
5. Fuzzy Systeme und Computational Intelligence

Beispiel : Automatik-Getriebe

Aufgabe: Verbesserung des VW Automatik-Getriebes

- **keine zusätzlichen Sensoren**
- **individuelle Anpassung des Schaltverhaltens**

Idee (1995):

Das Fahrzeug “beobachtet” und klassifiziert den Fahrer nach Sportlichkeit

- **ruhig, normal, sportlich** $\Rightarrow$ **Bestimmung eines Sport-Faktors aus $[0, 1]$**
- **nervös** $\Rightarrow$ **Beruhigung des Fahrers**

Testfahrzeug:

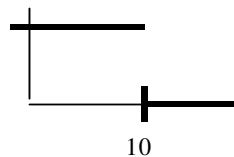
- **verschiedene Fahrer, Klassifikation durch Experten (Mitfahrer)**
- **gleichzeitige Messungen:**
 - **Geschwindigkeit,**
 - **Position,**
 - **Geschwindigkeit des Gaspedals,**
 - **Winkel des Lenkrades, ... (14 Attribute).**

Example

ling. description

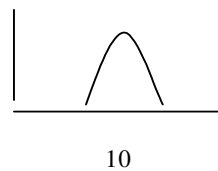
model

all numbers smaller
than 10



Indicator-
function

all numbers almost
equal to 10



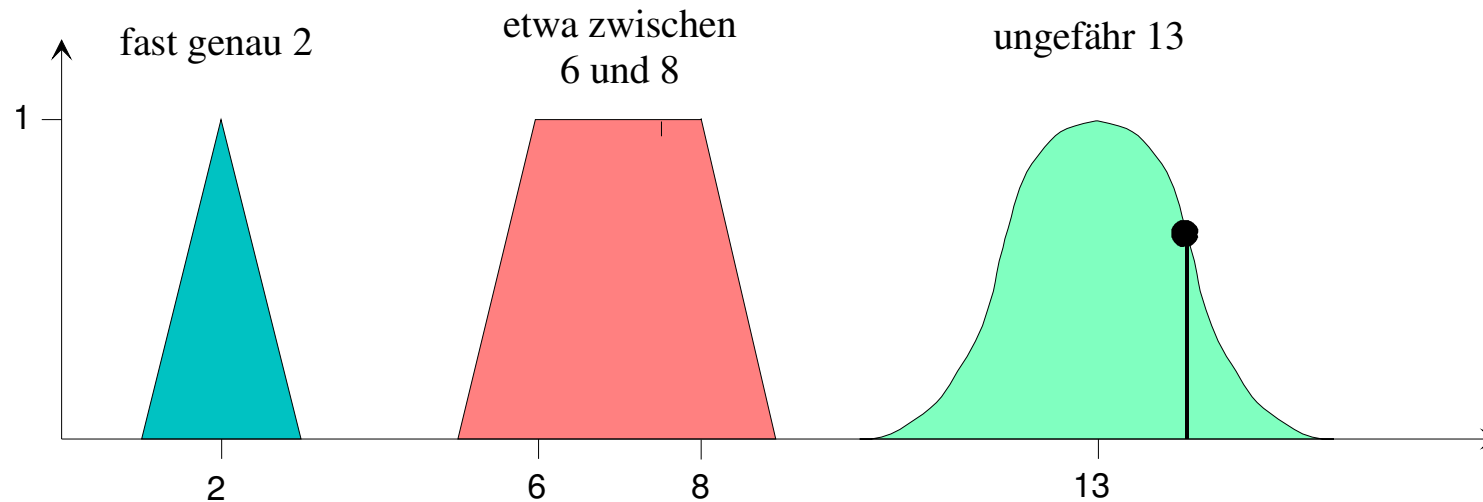
Membership
function of
“fuzzy set”

Definition

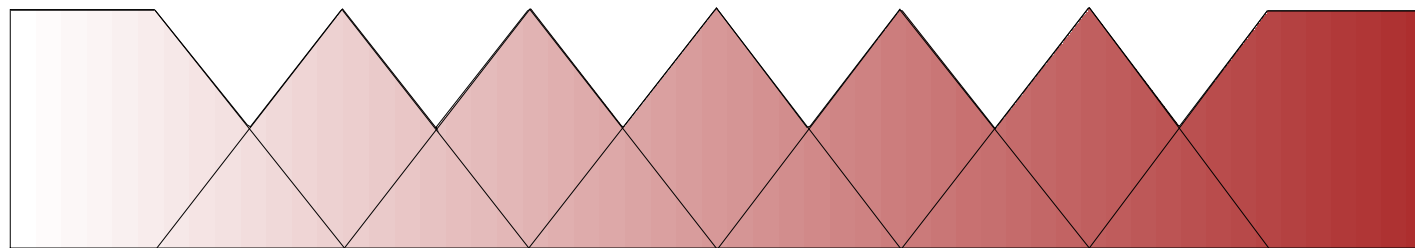
- a) A fuzzy set μ of $X \neq \emptyset$ is a function from the reference set X to the unit interval, i.e. $\mu: X \rightarrow [0, 1]$.
- b) $F(X) := \{\mu \mid \mu: X \rightarrow [0, 1]\}$

Modellierung unscharfer Informationen mit Fuzzy-Mengen

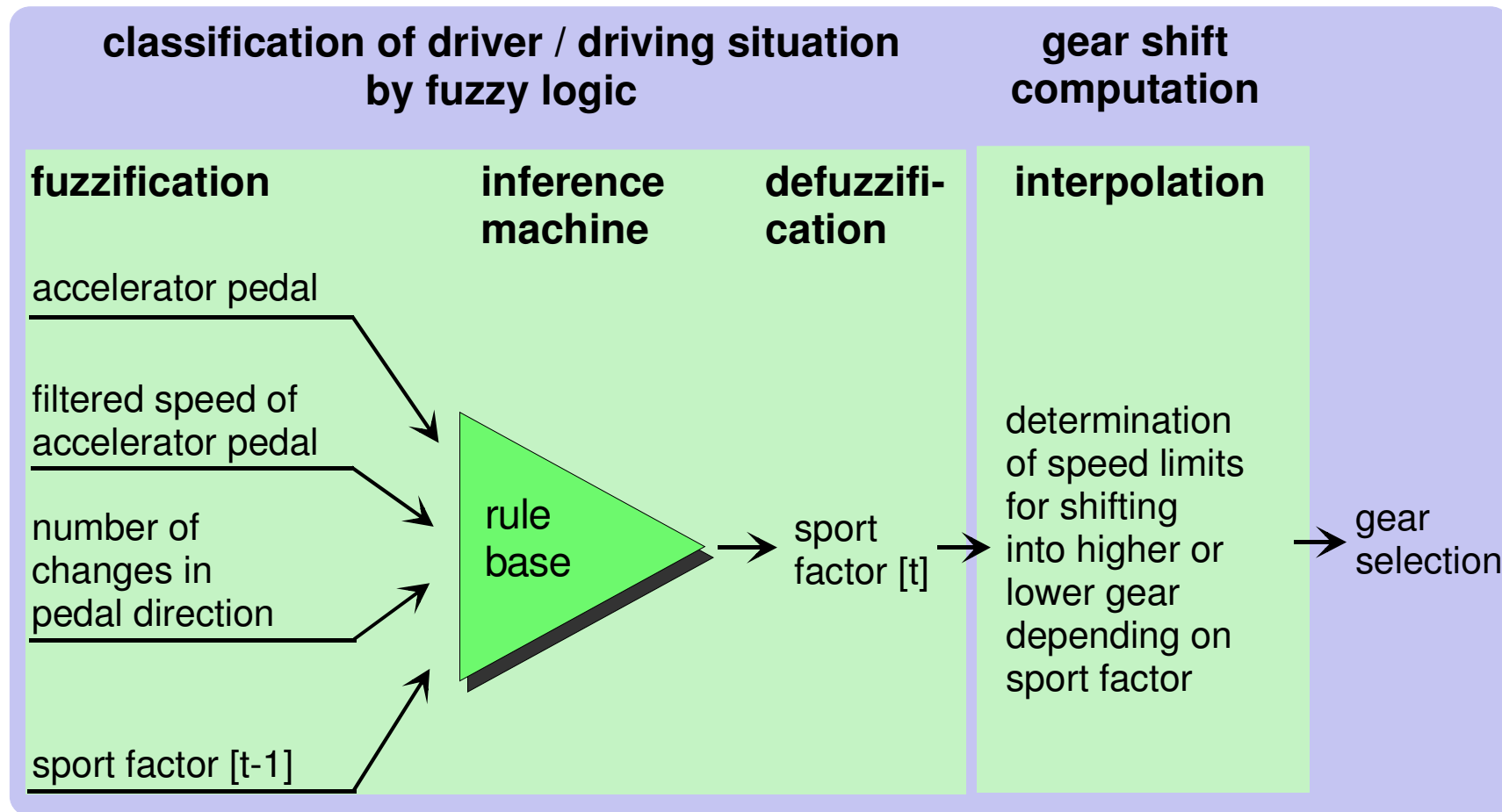
Zugehörigkeitsgrad



negativ groß negativ mittel negativ klein ungefähr null positiv klein positiv mittel positiv groß



Example: Continuously Adapting Gear Shift Schedule in VW New Beetle



Definition

a) We define on $F(X)$ the following operations:

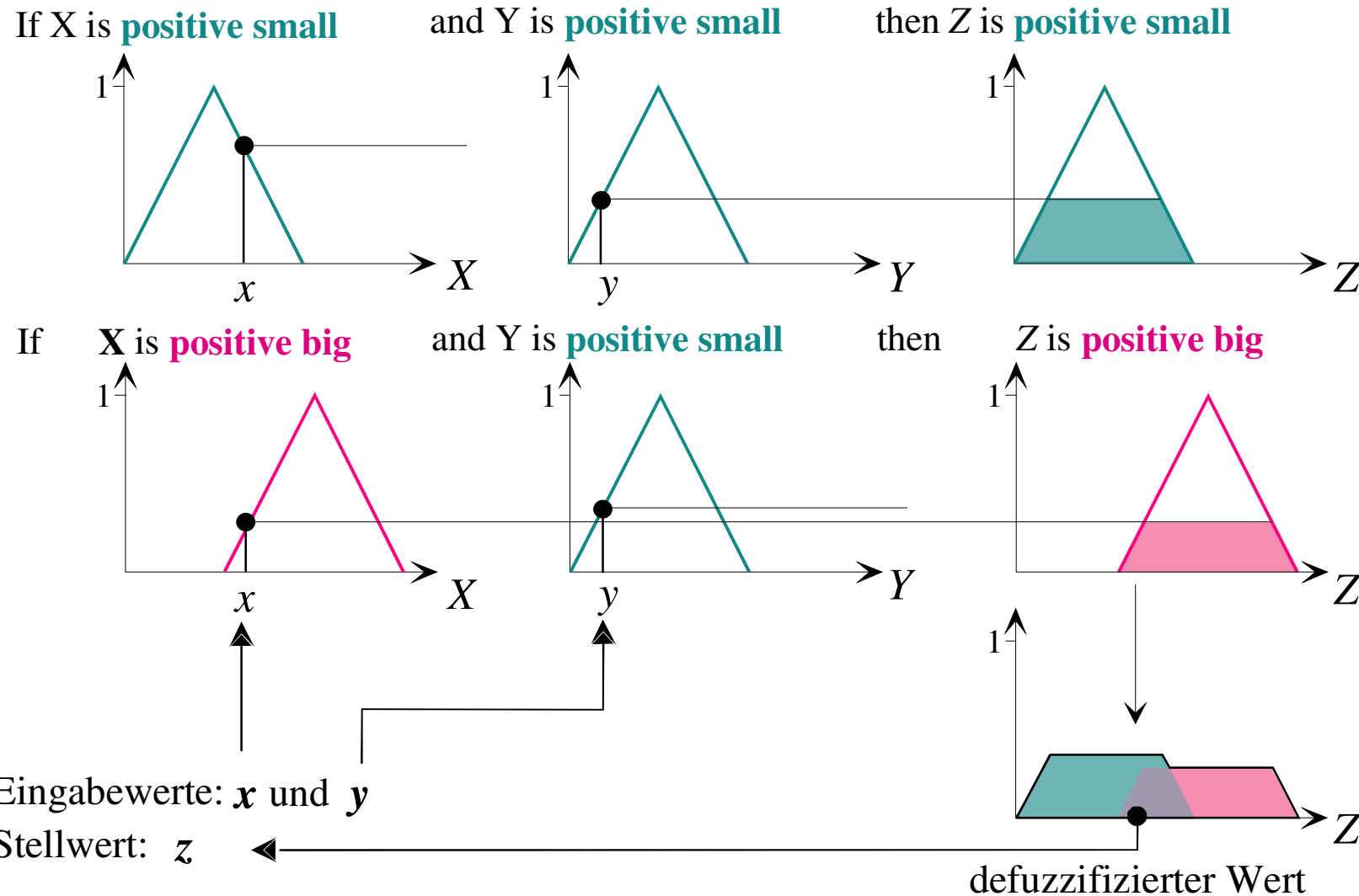
$(\mu \wedge \mu')(x) := \min\{\mu(x), \mu'(x)\}$ intersection (and)

$(\mu \vee \mu')(x) := \max\{\mu(x), \mu'(x)\}$ junction (or)

$\neg\mu(x) = 1 - \mu(x)$ complement

b) μ is subset of $\mu' \Leftrightarrow \mu \leq \mu'$.

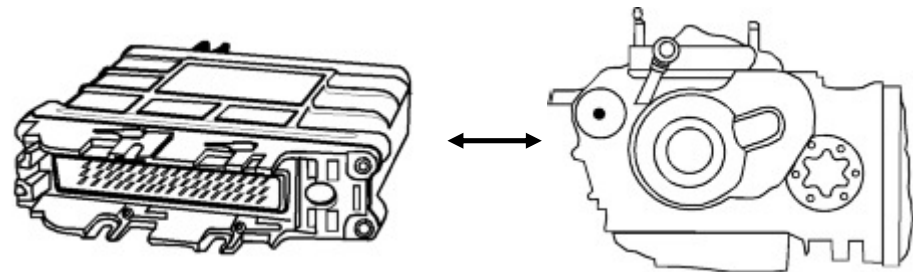
Definition of a function (Mamdani) : here 2 rules, 2 inputs, 1 output



Mamdani Controller

- Fuzzy-Regler mit 7 Regeln

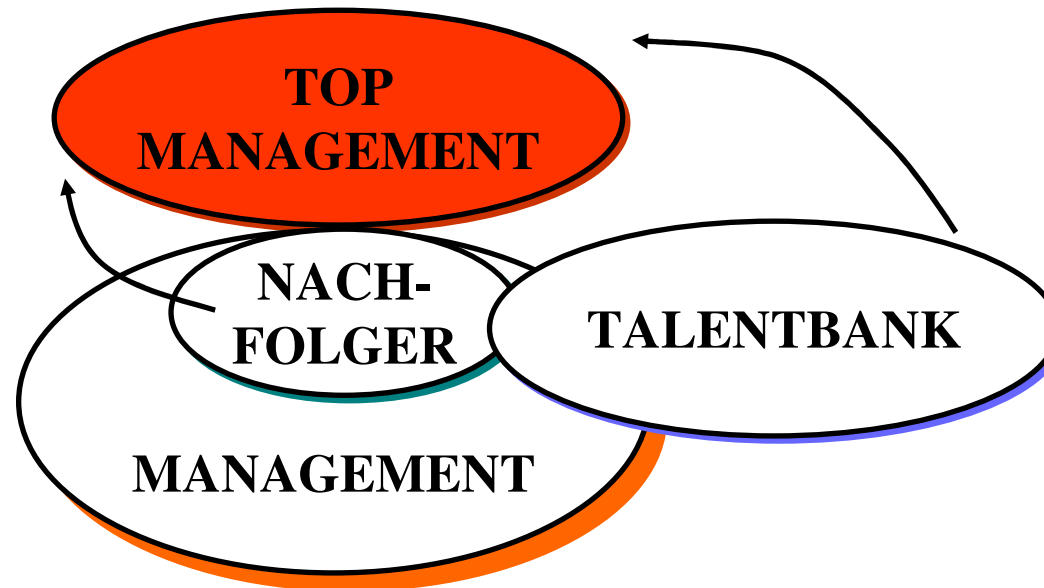
- Optimiertes Programm
 - 24 Byte RAM
 - 702 Byte ROM auf Digimat



- Laufzeit 80 ms,
12 mal pro Sekunde wird ein neuer Sportfaktor bestimmt
- In Serie im VW Konzern
- Erlernen von Regelsystemen mit Hilfe
von Künstlichen Neuronalen Netzen,
Optimierung mit evolutionären Algorithmen



Beispiel : Fuzzy Datenbank



Nachfolger für Top-Management Positionen

Vorstandspräsentation Dr. Peter Hartz 23.05.1996

Überblick

Rang 1, Übereinstimmung 0,92

Persönlicher Entwicklungsplan

Überblick



Santillana, Oscar

Alter **35 Jahre** Geburtsdat. **20.11.60** Familienst. verh. **Kinder 83/85/89**

Nationalität **Mexico**

Dipl. Ing. für Maschinenbau

Konzernzugeh. **11 Jahre** Eintrittsdatum **01.01.85** Pers. Nr. **M030471**

FK im M **5 Jahre** letzte Verändg. **01.01.96**

Kst. Bezeichg. **Montagen** **Volkswagen Mexico** in d. Aufg. **1 Jahr**

berichtet an **Lustig, Leopold** **Werkleitung**

Entwicklungsempfehlung

bleiben ☐

kurzfristig

horizontal ☒

vertikal ☐

12 - 24 Mon.

horizontal ☐

vertikal ☐

Profil

A B C D E

Unternehmer D

Innovator B

Experte D

Coach C

Partner D

Gesamtbeurteilung

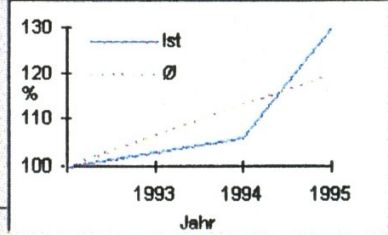
A B C D E

1995 D

1993 C

1992 D

Jahreseinkommen



Gehaltsgr. Gehalt

Example: Prognosis of the Daily Proportional Changes of the DAX at the Frankfurter Stock Exchange (Siemens)

■ Database: time series from 1986 - 1997

DAX	Composite DAX
German 3 month interest rates	Return Germany
Morgan Stanley index Germany	Dow Jones industrial index
DM / US-\$	US treasury bonds
Gold price	Nikkei index Japan
Morgan Stanley index Europe	Price earning ratio

Fuzzy Rules in Finance

- Trend Rule

IF DAX = decreasing AND US-\$ = decreasing
THEN DAX prediction = decrease
WITH high certainty

- Turning Point Rule

IF DAX = decreasing AND US-\$ = increasing
THEN DAX prediction = increase
WITH low certainty

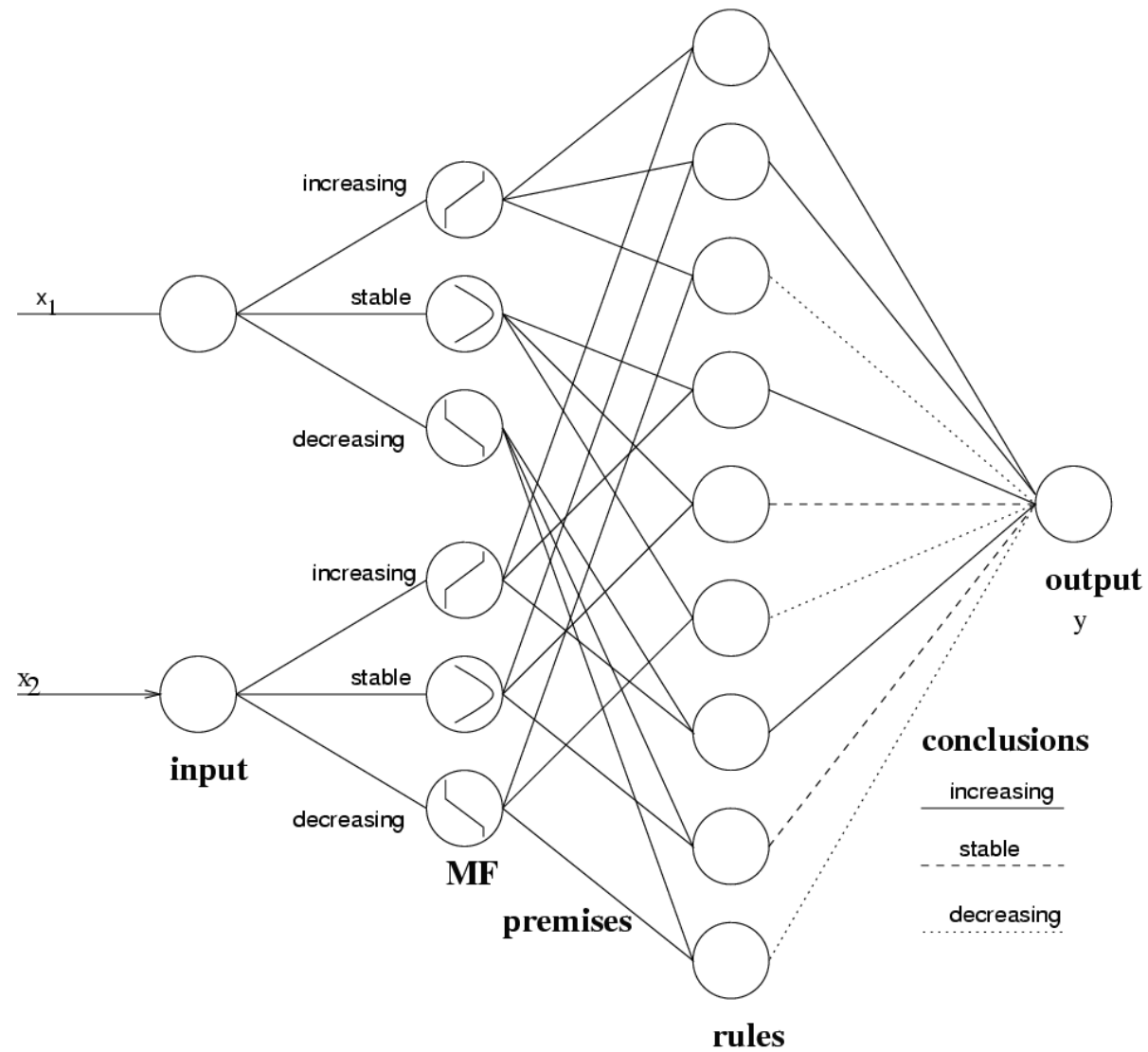
- Delay Rule

IF DAX = stable AND US-\$ = decreasing
THEN DAX prediction = decrease
WITH very high certainty

- In general

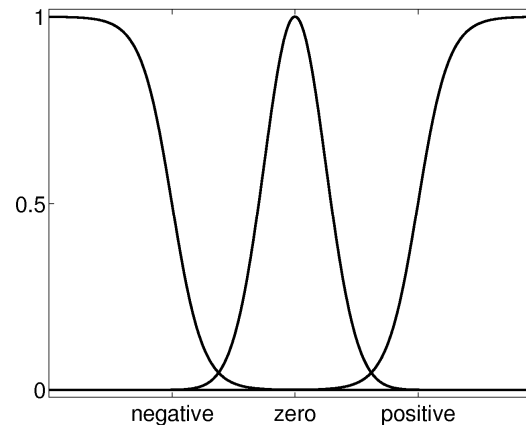
IF x_1 is μ_1 AND x_2 is μ_2
THEN $y = \eta$
WITH weight k

Neuro-Fuzzy Architecture



From Rules to Neural Networks

1. Evaluation of membership degrees



2. Evaluation of rules (rule activity)

$$\mu_l: \mathbb{R}^n \rightarrow [0,1]^r, \quad \underline{x} \Rightarrow \prod_{j=1}^{D_l} \mu_{c,s}^{(j)}(x_i)$$

3. Accumulation of rule inputs and normalization

$$\text{NF}: \mathbb{R}^n \rightarrow \mathbb{R}, \quad \underline{x} \Rightarrow \sum_{l=1}^r w_l \frac{k_l \mu_l(\underline{x})}{\sum_{j=1}^r k_j \mu_j(\underline{x})}$$

Reduction of the dimension of the weight space

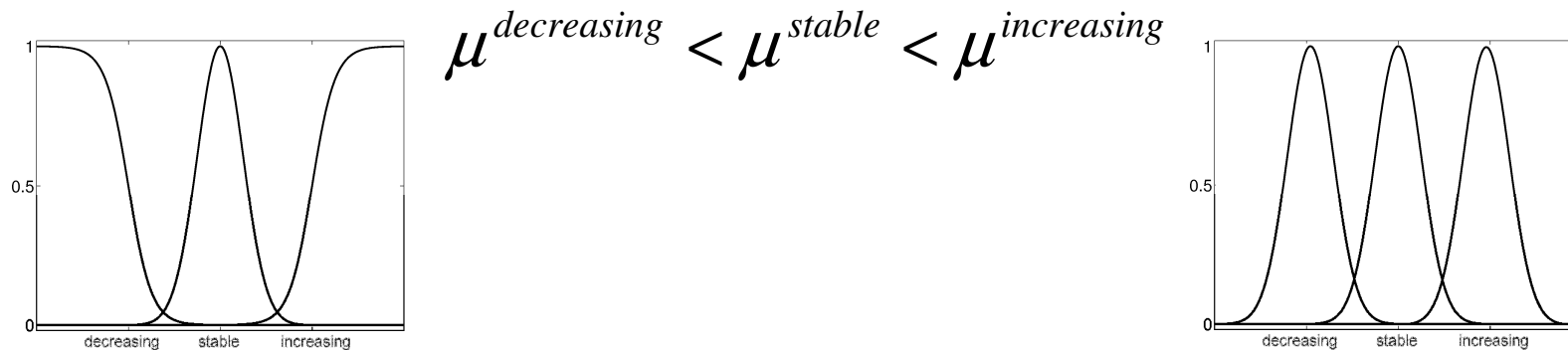
1. Membership functions of different inputs share their parameters,

e.g.

$$\mu_{dax}^{stable} \equiv \mu_{cdax}^{stable}$$

2. Membership functions of the same input variable are not allowed to pass each other, they must keep their original order,

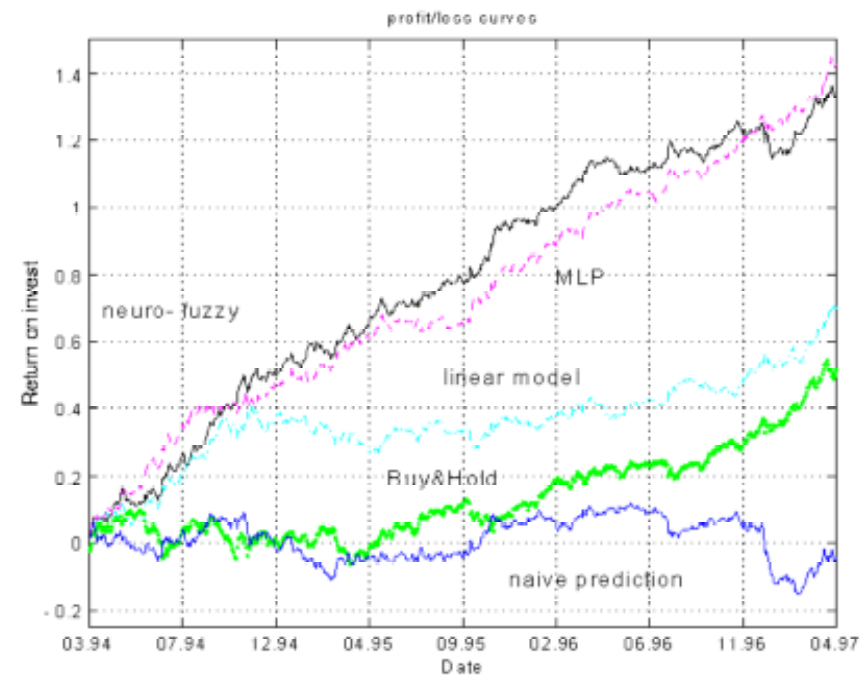
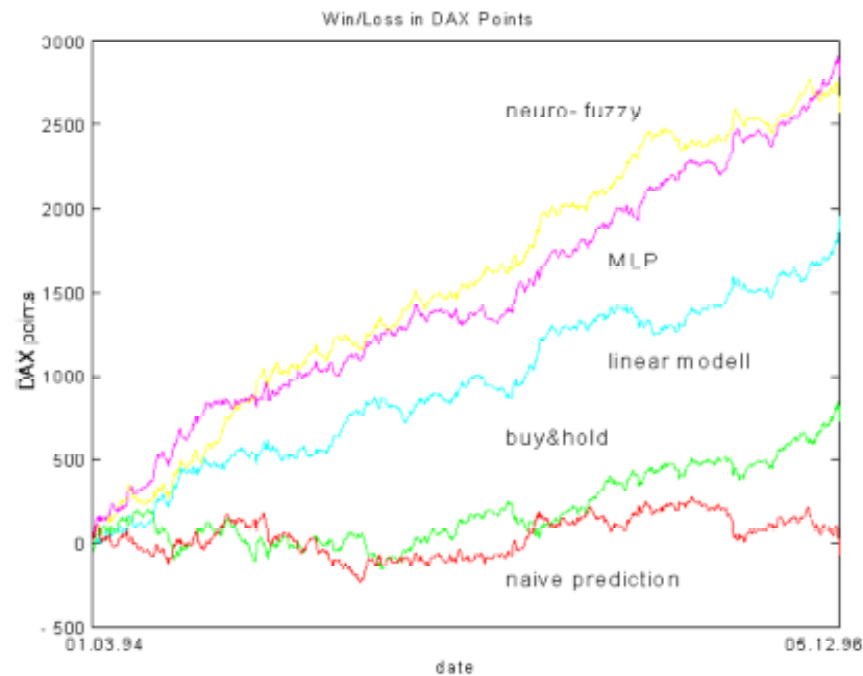
e.g.



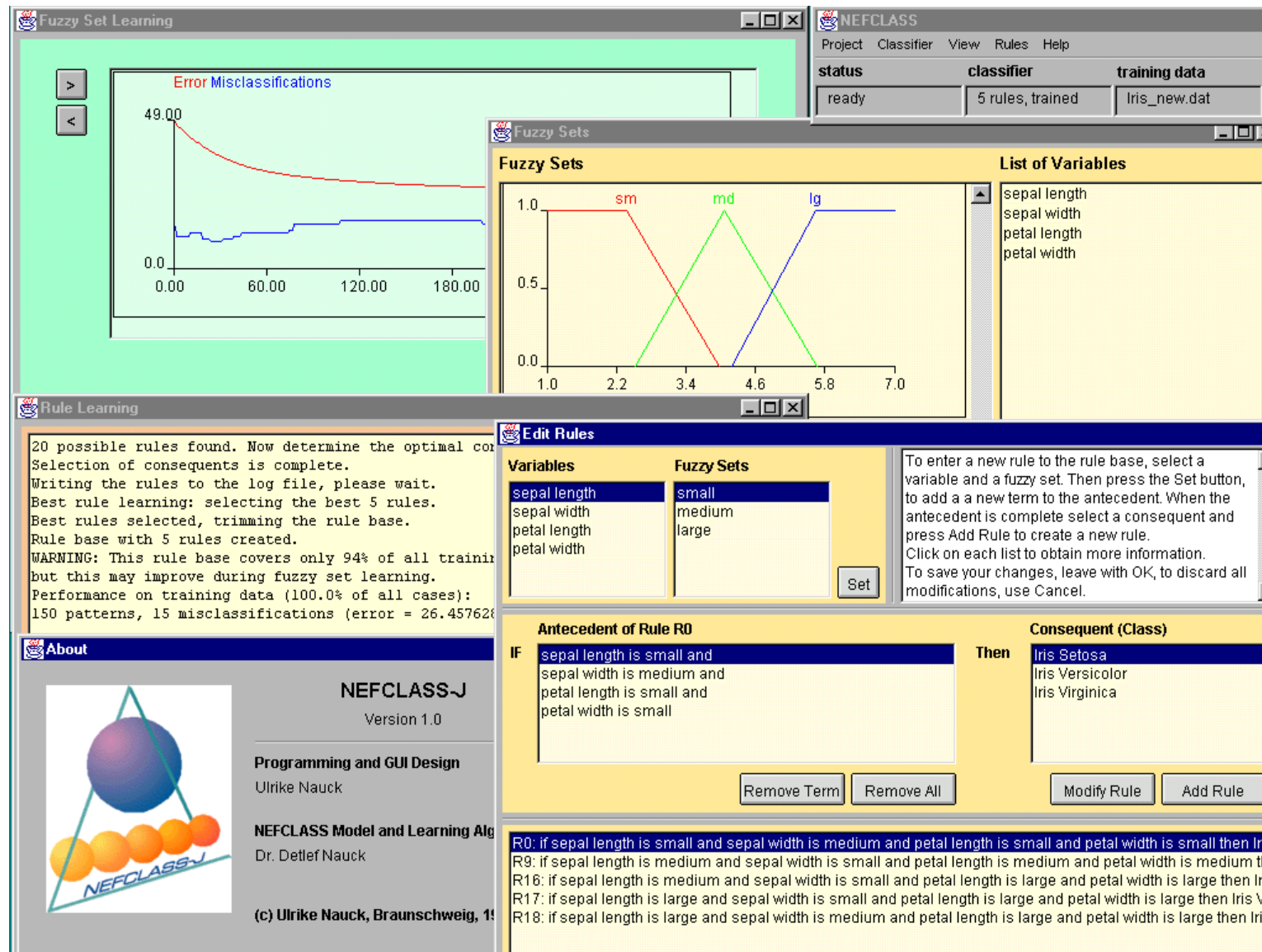
- Benefits:
- the optimized rule base can still be interpreted
 - the number of free parameters is reduced

Return-on-Investment Curves of the Different Models

Validation data from March 01, 1994 until April 1997



NEFCLASS-J



Surface Quality Control: the 2 Approaches

■ Today's Approach

The current surface quality control is done manually → an experienced worker treats the exterior surfaces with a grindstone. The experts classify surface form deviations by means of linguistic descriptions.

Cumbersome – Subjective - Error Prone Time Consuming

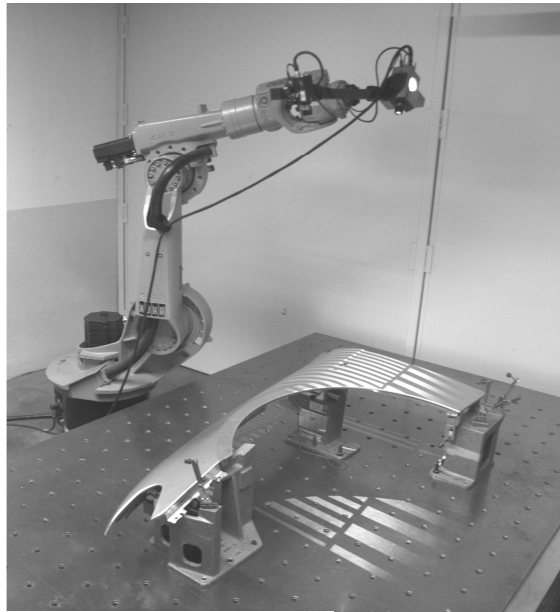


■ The Proposed Approach

Our Approach is based on the digitization of the exterior body panel surface with an optical measuring system.

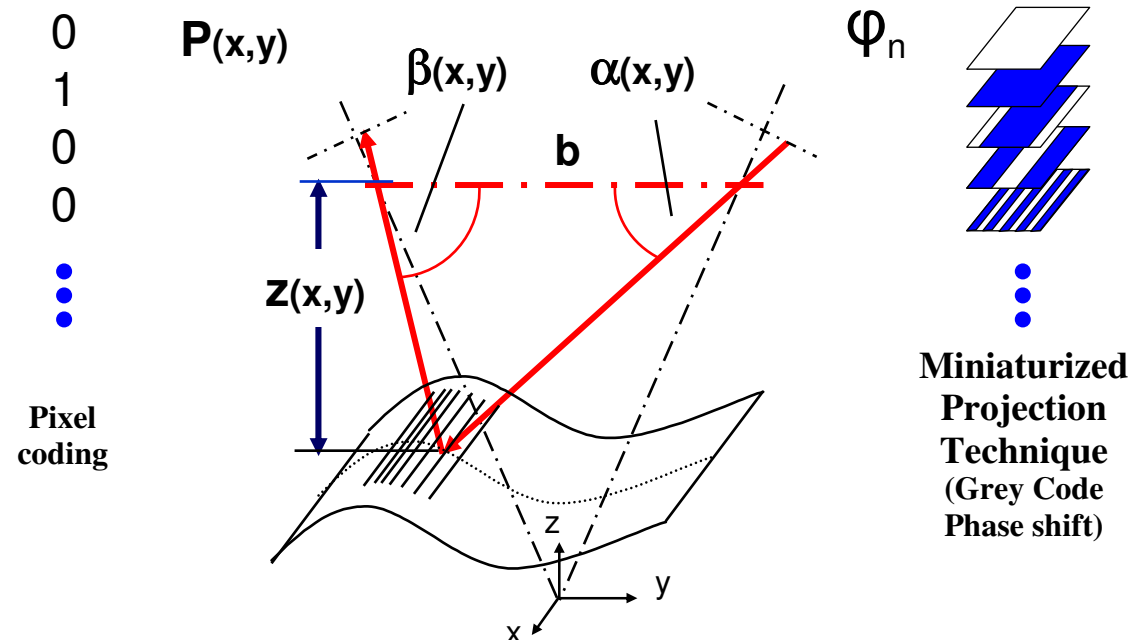
We characterize the form deviation by mathematical properties that are close to the subjective properties that the experts used in their linguistic description.

Topometric 3-D measuring system



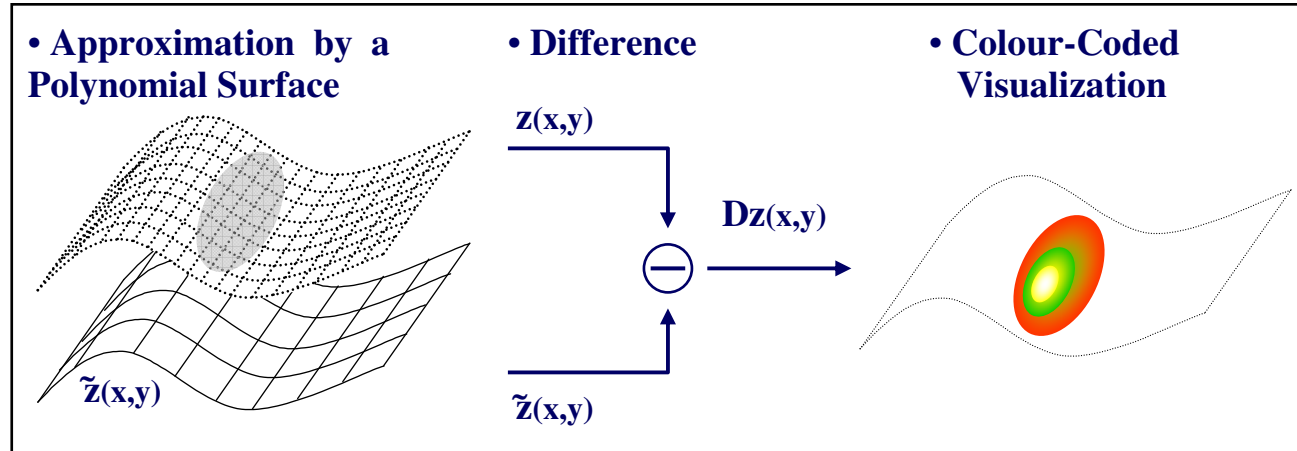
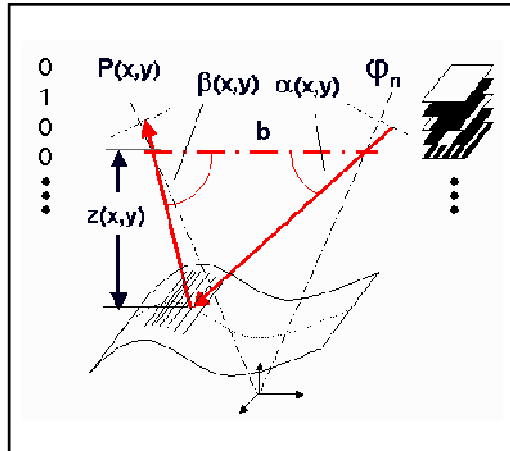
breuckmann 

Triangulation and Gratings Projection



- High Point Density
- Fast Data Collection
- Measurement Accuracy
- Contact less and Non-destructive

Data Processing



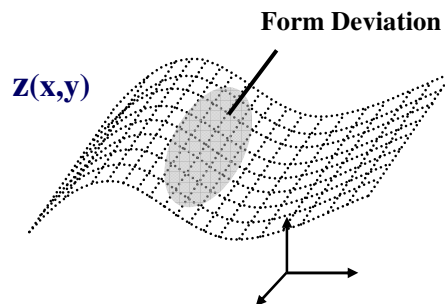
3-D Data Acquisition

Post-Processing

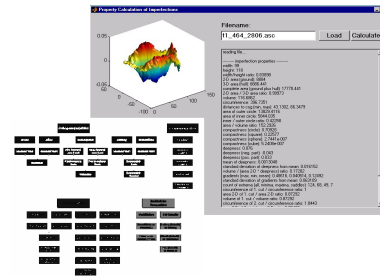
Detection of Form Deviation

Features Analysis

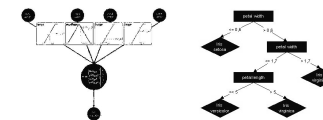
• 3-D-Point Cloud



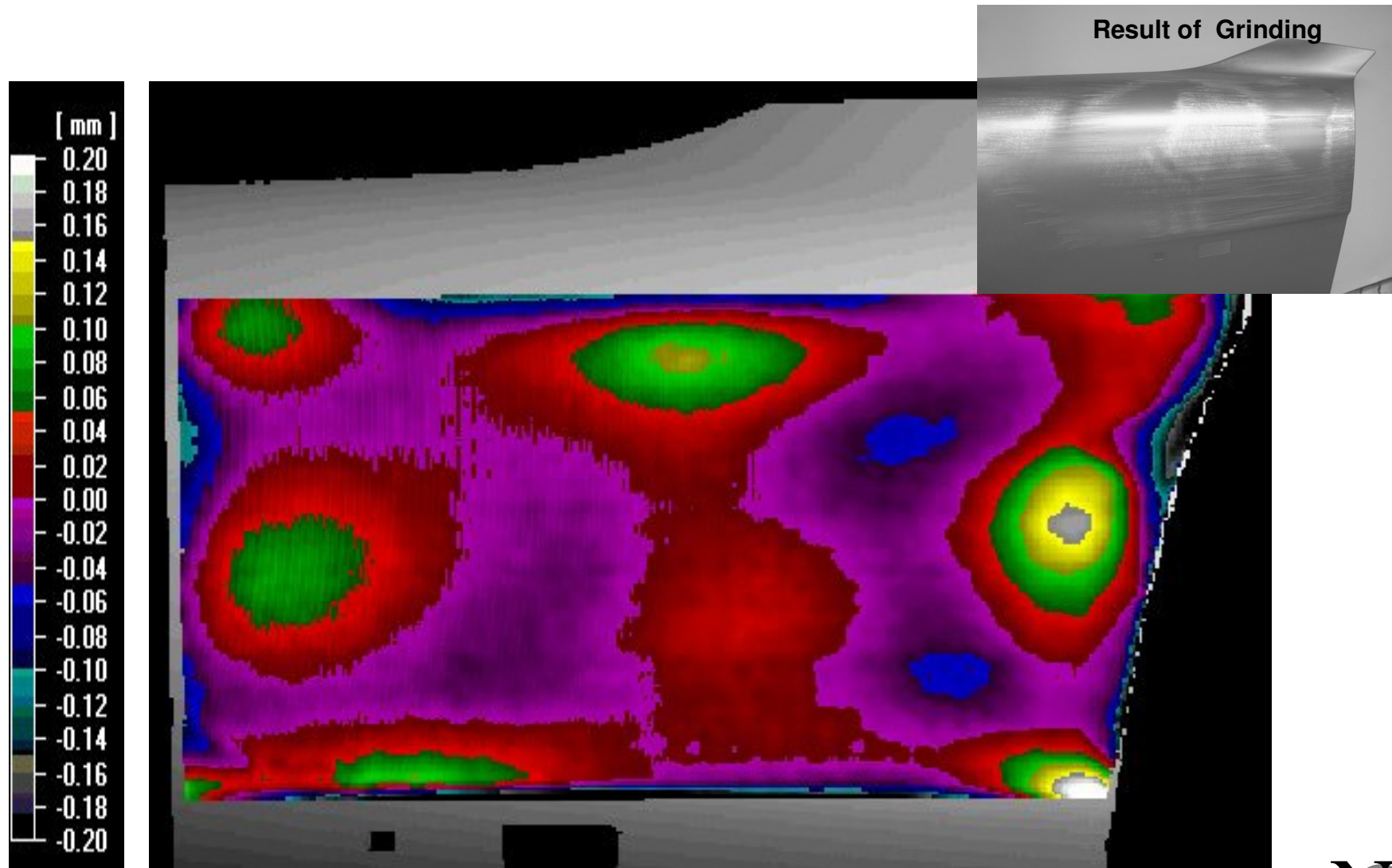
• Feature Calculation



• Classification (Data-Mining)



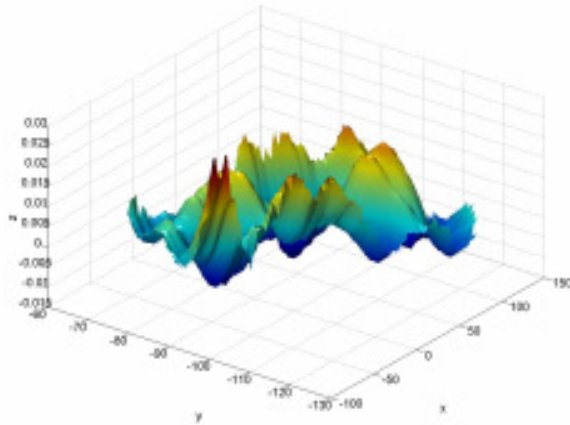
Color Coded Visualization



3D Visualization of Local Surface Defects

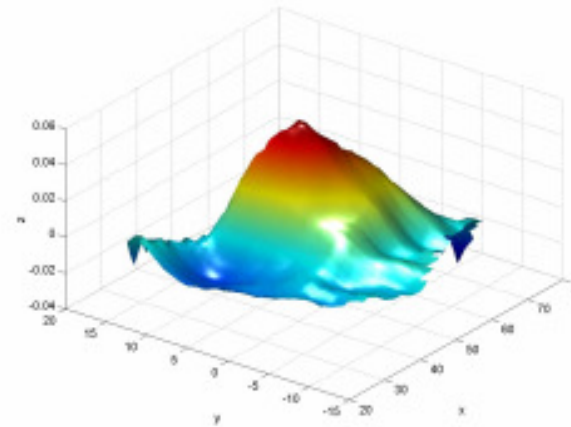
Uneven Surface

(several sink marks in series or adjoined)



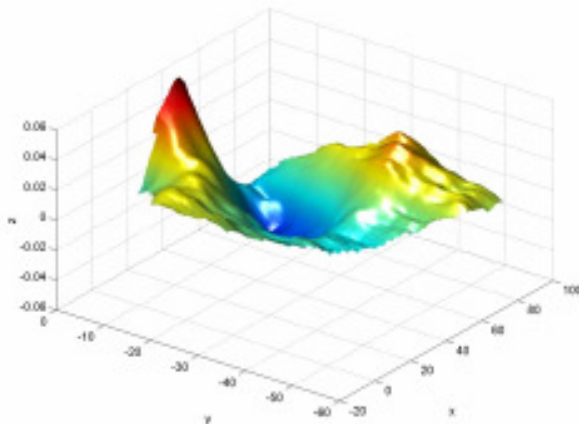
Press Mark

(local smoothing of (micro-)surface)



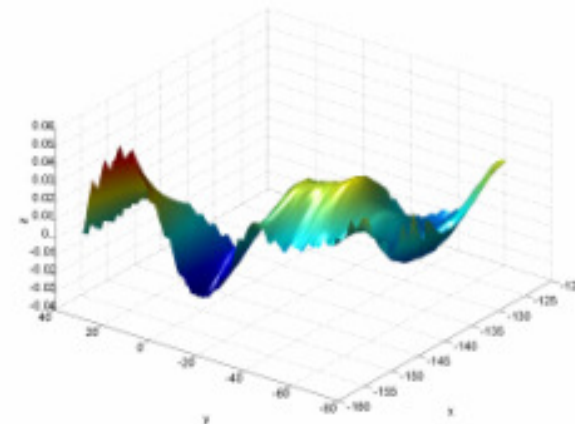
Sink Mark

(slight flat based depression inward)



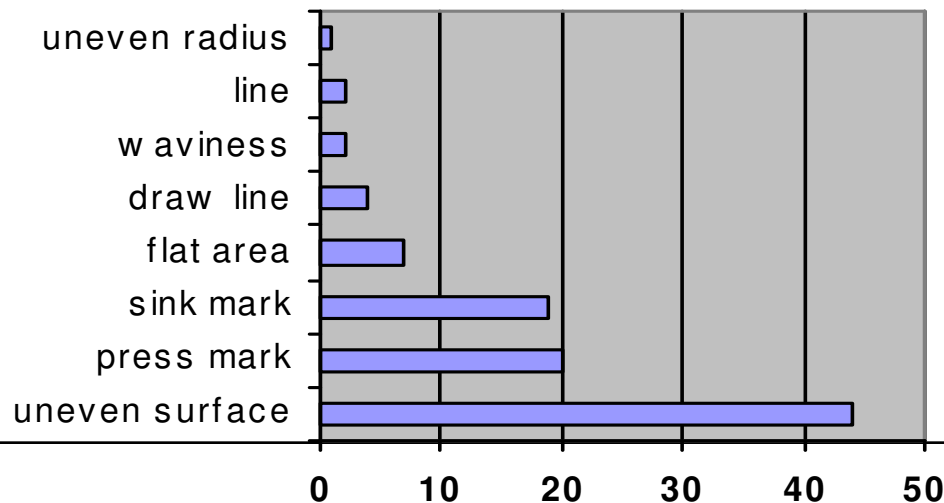
Waviness

(several heavier wrinklings in series)



Data Characteristics

- We analysed 9 master pieces with a total number of 99 defects
- For each defect we calculated 42 features
- The types are rather unbalanced
- We discarded the rare classes
- We discarded some of the extremely correlated features (31 features left)
- We ranked the 31 features by importance
- We use stratified 4-fold cross validation for the experiment.



Application and Results

The Rule Base for NEFCLASS

Rule base

- Rule 1: IF (max_distance_to_cog IS fun 2 AND min_extrema IS fun 1 AND max_extrema IS fun 1) THEN type IS press_mark
- Rule 2: IF (max_distance_to_cog IS fun 2 AND all_extrema IS fun 1 AND max_extrema IS fun 2) THEN type IS sink_mark
- Rule 3: IF (max_distance_to_cog IS fun 3 AND min_extrema IS fun 2 AND max_extrema IS fun 2) THEN type IS uneven_surface
- Rule 4: IF (max_distance_to_cog IS fun 2 AND min_extrema IS fun 2 AND max_extrema IS fun 2) THEN type IS uneven_surface
- Rule 5: IF (max_distance_to_cog IS fun 2 AND all_extrema IS fun 1 AND min_extrema IS fun 2) THEN type IS press_mark
- Rule 6: IF (max_distance_to_cog IS fun 3 AND all_extrema IS fun 2 AND max_extrema IS fun 3) THEN type IS uneven_surface
- Rule 7: IF (max_distance_to_cog IS fun 3 AND min_extrema IS fun 3) THEN type IS uneven_surface

Classification Accuracy

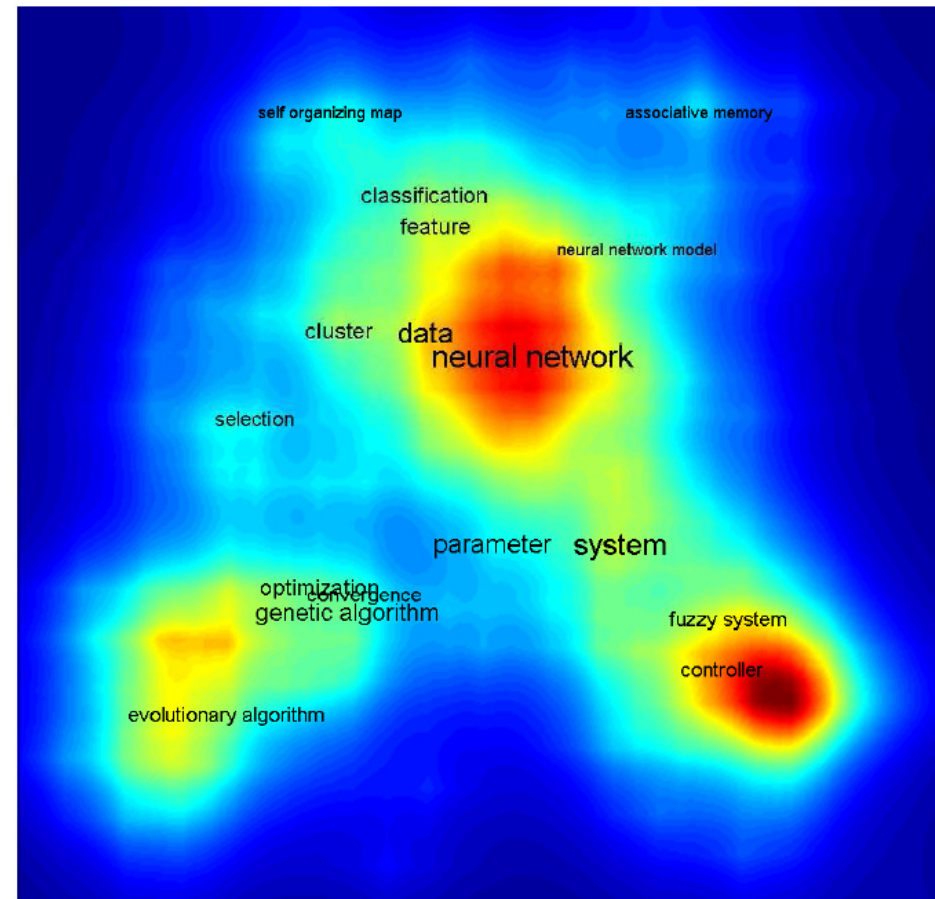
	NBC	DTree	NN	NEFCLASS	DC
Train Set	89.0%	94.7%	90%	81.6%	46.8%
Test Set	75.6%	75.6%	85.5%	79.9%	46.8%



Computational Intelligence ist charakterisiert durch:

- Meist "modellfreie" Ansätze (d.h., es ist kein explizites Modell des zu beschreibenden Gegenstandsbereichs notwendig; "modellbasiert" dagegen: z.B. Lösen von Differentialgleichungen)
- Approximation statt exakte Lösung (nicht immer ausreichend!)
- Schnelleres Finden einer brauchbaren Lösung, u.U. auch ohne tiefgehende Problemanalyse

CI-Forschungsthemen



Computational Intelligence (CI)

CI Core Technologies

- Neural Nets (NN)
- Fuzzy Logic (FL)
- Probabilistic Reasoning (PR)
- Genetic Algorithms (GA)
- Hybrid Systems

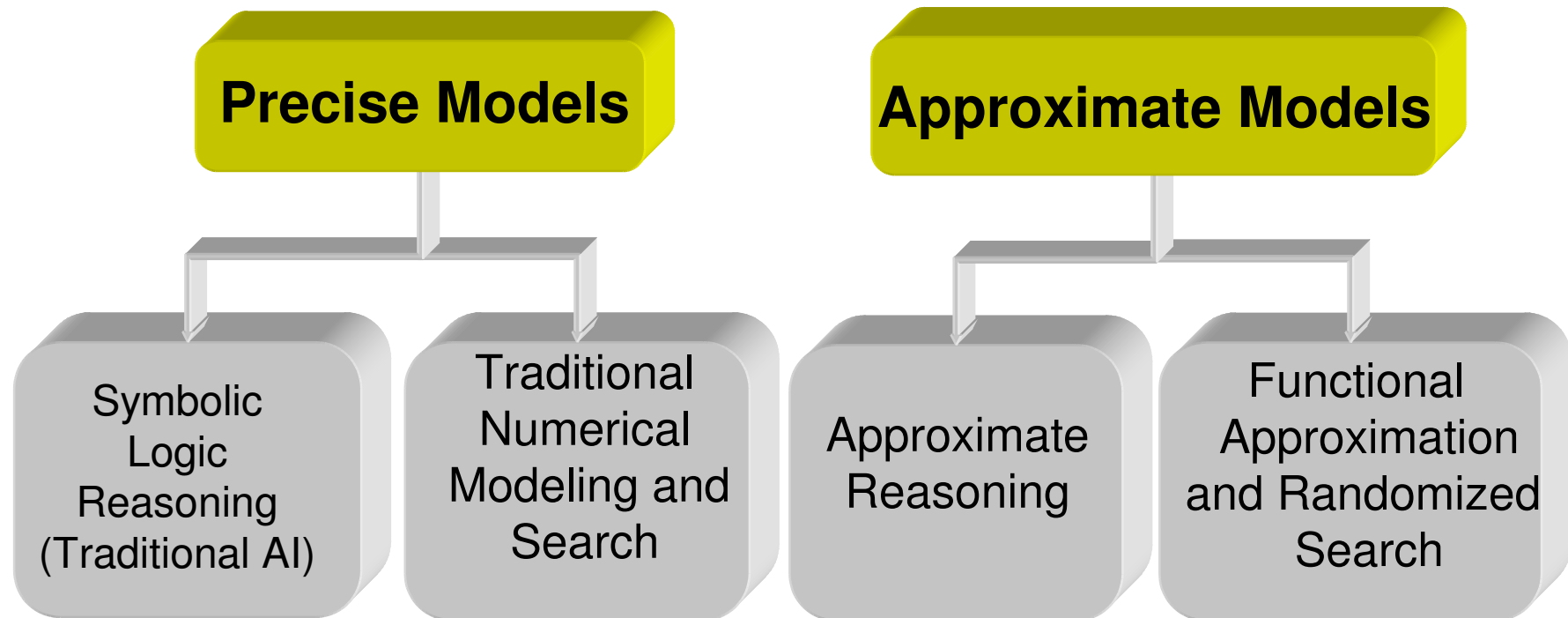
Related Technologies

- Statistics (Stat.)
- Artificial Intelligence (AI):
 - Case-Based Reasoning (CBR)
 - Rule-Based Expert Systems (RBR)
 - Machine Learning (Induction Trees)
 - Bayesian Belief Networks (BBN)

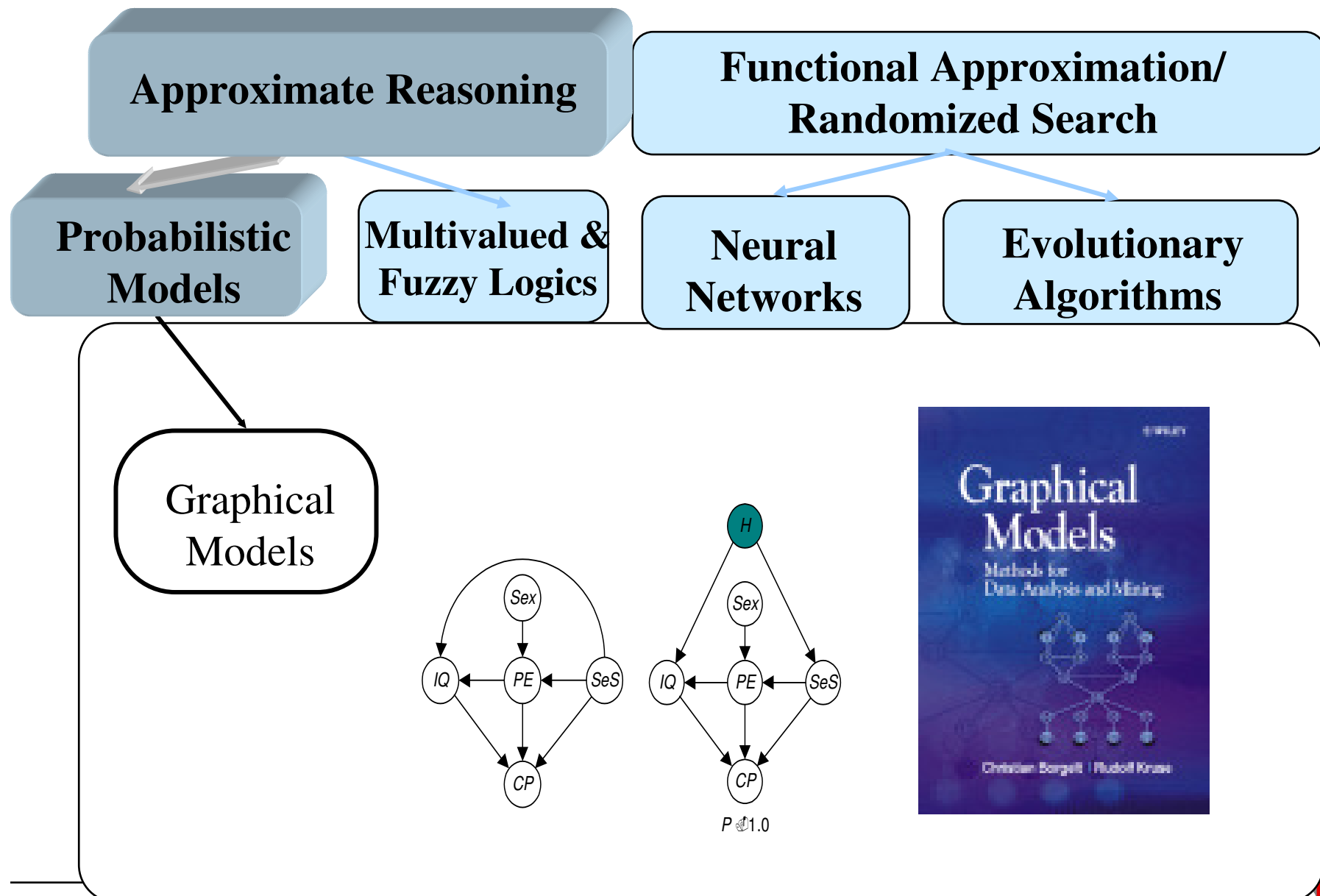
Applications

- Classification
 - Monitoring/Anomaly Detection
 - Diagnostics
 - Prognostics
 - Configuration/Initialization
- Prediction
 - Quality Assessment
 - Equipment Life Estimation
- Scheduling
 - Time/Resource Assignments
- Control
 - Machine/Process Control
 - Process Initialization
 - Supervisory Control
- DSS/Auto-Decisioning
 - Cost/Risk Analysis
 - Revenue Optimization

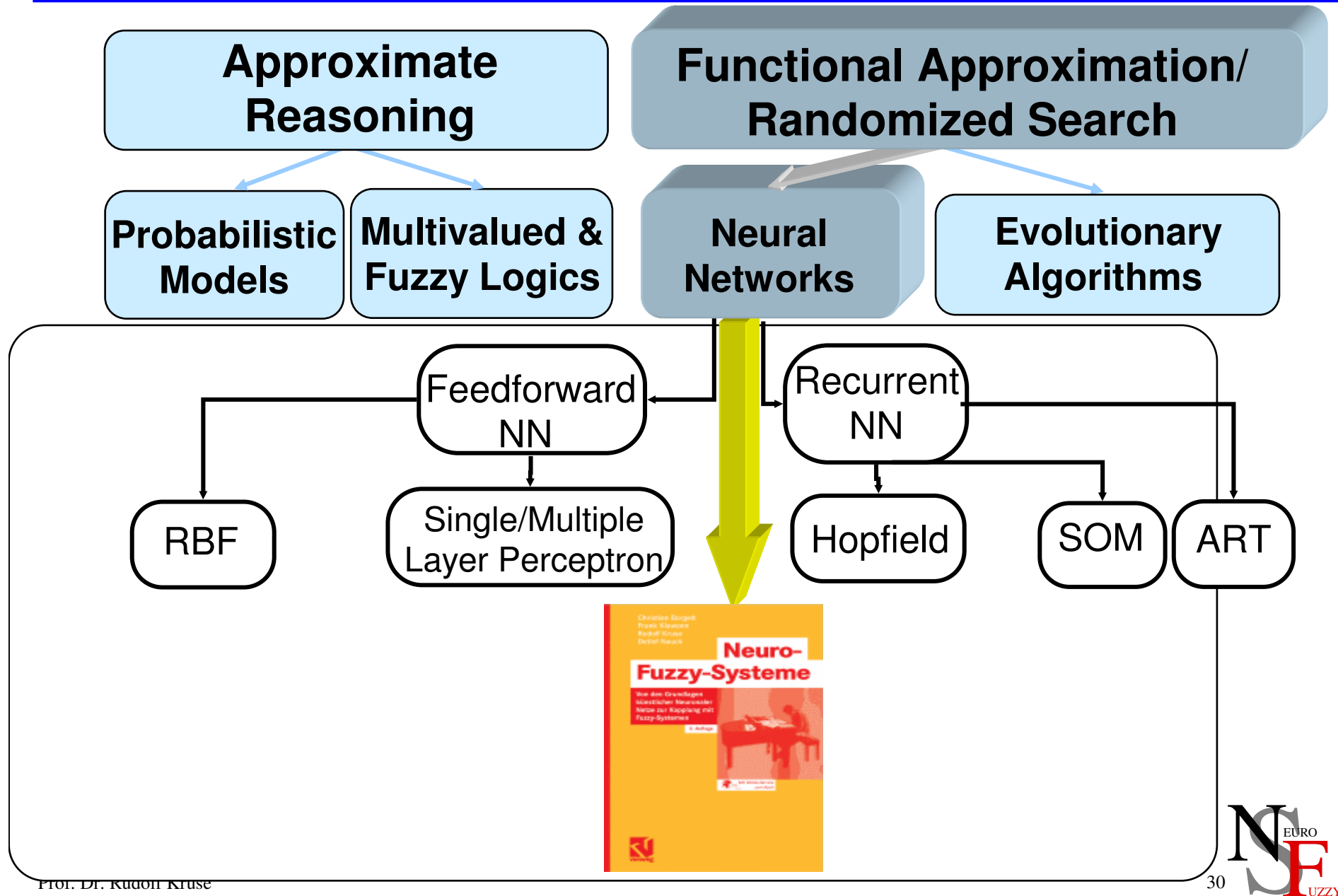
Problem Solving Technologies



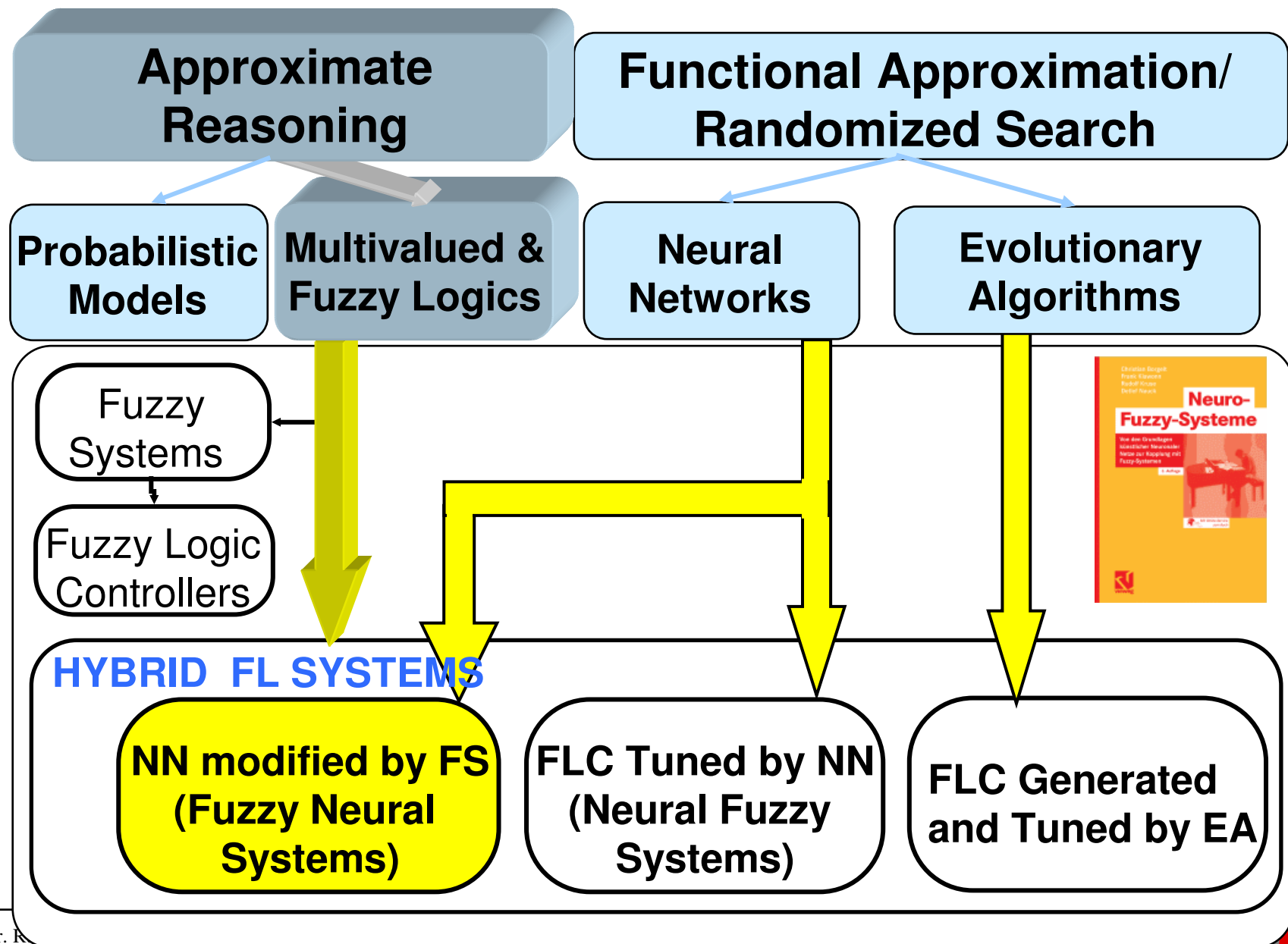
Computational Intelligence



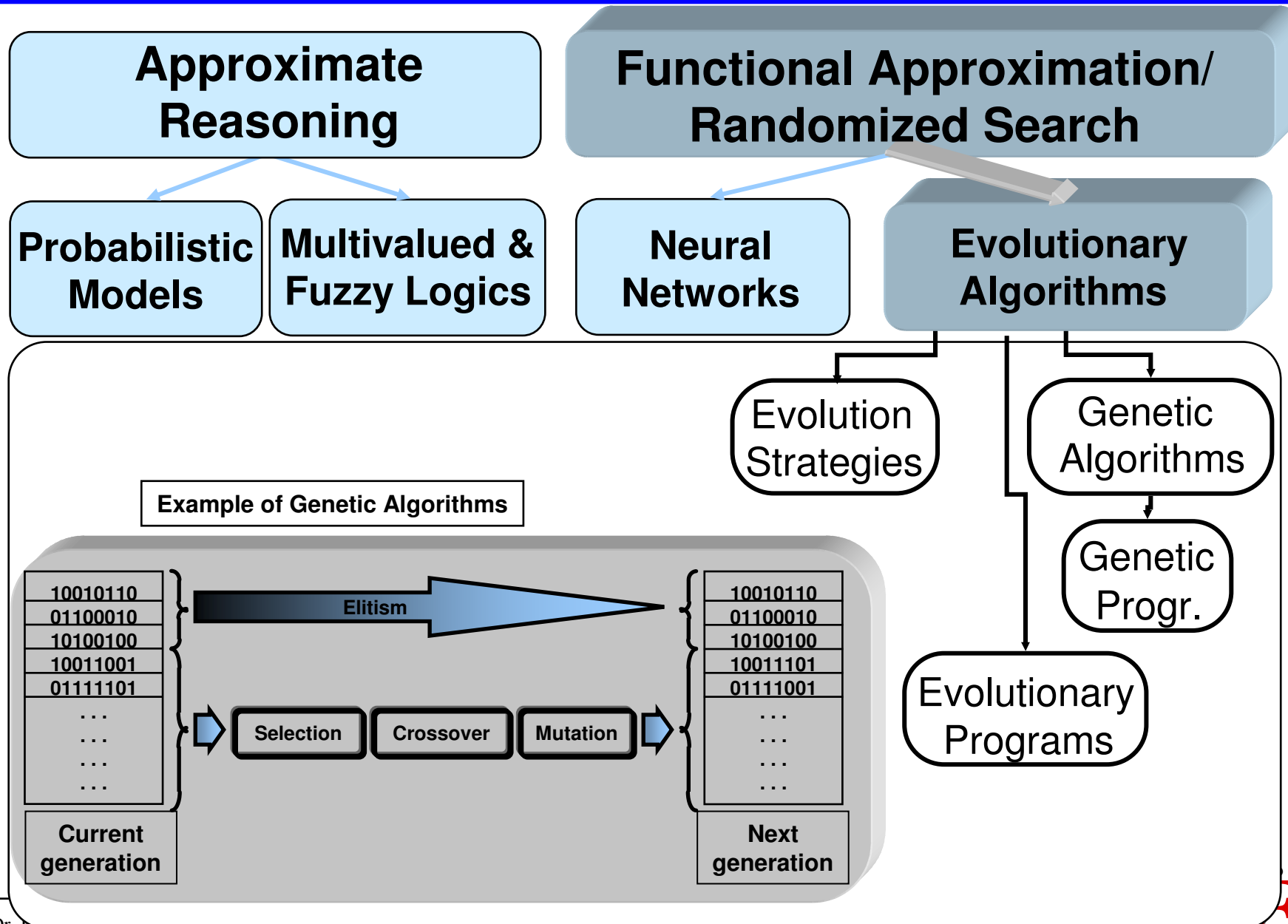
Computational Intelligence: Neural Networks



Comp Int. : Hybrid Neuro-Fuzzy Systems



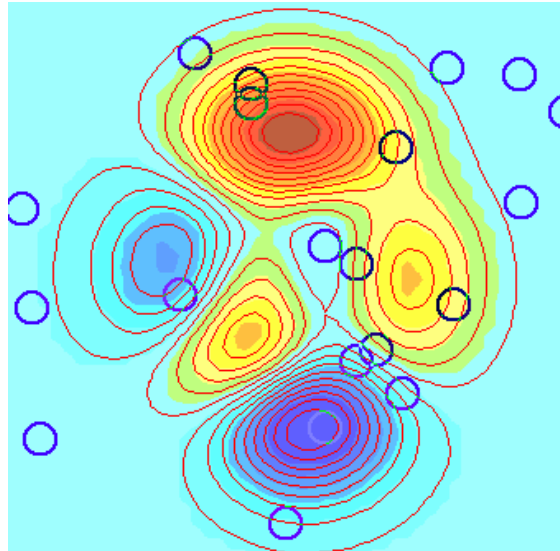
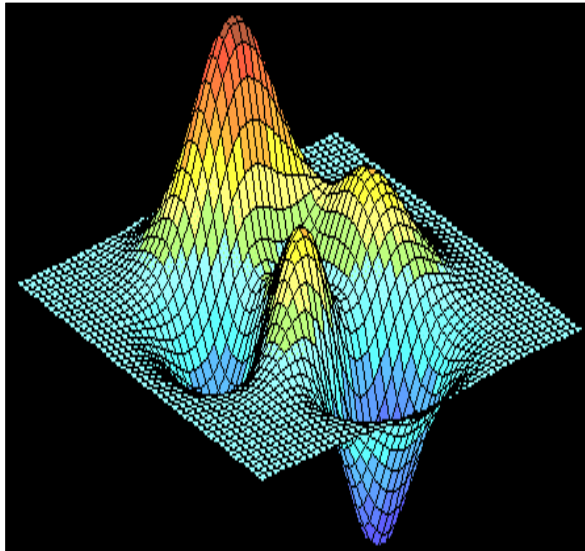
Computational Intelligence : EA Systems



Evolutionary Algorithms: Scalar-Valued Fitness Function Optimization

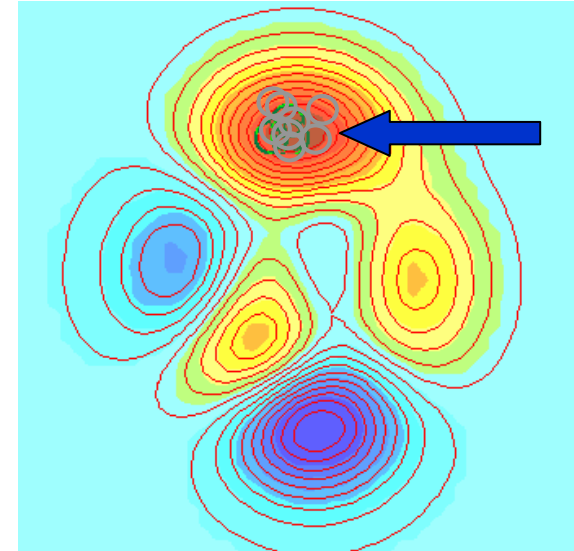
- Example: Find the maximum of the function $z(x,y)$

$$z = f(x, y) = 3*(1-x)^2*\exp(-(x^2) - (y+1)^2) - 10*(x/5 - x^3 - y^5)*\exp(-x^2-y^2) - 1/3*\exp(-(x+1)^2 - y^2).$$



Generation 0

Initialization of population providing a random sample of solution space



Generation 10

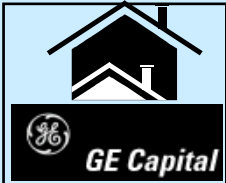
By evolving the individuals, we create a bias in the sampling and over-sample the best region(s) getting “close” to the optimal point(s)

CI Applications



Appliances

- Preferred Service Contracts (Stat.)
- Call Center Support (CBR)



Capital Services

- Mortgage Collateral Evaluation (Fusion/FL/CBR)



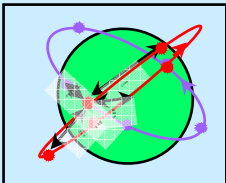
Financial Assurance

- GEFA LTC Preferred Customer (Stat./NN)
- GEFA Fixed Life Digital Underwriter (Stat, CBR, FL, GA)



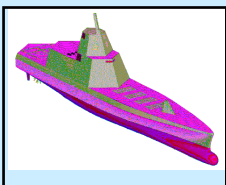
Plastics

- Automated Color Matching (CBR)



LM Fed. Systems

- Scheduling Maintenance for Constellation of Satellites (GA)



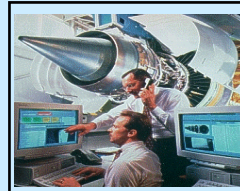
LM ORSS

- Vessel Management Syst. (AI/GA)



Medical Systems

- SPT Auto Analysis for MRI (FL)
- Reverse Engineering of Picker (FL)
- FE Analysis tool (FL)
- X-Ray error Logs Analysis (CBR)



Aircraft Engines

- Center for Remote Diagn. (CBR)
- Customer Response Center (CBR)
- Anomaly Detection (FL/Stat.)
- IMATE - Maintenance Advisor (NN/FL)
- Resolver Drift - Sensor Fusion (FL)



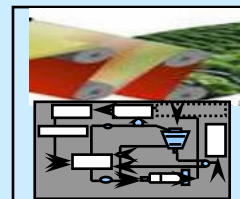
Transportation Systems

- Log from Transportation DB (CBR)
- Prototype Train Handling Cntrl. (FL/GA)
- Prototype Trend Analysis (Stat.)
- Embedded/Remote Diagnostics (BBN)



Power Gen. Systems

- Remote Anomaly Detection (Stat.)
- Embedded/Remote Diagnostics (BBN)
- Call Center Problem/Solution (CBR)



Industrial Systems

- Paper Web Breakage Prediction (NN/Stat./Induction)
- Control Mixing of Cement (FL/GA)

Enabling Soft Computing and Related Technologies

