

8 List of Figures

Figure 1: Prof. Lotfi. A. Zadeh. (adapted from <http://www-bisc.eecs.berkeley.edu>)

Figure 2: What does Soft Computing mean? (adapted from <http://modo.ugr.es>)

Figure 3: Fuzzy set representation.

Figure 4: Graphical representation of crisp sets

Figure 5: Graphical representation of the analytical representation given above

Figure 6: Fuzzy sets A and B

Figure 7: Fuzzy Complement

Figure 8: Fuzzy Union

Figure 9: Fuzzy Intersection

Figure 10: Example of fuzzy addition and subtraction

Figure 11: The first step is to take the crisp inputs (adapted from <http://www.4c.ucc.ie>).

Figure 12: Mamdani rule evaluation (adapted from <http://www.4c.ucc.ie>).

Figure 13: Clipping and scaling (adapted from <http://www.4c.ucc.ie>).

Figure 14: Aggregation of rule outputs (adapted from <http://www.4c.ucc.ie>).

Figure 15: Centre of gravity (COG) (adapted from <http://www.4c.ucc.ie>).

Figure 16: Sugeno-style rule evaluation (adapted from <http://www.4c.ucc.ie>).

Figure 17: Sugeno-style aggregation (adapted from <http://www.4c.ucc.ie>).

Figure 18: Sugeno-style defuzzification (adapted from <http://www.4c.ucc.ie>).

Figure 19: Components of a fuzzy system (adapted from <http://www.atp.ruhr-uni-bochum.de>).

Figure 20: Basic structure of a fuzzy controller (adapted from <http://www.atp.ruhr-uni-bochum.de>).

Figure 21: Air motor speed controller. Temperature (input) and speed (output) are fuzzy variables used in the set of rules (adapted from <http://www.data-machine.nl/fuzzy1.htm>).

Figure 22: The temperature of 22 deg. “fires” two fuzzy rules. The resulting fuzzy value for air motor speed is defuzzified (adapted from <http://www.data-machine.nl/fuzzy1.htm>).

Figure 23: Prototype membership functions for a fuzzy set with seven linguistic terms (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 24: Nonlinear characteristic of a fuzzy controller
(adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 25: Membership functions and static characteristic of the fuzzy controller
(adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 26: Influence of the (c) characteristic of a proportional fuzzy controller (a) without overlapping in the input membership functions and (b) with full overlapping in the output membership functions (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 27: Influence on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and (b) full overlap in the output membership functions (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 28: Influence on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and with (b) reduced support in the output membership functions (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 29: Influence on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and with (b) reduced support in the output membership functions (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 30: Influence on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and with (b) a small support in the output membership function AZ (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 31: Influence on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and with (b) a large support in the output membership function AZ (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 32: Influence on the rule base on the (c) characteristic of a proportional fuzzy controller with (a) full overlap in the input membership functions and (b) full overlap in the output membership functions (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 33: Control system with PD-type fuzzy controller: (a) block diagram and (b) 3D representation of the characteristics of the fuzzy system with $e1 = e$ and $e2 = e'$ (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 34: View of a portal-type loading crane (adapted from <http://www.atp.ruhr-uni-bochum.de>)

Figure 35: Problem solution using evolutionary algorithms (adapted from <http://jpmc.sourceforge.net>)

ie business school

#1 EUROPEAN BUSINESS SCHOOL
FINANCIAL TIMES 2013

#gobeyond

MASTER IN MANAGEMENT

Because achieving your dreams is your greatest challenge. IE Business School's Master in Management taught in English, Spanish or bilingually, trains young high performance professionals at the beginning of their career through an innovative and stimulating program that will help them reach their full potential.

- Choose your area of specialization.
- Customize your master through the different options offered.
- Global Immersion Weeks in locations such as London, Silicon Valley or Shanghai.

Because you change, we change with you.

www.ie.edu/master-management | mim.admissions@ie.edu |



- Figure 36: Structure of a single population evolutionary algorithm (adapted from www.sciencedirect.com)
- Figure 37: Roulette-wheel selection (adapted from <http://www.geatbx.com/>)
- Figure 38: Stochastic universal sampling (adapted from <http://www.geatbx.com/>)
- Figure 39: Linear neighbourhood: full and half ring (adapted from <http://www.geatbx.com/>)
- Figure 40: Two-dimensional neighbourhood; left: full and half cross, right: full and half star (adapted from <http://www.geatbx.com/>)
- Figure 41: Properties of tournament selection (adapted from <http://www.geatbx.com/>)
- Figure 42: Possible positions of the offspring after discrete recombination (adapted from <http://www.geatbx.com/>)
- Figure 43: Area for variable value of offspring compared to parents in intermediate recombination (adapted from <http://www.geatbx.com/>)
- Figure 44: Possible area of the offspring after intermediate recombination (adapted from <http://www.geatbx.com/>)
- Figure 45: Possible positions of the offspring after line recombination (adapted from <http://www.geatbx.com/>)
- Figure 46: Single-point crossover (adapted from <http://www.geatbx.com/>)
- Figure 47: Multi-point crossover (adapted from <http://www.geatbx.com/>)
- Figure 48: Effect of mutation of real variables in two dimensions (adapted from <http://www.geatbx.com/>)
- Figure 49: Individual before and after binary mutation (adapted from <http://www.geatbx.com/>)
- Figure 50: Result of the binary mutation (adapted from <http://www.geatbx.com/>)
- Figure 51: The Genetic Algorithm
- Figure 52: Traveling Salesman Problem (adapted from <http://www.amdusers.com/wiki/tiki-index.php?page=TSP/>)
- Figure 53: Result of the binary mutation (adapted from <http://www.geneticprogramming.com>)
- Figure 54: Crossover operation for genetic programming. The bold selections on both parents are swapped to create the offspring or children. The child on the right is the parse tree representation for the quadratic equation. (adapted from <http://www.geneticprogramming.com>)
- Figure 55: Crossover operation for identical parents. (adapted from <http://www.geneticprogramming.com>)
- Figure 56: Mutation operation. (adapted from <http://www.geneticprogramming.com>)
- Figure 57: Two-dimensional example of an objective function showing its contour lines and the process for generating v in scheme DE1. The weighted difference vector of two arbitrarily chosen vectors is added to a third vector to yield the vector v
- Figure 58: Illustration of the crossover process for $D=7$, $n=2$ and $L=68$
- Figure 59: Two dimensional example of an objective function showing its contour lines and the process for generating v in scheme DE69
- Figure 60: Canonical DE Schematic.
- Figure 61: A biological neuron (adapted from <http://www.idsia.ch>)
- Figure 62: A biological neuron (adapted from <http://www.idsia.ch>)

Figure 63: A simple artificial neuron

Figure 64: Graphs of activation functions.

Figure 65: Feed-forward networks

Figure 66: Recurrent networks

Figure 67: The perceptron

(adapted from http://www.saedsayad.com/artificial_neural_network_bkp.htm)

Figure 68: XOR problem (adapted from http://www.saedsayad.com/artificial_neural_network_bkp.htm)

Figure 69: Final decision boundaries for AND function in perceptron learning

Figure 70: A multilayer feedforward neural network

(adapted from <http://homepages.gold.ac.uk/nikolaev/311multi.htm>)

Figure 71: An intuitive approach to the gradient descent method, looking for the global minimum: a) is the starting point, b) is the final one.

Figure 72: A map of the world quality-of-life (adapted from <http://www.shy.am>).

Figure 73: SOM of world quality-of-life (adapted from <http://www.shy.am>).

Figure 74: Structure of a SOM (adapted from <http://www.shy.am>).

Figure 75: Radius of the neighbourhood (adapted from <http://www.shy.am>)

Figure 76: An initialised network (adapted from <http://www.shy.am>)

Figure 77: Best Matching Unit (BMU) (adapted from <http://www.shy.am>)

Figure 78: The BMU window (adapted from <http://www.shy.am>)

Figure 79: Dots correspond to the centres of the circles in Figure 76 (adapted from <http://www.shy.am>).

Figure 80: Error map corresponding with Figure 78 (adapted from <http://www.shy.am>).

Figure 81: A diagram representing a facial recognition system using a Hopfield network (adapted from http://en.wikipedia.org/wiki/File:Face_recognition_with_hopfield_network.jpg)

Figure 82: Hopfield network.

(adapted from <http://upload.wikimedia.org/wikipedia/commons/9/95/Hopfield-net.png>)

Figure 83: Energy Landscape of a Hopfield Network, highlighting the current state of the network (up the hill), an attractor state to which it will eventually converge, a minimum energy level and a basin of attraction shaded in green. Note how the update of the Hopfield Network is always going down in Energy

(adapted from http://upload.wikimedia.org/wikipedia/commons/4/49/Energy_landscape.png)

Figure 84: Hybrid Probabilistic Systems (adapted from <http://www-bisc.cs.berkeley.edu>)

Figure 85: Hybrid Fuzzy Logic Systems (adapted from <http://www-bisc.cs.berkeley.edu>)

Figure 86: Hybrid Neural Network Systems (adapted from <http://www-bisc.cs.berkeley.edu>)

Figure 87: Hybrid Evolutionary Algorithms Systems (adapted from <http://www-bisc.cs.berkeley.edu>)