

DATA ENGINEERING

FUZZY MATHEMATICS IN SYSTEM THEORY AND DATA ANALYSIS

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Introduction

General Issues:

- ✘ Teaching
- ✘ Lecture Notes [1]
- ✘ Recommended Literature
- ✘ Internet Resources
- ✘ Examination
- ✘ Questions



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Motivation

We see an ever-increasing move toward inter and trans- disciplinary attacks upon problems in the real world.

The system scientist has a central role to play in this new order, and that role is to first of all understand ways and means of how to encode the natural world into “good” formal structures.



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Data Engineering

.. and the rest of the world:

- ▷ Statistics
- ▷ System Theory

- ▷ Pattern Recognition
- ▷ Data Mining
- ▷ Soft Computing

Why...?



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What has changed..

✘ Data:

- ▷ Imprecise, fuzzy, random.
- ▷ Sparse, and large data sets.

✘ Systems:

- ▷ Nonlinearity.
- ▷ Complexity.

✘ Methodologies:

- ▷ Learning.
- ▷ Strategy.

✘ Technology:

- ▷ Computer Power.
- ▷ Database- and Web-Technology.
- ▷ Imaging.



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Data Engineering

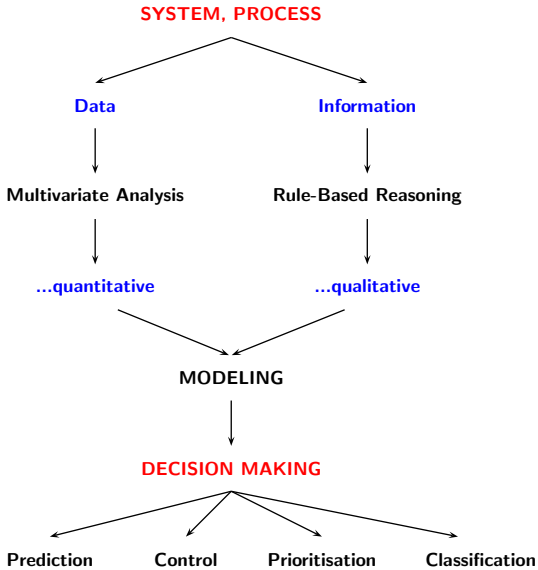
.. is *reasoning about data*:

1. [Decision Making](#)
... a unified framework for
prediction, control, prioritisation, classification.
2. [System Theory](#)
... the conceptual framework: *systems as graphs.*
3. [Learning from Data](#)
... matching data with models.
4. [Uncertainty Techniques](#)
... being precise about uncertainty.

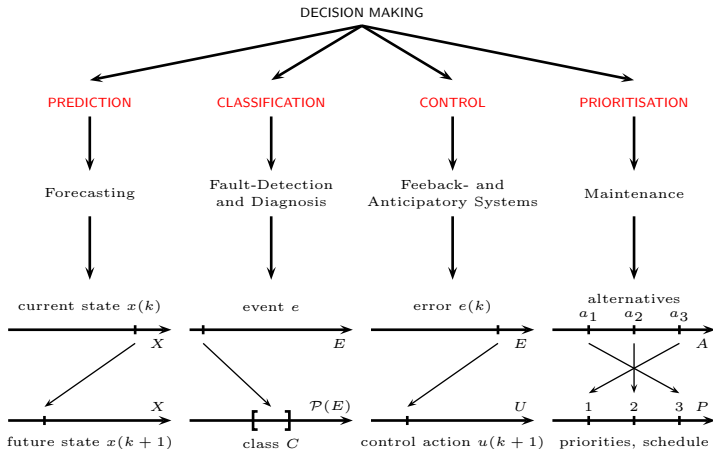


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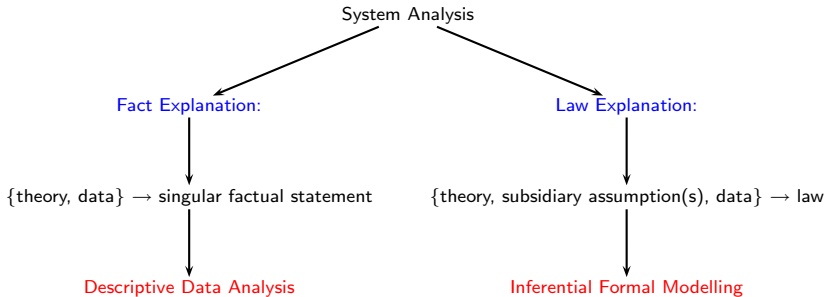
Data Engineering: Decision Making



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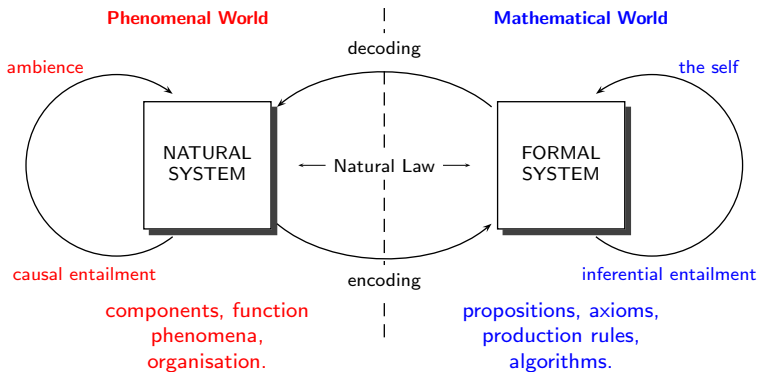
Data Engineering: System Theory



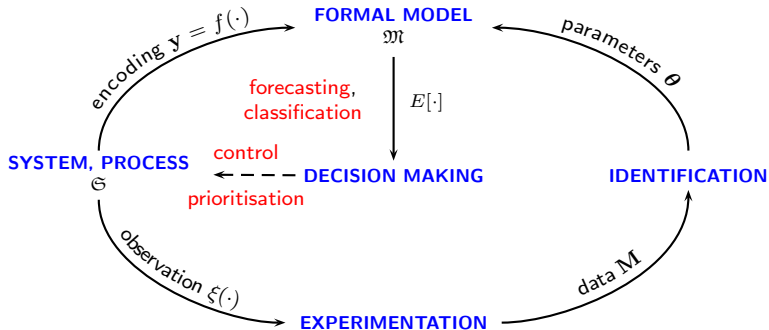
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Data Engineering: The Modelling Relation



Data Engineering: Learning from Data



Course Outline

Data, Systems, and Uncertainty:

- ▷ System Theory
- ▷ Uncertainty Techniques
- ▷ Learning from Data
- ▷ Clustering, Classification
- ▷ Fuzzy Systems Identification
- ▷ Fuzzy Mathematics
- ▷ Fuzzy Systems



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System Theory:

- ▷ The Modelling Relation.
- ▷ Observables.
- ▷ Representation of (dynamic) systems by mappings (as sets - graphs).
- ▷ Classical Modelling: differential equations, state-space modelling.

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Uncertainty Techniques:

- ▷ The Expectation Operator.
 - ▷ Descriptive Statistics.
 - ▷ The Least-Squares Criterion.
 - ▷ Linear Regression.
 - ▷ Maximum Likelihood Estimation.
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- ▷ Stochastic Processes, Kalman-Bucy Filtering.

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Learning from Data:

- ▷ System Identification.
- ▷ The Probabilistic Perspective.
- ▷ Basis Function Approximation.

- ▷ Kernel Density Estimation.

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Clustering:

- ▷ Pattern Recognition.
- ▷ Hard c -Means Algorithm.
- ▷ Fuzzy c -Means Algorithm.
- ▷ Gustavson-Kessel Algorithm.

..with application to

- ▷ Classification.
- ▷ System Identification.



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Fuzzy Systems Identification:

- ▷ Fuzzy Systems Model Structures.
 - ▷ Parameter Identification.
 - ▷ Takagi-Sugeno Modelling.
 - ▷ Switching Regression Models.
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- ▷ Forecasting.
 - ▷ Control.

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Fuzzy Mathematics:

- ▷ Fuzzy Sets.
- ▷ Fuzzy Logic.
- ▷ Fuzzy Relations: Similarity Relations.
- ▷ Possibility Theory.

- ▷ Approximate Reasoning.

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Fuzzy Systems:

- ▷ Fuzzy Inference Engines.
- ▷ Fuzzy Classification.
- ▷ Fuzzy Control.



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Internet Resources

1. Control Systems Centre : <http://www.csc.umist.ac.uk/>
2. Principia Cybernetica : <http://pespmc1.vub.ac.be/>
3. Pattern Recognition Information :
<http://www.ph.tn.tudelft.nl/PRInfo/>
4. Support Vector Machines : <http://svm.first.gmd.de/>
5. NFS Group Magdeburg : <http://fuzzy.cs.uni-magdeburg.de/>
6. BISC - The Berkeley Initiative in Soft Computing :
<http://www.cs.berkeley.edu/Research/Projects/Bisc/>

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Internet Resources

1. Virtual Laboratories in Probability and Statistics :
<http://www.math.uah.edu/stat/>
2. Probability Net : <http://www.probability.net/>
3. WWW Virtual Libraries :
 - Systems and Control :
<http://www-control.eng.cam.ac.uk/>
 - Mathematics :
<http://euclid.math.fsu.edu/Science/math.html>
4. The MathWorks : <http://www.mathworks.com/>
5. Wolfram Research : <http://www.wri.com/>



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Recommended Literature

Fuzzy Mathematics:

1. Babuska, R. : *Fuzzy Modelling for Control*. Kluwer, 1998.
See <http://lcewww.et.tudelft.nl/>.
2. Dubois, D. and Prade,H. : *Fuzzy Sets and Systems*. Academic Press, 1980.
3. Kruse, et.al. : *Foundations of Fuzzy Systems*. Wiley, 1994.
4. Nguyen, H.T. and Walker, E.A. : *A First Course in Fuzzy Logic*. CRC Press, 1997.
5. Pedrycz, W. : *Fuzzy Control and Fuzzy Systems*. RSP, 1993.
6. Wang, L.-X. : *A Course in Fuzzy Systems and Control*. Prentice Hall, 1997.
7. Zimmermann, H.-J. : *Fuzzy Set Theory*. Kluwer, 1996.

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Recommended Literature

Probability Theory, Statistical Inference:

1. Freedman, D. and Pisani, R. and Purves, R. : *Statistics*. Norton, 1997.
2. Larsen, H. : *Introduction to Probability Theory and Statistical Inference*. Wiley.
3. Papoulis, A. : *Probability, Random Variables, and Stochastic Processes*. McGraw Hill.



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References

- [1] Wolkenhauer, O. : *Data Engineering*.
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