Genetic algorithms and evolutionary programming

- Inspired by the Darwin’s theory of evolution
- A solution is represented as an instance, a “chromosome”.
- Evaluation (fitness) function is required
- Generic optimization techniques.
- Many applications
IndustrialApplication of Fuzzy Logic Control

- Fuzzy Logic Primer
  - History, Current Level and Further Development of Fuzzy Logic Technologies in the U.S., Japan, and Europe
  - Types of Uncertainty and the Modeling of Uncertainty
  - The Basic Elements of a Fuzzy Logic System
  - Types of Fuzzy Logic Controllers
History, State of the Art, and Future Development

- 1965 Seminal Paper "Fuzzy Logic" by Prof. Lotfi Zadeh, Faculty in Electrical Engineering, U.C. Berkeley, Sets the Foundation of the "Fuzzy Set Theory"
- 1970 First Application of Fuzzy Logic in Control Engineering (Europe)
- 1975 Introduction of Fuzzy Logic in Japan
- 1980 Empirical Verification of Fuzzy Logic in Europe
- 1985 Broad Application of Fuzzy Logic in Japan
- 1990 Broad Application of Fuzzy Logic in Europe
- 1995 Broad Application of Fuzzy Logic in the U.S.
Types of Uncertainty and the Modeling of Uncertainty

• Stochastic Uncertainty:
  • The Probability of Hitting the Target Is 0.8

• Lexical Uncertainty:
  • "Tall Men", "Hot Days", or "Stable Currencies"
  • We Will Probably Have a Successful Business Year.
  • The Experience of Expert A Shows That B Is Likely to Occur. However, Expert C Is Convinced This Is Not True.
– University of Otago, September 22, 1999
INTELLIGENT SYSTEMS FOR A KNOWLEDGE-BASED SOCIETY Prof. Nikola Kasabov Department of Information Science University of Otago
nkasabov@otago.ac.nz
What is a Knowledge-based Society?

- The society is knowledge-, not commodity- driven
- Intellectual achievements are highly ranked
- Global connectivity
- Global Market
- Creating, using, and trading information and knowledge.
The World of Information: Information and knowledge

- Data, information and knowledge
- The “macro” world of information:
  - medical and health information
  - business and economic information
  - geographic information
  - etc.
- The “micro” world of information:
  - the brain
  - genetic information
  - quantum information
- Exponential information increase with time
- Transforming information into knowledge, managing and utilizing it is the major challenge for a KB society.
**Information Science**

- The area of science that develops methods and systems for information and knowledge processing regardless of the domain area.
- The Information Science subject areas
- The emergence of Information Sciences
- Information Sciences versus Information Technologies.
- Information AND Computer Science.
Artificial Intelligence and Knowledge Engineering

- What defines intelligence?
  - Learning and adaptation
  - Generalisation
  - Knowledge acquisition and processing
  - Reasoning
  - Problem solving and decision making
  - Using language
  - Multi-modal communication: speech, vision, etc.
  - Creativity
  - etc.
Artificial Intelligence (AI)

- Some AI methods are inspired by the way the human brain works - ‘brain-like computing’
- AI also develops and applies its own methods and principles
- Often AI methods combine the two approaches
Symbolic AI systems

- Logic systems, e.g. propositional logic (Aristotle, 4th century BC)
- Rule-based systems that use IF-THEN rules
- Expert systems
- Rule-based systems are universal computational mechanisms but they only use two categories: true and false.
What is Fuzzy Logic?

- In traditional logic, statements can be either true or false, and sets can either contain an element or not.
- These logic values and set memberships are typically represented with number 1 and 0.
- Fuzzy logic generalizes traditional logic by allowing statements to be somewhat true, partially true, etc.
- Likewise, sets can have full members, partial members, and so on.
- For example, a person whose height is 5’9” might be assigned a membership of 0.6 in the fuzzy set “tall people”.
- The statement “Joe is tall” is 60% true of Joe is 5’9”.
- Fuzzy logic is a set of “if--then” statements based on combining fuzzy sets. (Beale & Demuth..Fuzzy Systems Toolbox.)
Fuzzy Sets, Statements, and Rules

- A crisp set is simply a collection of objects taken from the universe of objects.
- Fuzzy refers to linguistic uncertainty, like the word “tall”.
- Fuzzy sets allow objects to have membership in more than one set (e.g. 6’ 0”) has grade 70% in the set “tall” and grade 40% in the set “medium”.
- A fuzzy statement describes the grade of a fuzzy variable with an expression (e.g. Pick a real number greater than 3 and less than 8.)
Fuzzy Logic Control

• Fuzzy controller design consist of turning intuitions, and any other information about how to control a system, into set of rules.

• These rules can then be applied to the system.

• If the rules adequately control the system, the design work is done.

• If the rules are inadequate, the way they fail provides information to change the rules.
Example 1
Container Crane Case Study
Basic Elements of a Fuzzy Logic System

Container Crane Case Study:

- Ship
- Container
- Crane head
- Troller
### Fuzzy Set Definitions

**Discrete Definition:**

<table>
<thead>
<tr>
<th>Temperature °F</th>
<th>Membership Function μₗ(X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>μₗ(X) = 0</td>
</tr>
<tr>
<td>37</td>
<td>μₗ(X) = 0</td>
</tr>
<tr>
<td>38</td>
<td>μₗ(X) = 0.1</td>
</tr>
<tr>
<td>39</td>
<td>μₗ(X) = 0.35</td>
</tr>
<tr>
<td>40</td>
<td>μₗ(X) = 0.65</td>
</tr>
<tr>
<td>41</td>
<td>μₗ(X) = 0.9</td>
</tr>
<tr>
<td>42</td>
<td>μₗ(X) = 1</td>
</tr>
<tr>
<td>43</td>
<td>μₗ(X) = 1</td>
</tr>
</tbody>
</table>

**Continuous Definition:**

![Graph showing gradual increase in membership function μ(X) as temperature increases]
Linguistic Variable

- Terms, Degree of Membership, Membership Function, Base Variable...
Basic Elements of a Fuzzy Logic System

- Fuzzification, Fuzzy Inference, Defuzzification
Basic Elements of a Fuzzy Logic System

- Control Loop of the Fuzzy Logic Controlled Container Crane:
1. Fuzzification: - Linguistic Variables -

Term Definitions:
Distance := \{far, medium, close, zero, neg_close\}
Angle := \{pos_big, pos_small, zero, neg_small, neg_big\}
Power := \{pos_high, pos_medium, zero, neg_medium, neg_high\}

Membership Function Definition:
2. **Fuzzy Inference:** “IF-THEN-ELSE” Rules

**Computation of the “IF-THEN”-Rules:**

#1: IF Distance = medium AND Angle = pos_small THEN Power = pos_medium

#2: IF Distance = medium AND Angle = zero THEN Power = zero

#3: IF Distance = far AND Angle = zero THEN Power = pos_medium

- Aggregation: Computing the “IF”-Part
- Composition: Computing the “THEN”-Part
2. Fuzzy Inference: - Aggregation -

<table>
<thead>
<tr>
<th>Boolean Logic Only</th>
<th>Fuzzy Logic Delivers a Continuous Extension:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defines Operators for 0/1:</td>
<td>* AND: $\mu_{A^\land B} = \min{\mu_A; \mu_B}$</td>
</tr>
<tr>
<td></td>
<td>* OR: $\mu_{A\lor B} = \max{\mu_A; \mu_B}$</td>
</tr>
<tr>
<td></td>
<td>* NOT: $\mu_{\neg A} = 1 - \mu_A$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A^\land B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Aggregation of the “IF”-Part:

#1: $\min\{0.9, 0.8\} = 0.8$

#2: $\min\{0.9, 0.2\} = 0.2$

#3: $\min\{0.1, 0.2\} = 0.1$
2. Fuzzy-Inference: Composition

- Result for the Linguistic Variable “Power”:

<table>
<thead>
<tr>
<th>Term</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>pos_high</td>
<td>0.0</td>
</tr>
<tr>
<td>pos_medium</td>
<td>0.8</td>
</tr>
<tr>
<td>zero</td>
<td>0.2</td>
</tr>
<tr>
<td>neg_medium</td>
<td>0.0</td>
</tr>
<tr>
<td>neg_high</td>
<td>0.0</td>
</tr>
</tbody>
</table>

\[ = \max\{0.8, 0.1\}\]
3. Defuzzification

- Finding a Compromise Using “Center-of-Maximum”:

![Graph showing defuzzification process with membership functions and a compromise value of 6.4 kW.](image)
Example 2

Neuro-Fuzzy Inverted Pendulum Control System
Introduction to Pendulum

- Inverted Pendulum Problem
- Neural Network Architecture
- Fuzzy Logic Target Generator
- Balance the Inverted Pendulum
- Conclusion
Inverted Pendulum System

- State Variables
  
  \[
  \begin{pmatrix}
  \theta \\
  \dot{\theta} \\
  x \\
  \dot{x}
  \end{pmatrix}
  \]

- Dynamic Equations

\[
\begin{align*}
\ddot{x} + m \left[ g \cos \theta - \dot{\phi} \sin \theta \right] \\
\frac{(M+m)g \sin \theta - \cos \theta (f + m \dot{x}^2 \sin \theta)}{\sqrt{(M+m)^2 - m x^2}}
\end{align*}
\]
Neural Network Architecture

- Two Architectures
  - Regular Neurons
  - Linear Combination at output layer
- Back-Propagation Algorithm
- Batch Training
Fuzzy Logic Target Generator

- Singleton Fuzzifier
- Mamdani Max-min Inference Engine
- Centroid of Area Defuzzifier
Balance the Inverted Pendulum
Conclusion on Applying Fuzzy Logic to Inverted Pendulum

- ANN can solve this problem efficiently
- Advantage of Fuzzy Logic Target Generator (FTLG)
- Further Studying
  - Optimize FLTG using another ANN
  - 3-D Inverted Pendulum Problem
Example 3

Neural Net

versus

Fuzzy Logic
Neural Versus Fuzzy

- **Recap**: Neural Networks
- What is Fuzzy Logic?
- Fuzzy Sets, Statements, and Rules
- Fuzzy Logic Control
- Used in Expert System and Decision Systems
Neural Networks

- the problem of knowledge acquisition bottleneck
- computers with architectures and processing capabilities that simulate the human brain
- features
  - knowledge representations based on massively parallel processing
  - fast retrieval of large amounts of information
  - ability to recognize patterns based on experience
Artificial Neural Networks (ANN)

• model that emulates a biological neural network
• consists of
  – processing elements or neurons; each receives an input, provides processing, produces output
  – neurons are grouped together in layers
  – several topologies possible
Artificial neural networks (ANN) – (connectionist systems)

- Computational models that mimic the nervous system in its main function of adaptive learning.
- ANN are universal computational models
  - ANN could learn to “speak” (e.g. NetTalk by T. Sejnowsky) or to do some other intelligent tasks
  - Limitations
ANN Elements

Inputs

X1

X2

X3

X4

Weights

W1

W2

W3

W4

Summation (weighted)

Transfer

Output (Y)

Processing Element
Recap: A Layered Neural Network

\[ i = w_1 \ast p \]
\[ j = F(i) \]
\[ k = w_2 \ast j \]
\[ a = F(k) \]
Recap: Recursive Neural Networks for Dynamic Simulation and Model Predictive Control
Elements of an ANN

- **inputs**: each corresponds to one attribute
- **output**: correspond to the solution to the problem
- **weights**: relative strength of the initial entering data or the various connections that transfer data from one layer to another
- **summation function**: weighted sum of all input elements entering each PE
- **transfer function**: relationship between internal state and output
Learning in an ANN

- **Three tasks:**
  - compute outputs
  - compare output with desired target
  - adjust weights and repeat

- **Learning algorithms:** minimizing delta
  - discrete and continuous
    - type of input data
  - supervised and unsupervised
    - uses inputs for which desired outputs are known
    - only input stimuli shown; self-organizing
Building an ANN

- design choices
  - size of training and test data
  - learning algorithms
  - network topology: number of PE’s, their configuration
  - transfer function to be used
  - learning rate for each layer
  - diagnostic and validation tools
ANN Application Areas

• in marketing
  – unsolicited catalogs to physicians and dentists
  – on purchase, name added to customer db
  – the problem: dormants and how to assign telemarketing time
  – inputs: stat and demographic data; output: rating for each customer

• in stock market prediction
  – input data: economic data
  – output: TOPIX buying and selling timing
ANN and ES

- resource requirements advisor
  - analyzes experiential data in amount of time and effort required to complete previous database projects
- personnel requirements advisor
  - projects personnel resource reqmts. for maintaining networks & workstations at NASA
- diagnosis of airline malfunction
  - critical piece of avionic equipment; Singapore airlines
ANN, Fuzzy, ES

ANN

Fuzzy

ES

Fuzzy logic to create NN
NN compiled to Fuzzy logic
Fuzzy Logic

• Representation of descriptive or qualitative variables
• Supports gradual transition between variable values
• Mathematical foundation
  – Degree of set membership
• Not the same as probability
Fuzzy Logic in Rule Based Systems (RBS)

- production rule not “fired” until antecedent condition is met
- fuzzy RBS: all rules executed in each pass with variable strengths
- if antecedent fuzzy proposition is satisfied very well, result matches consequent of rule
- if antecedent fuzzy proposition only partially satisfied, assertion resembles consequent, but only “vaguely”
Benefits of Fuzzy Logic

• provide flexibility and more options: matches human reasoning
• allows for observation and avoids “literal minded” computers
• can be combined with more “exact” schemes
Fuzzy Logic

- Fuzzy logic is an extension of propositional logic (L. Zadeh, 1965)

Fuzzy propositions can have truth values between true (1) and false (0), e.g. the proposition “washing time is short” is true to a degree of 0.8 if the time is 4.9 min.

Fuzzy rules represent human knowledge, e.g. “IF wash load is small THEN washing time is short”
Fuzzy systems

- Fuzzy systems contain fuzzy rules and fuzzy reasoning mechanism
- Fuzzy systems are robust to changes in the conditions
- Balancing a pole on a cart with a live mouse on top of it
Health Monitoring Applications
Example 4: Hybrid neuro-fuzzy- genetic systems
Hybrid neuro- fuzzy- genetic systems

- Combine the strengths of different AI techniques
- FuNN - developed in KEL
- Learning from data
- Rule representation:
  - R1: IF $x_1$ is $A_1(DI_{11})$ and $x_2$ is $B_1(DI_{21})$ THEN $y$ is $C_1(CF_{1})$,
  - R2: IF $x_1$ is $A_2(DI_{12})$ and $x_2$ is $B_2(DI_{22})$ THEN $y$ is $C_2(CF_{2})$. 
Real values input layer

Condition elements layer (S, a, O)

Rule layer (S, a, O)

Action elements layer (S, a, O)

Real-values output layer (S, a, O)

---

Diagram:

- **Nodes (A, B, C, D, E, F)**
- **Connections:
  - Preset connections
  - Initial value is zero
  - Optimal connection

- Inputs (X1, X2)
- Outputs (R1, R2, S1, S2)
Soft Computing and other AI paradigms

- Soft Computing
- Case-based reasoning
- Data mining
- Cellular automata
- Intelligent distributed systems
- Intelligent agent-based systems
- Artificial life
- Virtual reality
- Emerging computing and AI paradigms: brain computers; DNA computing; evolving systems
Evolving Connectionist Systems (ECOS) – a New AI Paradigm?

- ECOS are systems that:
  - do “life-long” learning from data
  - learn through interaction with the environment
  - create and evolve their own algorithm based on the data that has been presented to them
  - are self-programmable systems
ECOS applied to a benchmark data
Systems that learn to recognize speech and languages

- The Otago Speech Database of NZ English and Maori
- Bilingual English and Maori Web dictionaries
- Voice recognition in a noisy environment
- Computer modeling of speech and language acquisition
- Multi-modal systems (using both auditory and visual information)
Systems that learn to recognise patterns in images
Systems that discover genes in DNA

- ANN are used:
  - to identify genes in DNA
  - to identify exon/intron splice junctions in mRNA
Interactive robots that learn

- Continuous learning of the environment
- Interactive communication in a spoken language
- Rokel - an experimental robot at KEL
Decision support systems that learn from economic and financial data

- Information is collected from the Internet
- Trends in economic development are found
- Clusters of countries whose economic performance is similar are indicated
Intelligent systems in horticulture
Intelligent systems for the analysis of Chaotic Time Series

- Medical data: heart rate variability
- Financial data: SE40
- Environmental data: waste water flow
Systems that learn from geographic data
Necessity of Sign Language Recognition

Research for Intelligent System
- Implementing expert knowledge
- Management vagueness in linguistic information

Rehabilitation for Hearing Disabled Person
- KSL Recognition System + Sign Language Interpretation System
- Text to Sign Generation System

Systematic Approach to Gesture Recognition
- Gesticulation → Language-like Gesture
- Pantomimes → Emblems → Sign Languages
• Gesticulation
  » Language-like Gesture
  » Pantomimes
  » Sign Languages
  » Emblems
• Implementing expert knowledge
• Management vagueness in linguistic information
  » Sign Language
  » Interpretation System
• KSL Recognition System +
• Text to Sign Generation System
  » Necessity of Sign Language Recognition
EXAMPLE 5

Autopilot : Performance Tuning in Distributed Computing Environments
Pablo and Autopilot: Performance Tuning in Distributed Computing Environments

- Pablo Research Group
- Department of Computer Science
- University of Illinois at Urbana-Champaign
- http://www-pablo.cs.uiuc.edu
Autopilot Toolkit

- Provides a framework for the capture and analysis of real-time application and infrastructure data in a multi-threaded distributed environment
- Offers the ability to control volume of performance data through
  - selective registration and property matching
  - analysis and data reduction at point of collection
  - constant, periodic, or on-demand transmission of data
  - ability to dynamically enable/disable data collection
- Includes a control interface to allow steering of infrastructure policies and applications, either interactively or via automated decision procedures
Basic Autopilot Concepts

• Sensors: provide data to remote processes, allowing real-time monitoring
  • intrinsic (procedural - push)
  • extrinsic (threaded - push)
  • transfer data when requested by remote process (pull)

• Sensor Attached Functions: transform sensed data via user-defined functions before it is recorded by the sensor, providing an important data-reduction technique
Basic Autopilot Concepts

• Actuators: provide remote processes the ability to invoke local functions or update data, allowing remote steering
  • synchronous (application controls when updates are made; requests may be held in pending buffer)
  • asynchronous (updates are made when request received from external agent)

• Properties: key-value pairs that are associated with and used to identify a sensor or actuator, allowing remote processes to be selective about the sensors and actuators they connect to
Basic Autopilot Concepts

- Sensor Client: a process that connects to one or more sensors with matching properties and receives data from those sensors
- Actuator Client: a process that connects to one or more actuators with matching properties and sends data to those actuators, causing application variables controlled by the actuators to be updated or functions to be invoked
Basic Autopilot Concepts

• Autopilot Manager: a daemon process that is responsible for handling registration requests from sensors and actuators, and matching sensor client and actuator client requests to registered sensors and actuators.

  • AutopilotManager daemons may be run on multiple hosts throughout the computational grid, allowing sensors, actuators, and clients to tailor data transfer volumes to appropriate levels for local and distant tasks.
Tagged Sensors, Actuators, Clients

• Information about the structure of the data is forwarded when a client first connects to a matching sensor or actuator, allowing the client to perform verification checks and ignore unwanted data.

• Tagged data sets map naturally into what we normally think of as event trace records.

• Sometimes called “SDDF-enabled” because the buffer contents can easily be translated to SDDF
Autopilot and Nexus/Globus

- Autopilot uses the Nexus component of the Globus toolkit (http://www-globus.org) to provide...
  - communication substrate & multithreading capabilities
- Nexus creates a global address space that encompasses all processes executing on a distributed network
- Nexus Remote Service Requests (RSRs) used by Autopilot classes to transmit messages, insuring optimal underlying transfer protocol
- Nexus multi-threaded handlers used by Autopilot classes to process RSRs
- Most Nexus details hidden by Autopilot classes
Autopilot Component Interactions

1. sensors and actuators register with their properties
2. clients request matching sensors and actuators
3. global pointers returned for matches
4. sensor and actuator controls and actuator data
5. sensor data
Instrumented Tasks

- May contain multiple sensors and/or actuators
- Many instrumented tasks may be active at any given time
- May register sensors and actuators with multiple Autopilot Managers running on different hosts
Monitor/Control Tasks

• May contain multiple sensor clients and/or actuator clients

• Many monitor/control tasks may be active at any given time

• May query multiple Autopilot Managers running on different hosts

• May implement “human in the loop” (Autodriver, Virtue) or automated fuzzy logic decision server (PPFS II)

• May be monitor only, writing collected data to a file or displaying it
Fuzzy Logic Rationale

• Humans rely on qualitative rules
  • If the system is BUSY, backups should be POSTPONED
• Fuzzy logic expresses these rules formally
  • Elegantly integrates qualitative data
  • prefetch for small, sequential, read only requests
  • Supports conflicting goals
  • Processes “gray” statements
• Well-developed theory and software base
Fuzzy Variables: Degrees of Truth

The diagram illustrates the relationship between luminance range, fuzzy variable truth value, and degrees of lightness. The x-axis represents the luminance range from 1 to 256, with three identified levels: Dark, Dim, and Light. The y-axis shows the fuzzy variable truth value ranging from 0 to 1. The graph depicts how different luminance levels correspond to varying degrees of truth in the fuzzy system.
Fuzzy Controller Structure

- **Fuzzifier**
  - scales and maps input variables to fuzzy sets

- **Inference mechanism**
  - approximate reasoning block
  - deduces the control action
  - Compositional Rule of Inference (CRI)

- **Defuzzifier**
  - converts fuzzy outputs into control signals
  - several defuzzification methods
Fuzzy Logic Decision Infrastructure

Monitor/Control Task(s)
- Knowledge Repository
- Fuzzy Logic Rule Base

Fuzzy Logic Decision Process

Defuzzifier

Outputs

Inputs

Fuzzifier

Sensors

System

Actuators

Instrumented Task(s)
Fuzzy Inference Process

• Interpreting an IF-THEN rule
  • evaluate the antecedent (fuzzify inputs)
  • apply the result to the consequent
  • if the antecedent (premise) is true to some degree then the consequent is true to the same degree

• Multiple rules active for the same input
  • multiple outputs combined
  • combination can yield complex behavior

• Defuzzification yields final output(s)
Adaptive File Striping Example

- Files striped across disks based on utilization
- disk parallelism is intra-request disk stripe count
- if the system is highly utilized
- decrease individual request parallelism
- this decreases contention
- if the system is under utilized
- increase individual request parallelism
- this increases throughput
Fuzzy Rule Set Example

- if (Utilization == LOW)
  - {DiskParallelism = HighPar;}
- if (Utilization == MEDIUM)
  - {DiskParallelism = MediumPar;}
- if (Utilization == HIGH)
  - {DiskParallelism = LowPar;}
- One can also associate certainties with rules!
Fuzzy Variable Definitions

rulebase StripingRB;

var Utilization(0,100) {
set trapez LOW (0, 25, 0, 25);
set triangle MEDIUM (50, 25, 25);
set trapez HIGH (75, 100, 25, 0);
}

var DiskParallelism(0,64) {
set triangle LowPar ( 0, 0, 32);
set triangle MediumPar (32, 32, 32);
set triangle HighPar (64, 32, 0);
}
Fuzzy Variables (Membership)

- The truth of any statement is a matter of degree
- Membership function is the curve that defines how true a given statement is for a given input value
Fuzzification Process

Utilization = 37.5
LOW 2 0.5
MEDIUM 2 0.5
HIGH 2 0

Utilization

\( u(x) \)

LOW       MEDIUM       HIGH

\( 0 \)        \( 50 \)        \( 100 \)
if (Utilization == LOW)
    {DiskParallelism = HighPar;}
    LOW has truth value = .5

if (Utilization == MEDIUM)
    {DiskParallelism = MediumPar;}
    MEDIUM has truth value = .5

if (Utilization == HIGH)
    {DiskParallelism = LowPar;}
    HIGH has truth value = 0
Fuzzy Composition

Disk Parallelism

HighPar

MediumPar

LowPar

Maximum

Bounded Sum
Defuzzification

- Defuzzification methods
  - center of gravity
  - first maximum
  - mean of maxima

\[
\text{center of gravity} = \frac{\int \mu(x) \, dx}{\int x \, dx}
\]
Decision Infrastructure Summary

- Autopilot sensors provide streams of measurements. After fuzzification, these streams define the values of the input fuzzy variables.
- Rules whose conditions are non-zero all contribute to determining the value of the output fuzzy variables. After defuzzification, the value of the output fuzzy variables define the actions taken by the Autopilot actuators.
- Fuzzy logic handles noisy data and conflicting goals.
- Fuzzy logic separates data sets (definition of fuzzy variables) and rules (assertions and consequents) allowing each to be independently adjusted for a particular computing environment without re-coding the decision procedure.
Autodriver Monitor and Control Architecture

- Autodriver Monitor and Control
- Autodriver
  - Java GUI
- Instrumented Task
- Autopilot Manager
- Autopilot - Autopilot Adapter Task
  - Java Remote Method Invocation
  - Unix
Example 6

Prediction of Customer’s Response to Advertisement
So how might you do better?

- Build STATISTICAL models to predict response?
- **YES but** its simultaneously
  - complex
  - non automated
  - hard to build
  - even harder to explain
  - highly assumption dependent
  - performance is questionable
Use a Neural Network

- Often more accurate than a statistical model
- Easier to apply
- Insensitive to data noise
- Highly non-linear
- Has few assumptions
- Offers good levels of performance

Easy to describe but impossible to explain WHAT the model is
BUT
YOU should now be seriously considering greater use of Neural Networks embed them in a statistical research design
Genetic Programming and Evolutionary Computing Targeters

- Offers prospect of even BETTER levels of performance than Neural Networks
- It's more FLEXIBLE technology
- Highly adaptive

**BUT** it may require High Performance Computing to get the best results
High Performance Computing

- Highly parallel computers offer vast amounts of computational power.
- Leading edge machines will soon reach teraflop speeds with hundreds of gigabytes of RAM.
  - e.g. a 50,000 times faster than a PC.
BUT
How many of **YOU** are either already **USING** or **PLANNING** to use **High Performance Computers**?
NO...

- The aim is not just to make existing methods go 1,000's of times faster

- It is to **EXPLOIT the NEW OPPORTUNITIES** that HPC provides YOU with for doing database marketing in a more computationally orientated and machine intelligent manner
Fuzzy Logic Modeling is also worth considering!

- As good as neural networks
- Unlike neural networks it can incorporate your knowledge, skills, and marketing experience and intuition
- Easy to apply
- The results can be described in Plain English
An Example

■ You want to mail clients who meet the following criteria:
  - middle aged
  - recent customers

■ You can convert these linguistic statements into a mathematical prediction model

■ You can optimize performance subsequently
An Example

- You want to mail clients who meet the following criteria.
  - middle aged
  - recent customers
- You can convert these linguistic statements into a mathematical prediction model
- You can optimize performance subsequently
A Case Study

- Model a database of several million customers
  - A simple Fuzzy Logic Model achieved an accuracy level of 46%
  - A Genetic Algorithm optimized version of the same FLM achieved 85%
Fuzzy Logic Model based Segmentation

- If you then applied this FLM to mail 50,000 best prospects you would achieve a response rate of **25%**

- Not quite as good as before but this reflects:
  - use of only 3 variables
  - no search for good variables
  - a desire for an easily explanation
  - still 5 times better than a standard geodemographics
What Else?

- What about an Exemplar Machine Learning technique?
- On previous example it achieved an accuracy of over 85% after seeing a random sample of only 550 cases.
- Yet, it is
  - fully automated
  - works well with very low response rates
Building Intelligent Hybrid Computational (Marketing) Systems

- Need to think in terms of intelligent adaptive database marketing systems that incorporate feedback loops

- Intelligence isn’t just due to the use of individual AI tools, it needs to be built into the design of the marketing process itself
Summary

- Fuzzy logic captures intuitive, human expressions.
- Fuzzy sets, statements, and rules are the basis of control.
- The technique is extremely powerful, and appears in mills at a growing rate.
- Many mixtures possible
- Many systems practically used in various applications