Neuronal Coding of Sensory Information

Objective: Current and future advanced generations of computational schemes needed to develop intelligent machines and algorithms need a detailed understanding of the brain. The objective of the course is to provide modern knowledge about coding by neural systems in the brain, especially pertaining to sensory information (but not limited to it). Such knowledge will enable engineering students to take up careers in machine learning, deep learning, brain-computer interface development etc with the depth and insight of neuroscientists, which is largely lacking among modern engineers working in the above mentioned fields and many more. The course leads into theories of computational intelligence, which is largely an integration of neuroscience, cognitive science and artificial intelligence. The course is designed to give biological background and quantitative understanding of coding and decoding principles used in the brain. The course will enable students to explore how does the brain process sensory information to produce intelligent behaviour, and how design of intelligent computer algorithms that behave similarly, may be made possible.

Contents:
1) Neuroanatomy of the Sensory Systems
2) Computations, Coding and Representation of Information in the Sensory Pathways
3) Optimal Coding Principles Employed (Evolution?)
4) Neural Mechanisms of Learning
5) Cognitive Neurosciences - Integration of Sensory Information
6) Probabilistic Theories of Cognition

Detailed Syllabus:
Sensory pathways in the brain – biological/neural circuits for vision, audition, somatosensation, olfaction and gustation – transduction to perception based on distributed responses – coding of features in sensory spaces – neural mechanisms, representation in activity of neurons of aspects of sensory stimuli – timing and rate codes – optimal coding and efficient coding principles – aspects of optimal coding in the visual system and auditory system, development of feature maps – principles of learning in sensory circuits – cognitive aspects in coding – decision making, planning, attention and reward based learning – frontal cortical modulation of sensory processing – sensory integration – cognition – probabilistic theories.

Lecture-wise Breakup:
Lecture 1: Introduction: Computational Intelligence, Sensory Systems
Lecture 2-5: Visual System, Encoding and Perception, Biological and Computer Vision
Lecture 6-9: Auditory System, Encoding and Perception
Lecture 10-11: Somatosensation, Encoding and Perception, Pain
Lecture 12: Gustatory coding
Lecture 13-14: Olfactory Encoding, Distributed Codes
Lecture 15-16: Efficient Coding, Optimal Coding, Examples in the Brain
Lecture 17-18: Development of Sensory Circuits
Lecture 19: Cognitive Neurosciences, Overview
Lecture 20-21: Modulation of sensory processing by cognitive demands
Lecture 22-24: Computational theories of Attention, Decision making and Learning
Lecture 25-26: Probabilistic models of Cognition
Lecture 27-28: Project Presentations