of ANN research, cover basic neural network architectures and learning algorithms, and discuss applications in image processing, speech processing, pattern recognition, computer vision, and computational neuroscience. This course has both graduate and undergraduate versions for students in computer science, mathematics, physics, and engineering.

Feedforward neural networks
- Approximation power: Hornik’s theorem, Blum-Li theorem, SgnNet2 is uniformly dense in $L_2$ spaces.
- Perceptron: binary classifier, the perceptron algorithm and its convergence.
- Multilayer perceptron: the backpropagation algorithm.

Statistical physics
- Boltzmann machines: maximum likelihood estimation of Boltzmann machines, applications.

Linear networks
- Neural principle component analysis.
- Neural independent component analysis.

Self-organizing and topological networks
- Self-organizing maps: Kohonen’s SOM algorithm.
- Nonlinear principal component analysis.

Recurrent neural networks
- Recurrent neural network teaching with extended Kalman-filtering.
- Echo state networks: dynamical reservoir, damped dynamics, ESN training.
- Neural Kalman-filter.

Computational neuroscience
- Modeling the Entorhinal-hippocampal (EC-HC) loop.
- Primary visual cortex (V1). Edge detector cells. Independent component analysis.