Class Presentation of CSC481
- Artificial Neural Networks

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Outline

- Problems in classification systems
- Introduction of neural networks
- How to use neural networks
- Applications
- Summary
Classification Systems

<table>
<thead>
<tr>
<th>Observation space</th>
</tr>
</thead>
<tbody>
<tr>
<td>0~255</td>
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<td>0~255</td>
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Mapping Relationship: Statistical classifier, ANN-based classifier

<table>
<thead>
<tr>
<th>Solution space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
</tr>
<tr>
<td>Category ..</td>
</tr>
<tr>
<td>Category …</td>
</tr>
<tr>
<td>Category …</td>
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<tr>
<td>Category …</td>
</tr>
<tr>
<td>Category …</td>
</tr>
<tr>
<td>Category N</td>
</tr>
</tbody>
</table>

Classification Process for Remote Sensing Image

<table>
<thead>
<tr>
<th>Observation space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat TM</td>
</tr>
<tr>
<td>Band1</td>
</tr>
<tr>
<td>Band2</td>
</tr>
<tr>
<td>Band3</td>
</tr>
<tr>
<td>Band4</td>
</tr>
<tr>
<td>Band5</td>
</tr>
<tr>
<td>Band6</td>
</tr>
<tr>
<td>Band7</td>
</tr>
<tr>
<td>0~255</td>
</tr>
<tr>
<td>0~255</td>
</tr>
<tr>
<td>0~255</td>
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<td>Category …</td>
</tr>
<tr>
<td>Category …</td>
</tr>
<tr>
<td>Category …</td>
</tr>
<tr>
<td>Category N</td>
</tr>
<tr>
<td>Water, wetland</td>
</tr>
<tr>
<td>Forest</td>
</tr>
<tr>
<td>Agri.</td>
</tr>
<tr>
<td>Urban</td>
</tr>
<tr>
<td>Residential</td>
</tr>
</tbody>
</table>

(pattern) Category: Forest
Supervised Remote Sensing Image Classification

Statistical Methods

- Need Gaussian (Normal) distribution on the input data which is required by Bayesian classifier.

- Restrictions about the format of input data.
Statistical Methods:

How to find a boundary for the following patterns?

Artificial Neural Network Approach

- No need for normal distribution on input data
- Flexibility on input data format
- Improved classification accuracy
- Robust and reliability
Introduction to Neural Networks
-- Artificial Neural Network Is Defined by ...

• Processing elements
• Organized topological structure
• Training/Learning algorithms

Processing Element (PE)

Artificial counterparts of neurons in a brain
Function of Processing Elements

- Receive outputs from each PEs locate in previous layer.
- Compute the output with a Sigmoid activation function $F(\text{Sum}(O_i \cdot W_{ji}))$
- Transfer the output to all the PEs in next layer

Organized topological structures
ANN Structure
- A multi-layer feedforward NN

Training/Learning Algorithm
- Backpropagation (BP)
Training/Learning Algorithm
Back-propagation Mechanism

• Compute total error

\[ \frac{1}{2} \sum_{p \in P} \sum_n (t^n_p - s^n_p)^2 \]

• Compute the partial derivatives

\[ \frac{\partial E}{\partial w_{ij}} \]

• Update the weights and go to next epoch

\[ W(t+1) = W(t) + \Delta W \]

Back-propagation Mechanism
How to use a neural network

• Analysis the problem domain
• ANN design
  – What structure of ANN to choose
  – What Algorithm to use
  – Input and Output
• Training
• Applying the well-trained neural network to your problem
Pattern Recognition
- Understand the problem

What ANN structure to choose?
- Multi-layer feed-forward

What ANN training algorithm?
- Back-propagation

ANN Design

How many PEs we need - Basic rules in designing an ANN.
- Input layer PEs - by dimension of input vector
- Output layer PEs - by total number of patterns (classes)
ANN Training
- From Pattern to Land Cover Category

Vegetation:
- (10, 89) ----> (1,0,0)
- (11,70) ----> (1,0,0)
- … … … (1,0,0)

Water:
- (10, 21) ----> (0,1,0)
- (15, 32) ----> (0,1,0)
- … … … (0,1,0)

Soil:
- (50, 40) ----> (0,0,1)
- (52, 40) ----> (0,0,1)
- … … … (0,0,1)

A vegetation pixel
(10, 89) ----> (1,0,0)

Feed Forward
Back-Propagate

Pattern --------> Land Cover Category

After Training

A new pixel (x,y), x in band 1, y in band 2

A Well-trained Neural Network
Real-world Applications

• Pattern recognition - Remote sensing image classification
• Banking – credit evaluation
• Stock market data analysis and prediction
ANN Design

What ANN structure to choose? – Multi-layer feed-forward
What ANN training algorithm? – Back-propagation & RPROP
PE in each layer? -- 6 – X – 10

Training and Testing Pattern

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Training Sample Size (pixels)</th>
<th>Testing Sample Size (pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>116</td>
<td>153</td>
</tr>
<tr>
<td>Barren Land</td>
<td>146</td>
<td>125</td>
</tr>
<tr>
<td>Conifer Forest</td>
<td>173</td>
<td>146</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>343</td>
<td>217</td>
</tr>
<tr>
<td>Mixed Forest</td>
<td>265</td>
<td>155</td>
</tr>
<tr>
<td>Brush Land</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Urban Area</td>
<td>287</td>
<td>108</td>
</tr>
<tr>
<td>Water</td>
<td>238</td>
<td>133</td>
</tr>
<tr>
<td>Non-forest Wetland</td>
<td>248</td>
<td>163</td>
</tr>
<tr>
<td>Forest Wetland</td>
<td>52</td>
<td>57</td>
</tr>
<tr>
<td>Total Pixels</td>
<td>1943</td>
<td>1332</td>
</tr>
</tbody>
</table>
Classification Result

Some stats on the classification:
Training: 1943 pixel, ANN structure: 48-350-11, Training time: 5 hours, final error: (100% - 92.7%)
Classification: over 9 Million pixels, takes 6 hours to get the land-cover map.

Classification Result
- A Close Look

Rhode Island 1999 ETM+
Rhode Island 1999 Land-use and Land-cover map
Banking – credit evaluation

• 10 ~ 20 attributes as input
  – Yearly income, marriage status, credit history, residence, children, etc
• Expert to choose typical training data set
• Choose NN structure and training algorithm
  – A dynamic NN structure applied
  – Self-growing algorithm …

Stock market data analysis and prediction – a world full of patterns

• 10 ~ 20 attributes
  – P/E, Weekly Volume, Book Value etc
• Expert to choose training data set
  – Typically upon a certain pattern/theory
• NN structure – this time, it is different, “time” plays an important rule.
NN structure and training algorithm in stock market

- Recurrent network, Generalized neural network
- Normal BP, Conjugate Gradient Method (CG), Quick-Prop

Hopfield Network
(Recurrent network)

Summary

- A Neural Network consists
  - Processing Element (PE)
  - Topological structure
    - Multi-layer feed-forward
  - Training/learning algorithm
    - Back-propagation
  - Numbers of PEs in each layer
Summary – cont.

Basic Back-propagation has the following shortcomings:
• Time-consuming
• Black box - uncontrollable training
• Training result unpredictable

Some reference

• A good starting point
  – Timothy Master’s “Practical neural network Recipes in C++”

Other site:
IEEE Neural Network community
Thank You!