SE367: Introduction to Cognitive Science

Ankit Awasthi
Supervised by
Prof. Amitabha Mukerjee
The purpose of this talk is..

- To make you all foam at the mouth with eagerness to read through the references
- More formally, to give you an intuitive feel for the main ideas involved
Learning Algorithms

- Supervised
- Unsupervised
- Reinforcement (Will not be discussed 😞)
- Semi-Supervised (Sometime Later 😊)
Features

• A representation of the input data which facilitates learning.

We will use $X$ for a feature vector
Supervised Learning

- Task: Classify a given image to be of a professor or a student
A feature extraction technique that works

$X = \{ x_1, x_2 \}$

$x_1 = \#$ of grey pixels

$x_2 = \#$ of black pixels

Students: high $x_2$, low $x_1$

Professor: high or low $x_1$, low $x_2$

A better scheme is to use color histograms as features
For Test Images

Depending upon which side of the hyperplane the input lies it is given the label of ‘student’ or ‘professor’

Given our features....where should this one be??
Unsupervised Learning

• **NO** labels!!

Clustering is an important kind of unsupervised learning.

A similarity/dissimilarity measure is needed!!
Any Questions till now?

One or two quick ones only!!
Piaget’s Theory

• Four stages of cognitive development
• First Stage: Sensorimotor Stage ( - 2 years)
  – Circular Reaction
  – Intentionality, Reaching out, Grasping
Workspace vs Configuration Space

• Workspace is a volume of space which the end-effector of the manipulator can reach.

• A configuration describes the pose of the object, and the configuration space C is the set of all possible configurations. Determined by controllable degrees of freedom
Making sense of sensory and motor signals (Saxon and Mukerjee, 1991)

Problem: To come up with a consistent correlation between visual input \((x,y)\) and motor “thoughts” \((\theta_1, \theta_2)\)
Learning the cognitive/position map

- Connections to the self-organising map (SOM) - unsupervised
  \((x, y, \theta_1, \theta_2)\)

  **Winner Take All:** There is one element which best correlates with the input signal. This is called the winner

- A simpler example of SOM
The network is trained in an unsupervised manner with the robot wandering over a subset of the entire configuration space. Here $0<\theta_1<90$, $-135<\theta_2<135$

The network gradually learns to fill in the legal space
Path Planning

• With no obstacle – graph search, spreading activation
  
  A square room with square array of neurons.
  In this example workspace and configuration space are the same.

• With an obstacle – position map is gated by the visual input
  
  Obstacle is introduced in the workspace

- Sensory-Motor Coordinations
  - Locating a stationary targets with movable sensors (take this capability as given for our discussion)
  - Reaching arbitrarily positioned and oriented targets in 3D space with multijoint arms (our concern)
    - Uses self consistency and topography
Circular Reaction

Rendering of the mechanical system used for seeing and grasping as simulated on a graphics workstation
Neural Network in a typical trial
Results

A. Average position errors

B. Average orientation errors
Map Learning using Uninterpreted Sensors and Effectors
(Kuipers and Pierce 1997)

• A mobile robot has to learn
  – Learn the sensory apparatus
  – Learn the motor apparatus (controls for each degree of freedom)
  – Find features which the robot can control
  – Error signals and control laws
Neural Networks

- Perceptron
Second generation neural networks (~1985)

Back-propagate error signal to get derivatives for learning

Compare outputs with correct answer to get error signal
Deep Motivations

• Brains have a deep architecture
• Humans organize their ideas hierarchically, through composition of simpler ideas
• We break-up solutions into multiple levels of abstraction and then compose them to represent more abstract ones
• Unsufficiently deep architectures can be exponentially inefficient
• Deep architectures facilitate feature and sub-feature sharing
Why learn features??

• Minimal hard coded filters are innate
• Hubel Wiesel showed that irreversible damage was produced in kittens by sufficient visual deprivation during the so-called “critical period”
• Avoids different feature extraction schemes for different kinds of input data
• Hypothesis:
  
  Good Reconstruction ==> Good Recognition
Autoencoder (fancy name...huh?)

![Autoencoder Diagram]

- Input
- Hidden Representation
- Reconstructed Input
Training a Deep Autoencoder (stacking autoencoders)
How can you use Deep Learning

- Unsupervised feature learning
- Classification
- Regression
- Can be used with any modality
- With multimodal input to learn hybrid representations
Testimonials (feature learning)
Testimonials (Classification)

• State of the art performance on MNIST data.
• Variants of the algorithm have state of the performance on CIFAR dataset for object classification
Questions or Comments

Hint: Ask those questions you think can be asked in your exams 😊
References

• M Kuperstein, 1988, Neural Model of Adaptive Hand-Eye Coordination, Science
• J. Saxon and A. Mukerjee, 1991, Learning the motor map of a robot arm with neural networks, IJCNN