BISC

The Berkeley Initiative in Soft Computing

Electrical Engineering and Computer Sciences Department

Berkeley

University of California

Neuro-Fuzzy-Evolutionary Computing

(NeF-ECom)

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Genetic and Evolutionary Computation Conference

June 25-29

Washington DC

Outline

- BISC Decision Support System
- Neuro-Fuzzy-Evolutionary Computing: NeF-ECom
  - Multi-Criteria Decision Analysis with Uncertain and Incomplete Information
- Application Areas
  - ASIS

BISC- Decision Support System

BISC-DSS

OBJECTIVES

Develop soft-computing-based techniques for decision analysis

- **Tools to assist decision-makers in assessing the consequences of decision made in an environment of imprecision, uncertainty, and partial truth and providing a systematic risk analysis;**
- **Tools to assist decision-makers answer "What if Questions", examine numerous alternatives very quickly and find the value of the inputs to achieve a desired level of output;**
- **Tools to be used with human interaction and feedback to achieve a capability to learn and adapt through time;**

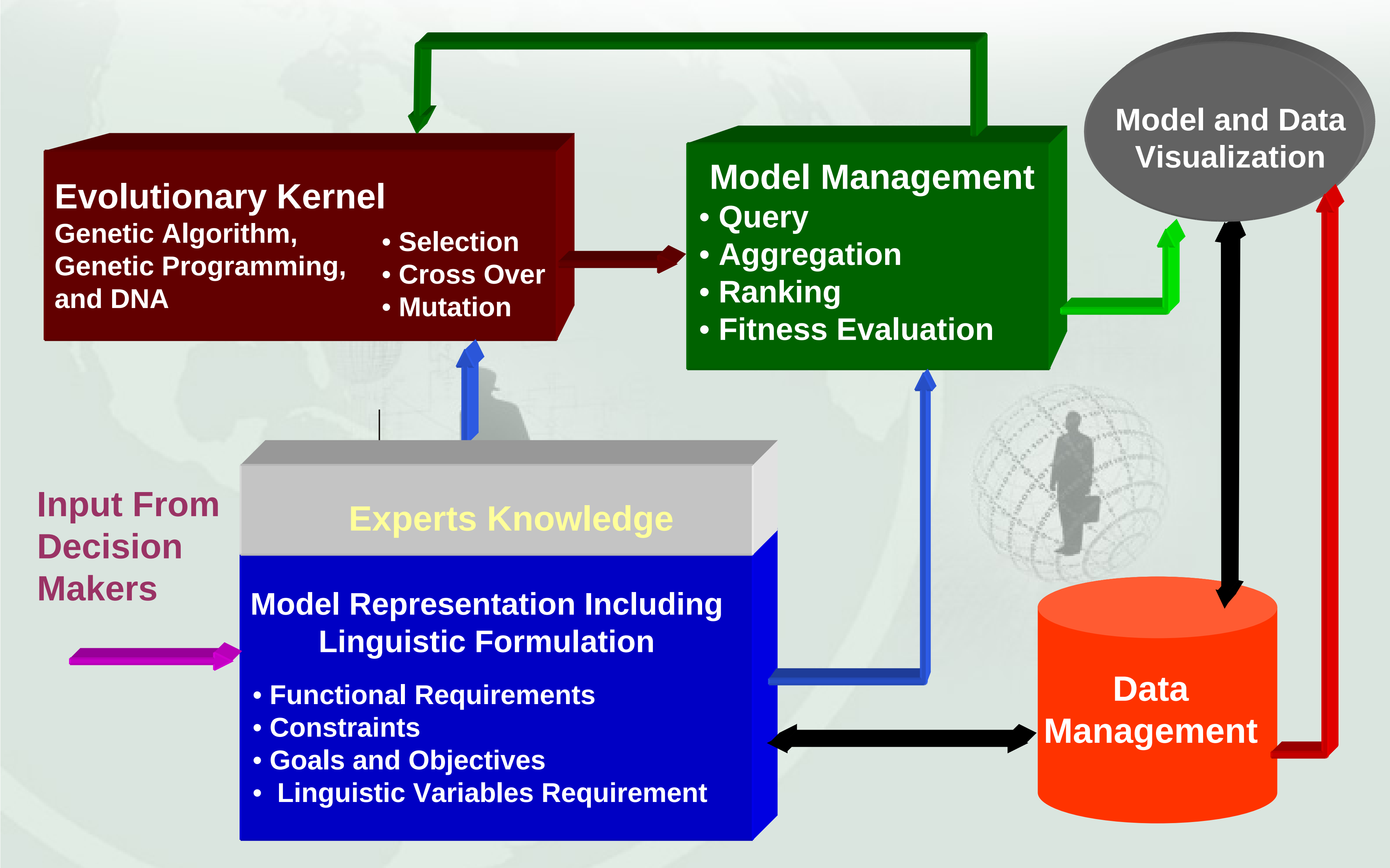
BISC - Decision Support System

DECISION ENVIRONMENT

- Information (Can be uncertain)
- Granular (Scale and Precision)
- Query (Can be imprecise)
- Measure (Similarity)
- Aggregation (Can be fuzzy)
- Ranking (Provide Alternatives)
- Optimization (Multi-Objective & Multi-Criteria)

BISC - Decision Support System

BISC DSS: Components and Structure



BISC - Decision Support System

Query (Request): Q

$$Q = f\left(v_1\{(\mu_1, \mu_2, \ldots), w_1\}, v_2\{(\mu_1, \mu_2, \ldots), w_2\}, \ldots\right)$$

v_i : Variables

μ_i: Degree in which v_i belong to a certain grade

w_i : Preferences

- find if such query exists ➔ degree of match ➔ rank ➔ decision (i.e. resource allocation)
- compare queries ➔ rank ➔ decision (task allocation)
- Use Fuzzy Min-Max with degree of preferences

BISC - Decision Support System

Objective function: Cost Function/ Fitness Function

$$J = \sum_k \left[\frac{\sum_i^n \left(f\left(v_i\{(\mu_1, \mu_2, \ldots), w_i\}\right) \mathrm{I} \ \hat{f}\left(v_i\{(\mu_1, \mu_2, \ldots), w_i\}\right) \right)}{\sum_i^n \left(f\left(v_i\{(\mu_1, \mu_2, \ldots), w_i\}\right) \mathrm{Y} \ \hat{f}\left(v_i\{(\mu_1, \mu_2, \ldots), w_i\}\right) \right)} \right]_k$$

This may involve multi-objective, multi-criteria optimization with conflict and fuzzy variables. *Therefore, use fuzzy-GA to solve the objective function.*

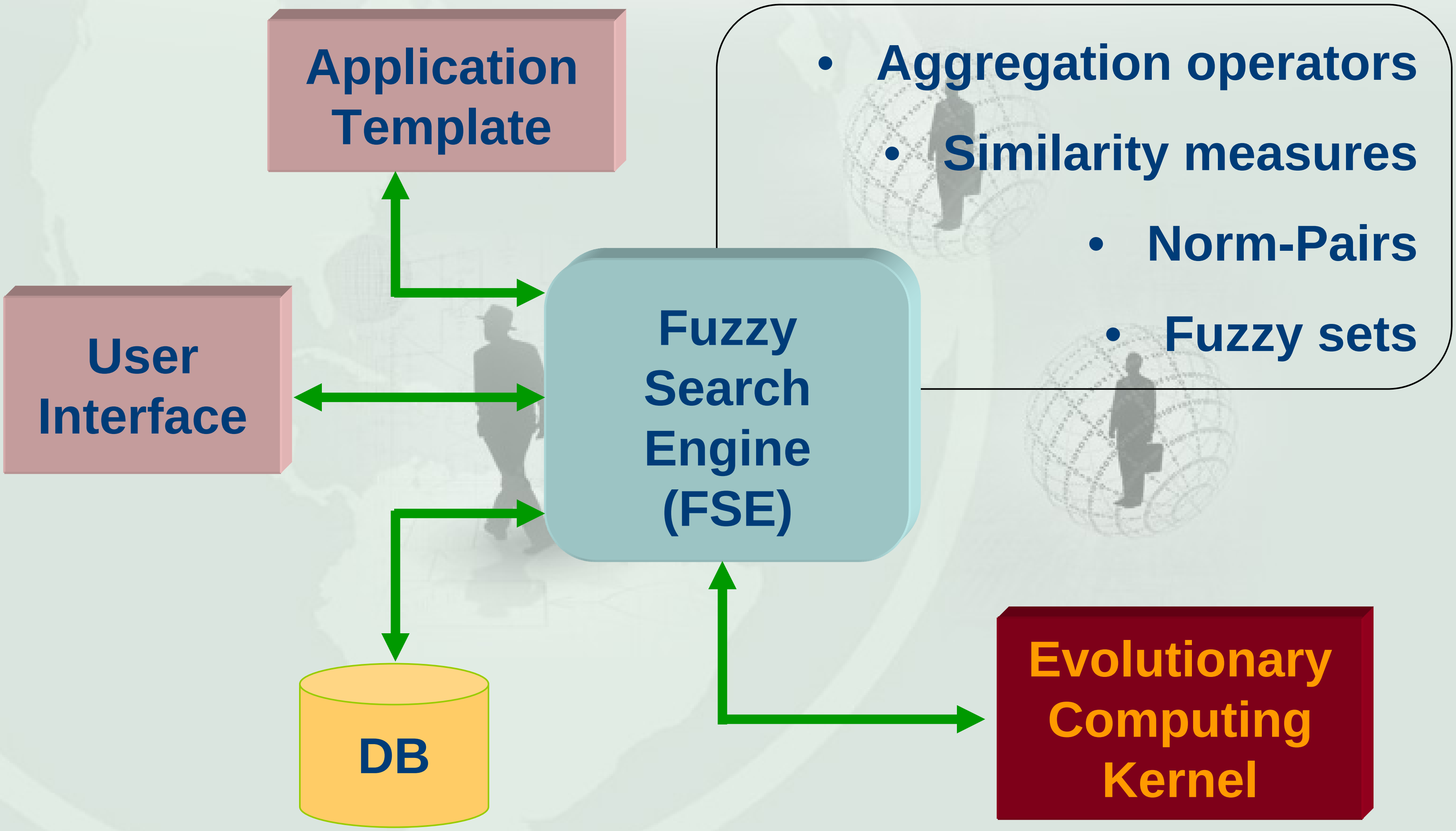
Neuro-Fuzzy-Evolutionary Computing

Multi-Criteria Decision Analysis with Uncertain and Incomplete Information

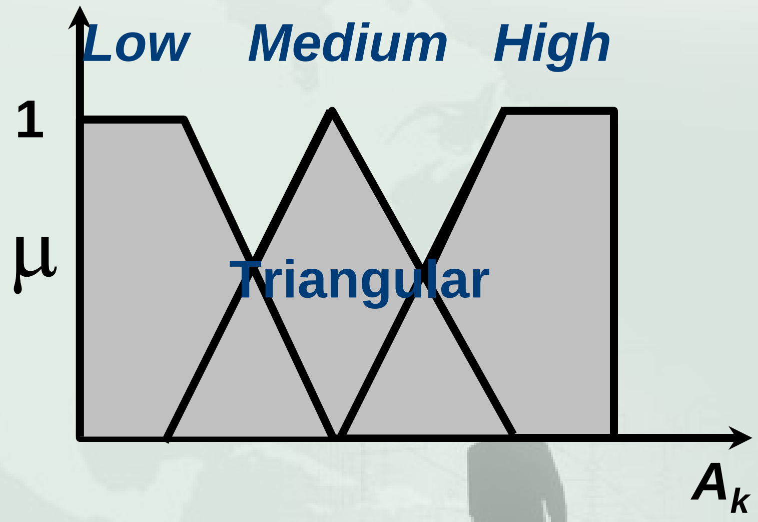
NeF-ECom

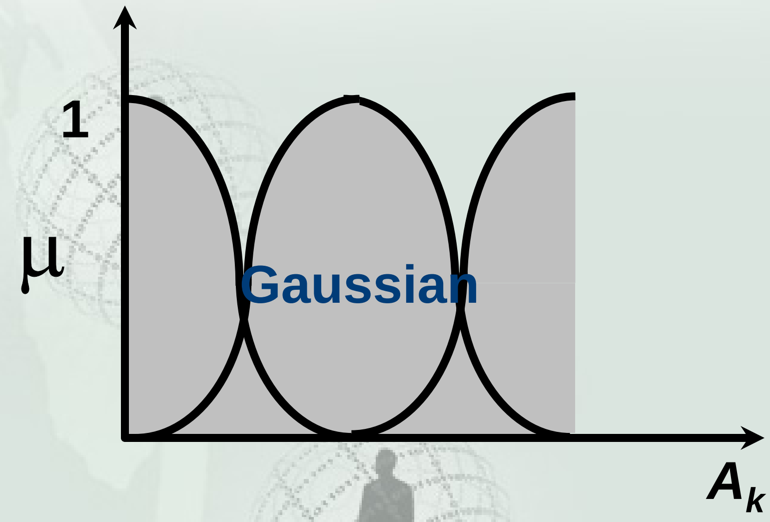
BISC - Decision Support System

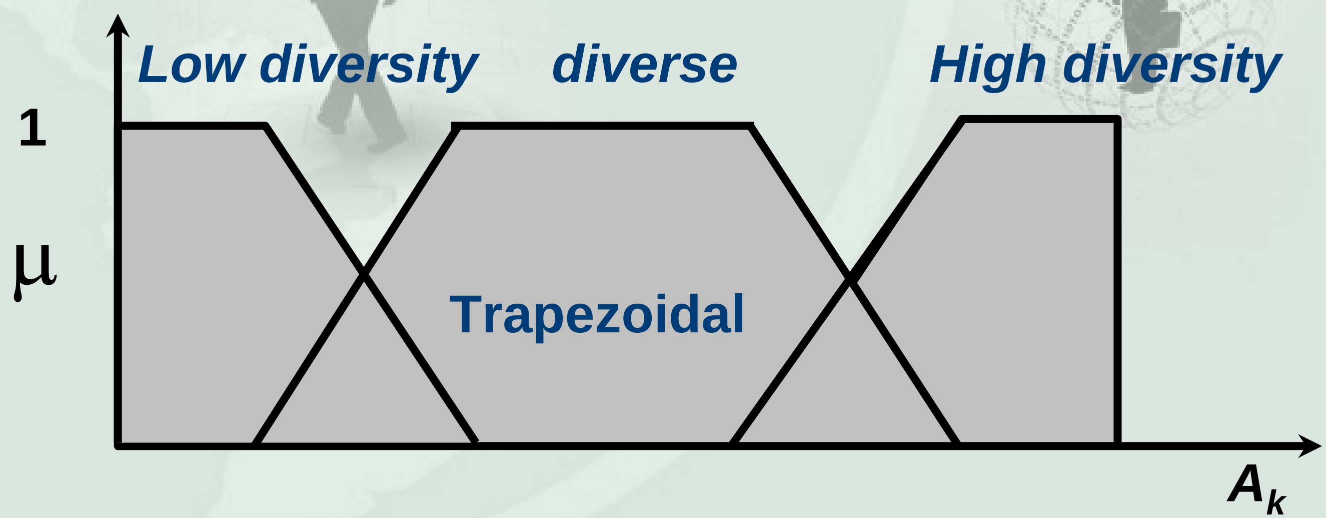
BISC – DSS Software: Architecture



Fuzzy sets/ Membership Functions (MFs)







Fuzzy similarity measures

$$\text{Simple matching}: \ |X \cap Y|$$

$$\text{Dice}: \ 2\frac{|X \cap Y|}{|X| + |Y|}$$

$$\text{Jaccard}: \ \frac{|X \cap Y|}{|X \cup Y|}$$

$$\text{Cosine}: \ \frac{|X \cap Y|}{|X|^{1/2} \times |Y|^{1/2}}$$

$$\text{Overlap}: \ \frac{|X \cap Y|}{\min(|X|, |Y|)}$$

X and Y are fuzzy measures defined over the same fuzzy sets with MFs:

$\mu_1, \mu_2, \ldots, \mu_m$

Norm-Pair operators $\cap$ et $\cup$ (norm-conorm)

Norm-Pairs

	Fuzzy AND [$\cap$]	Fuzzy OR [$\cup$]
MinMax	$\min(x, y)$	$\max(x, y)$
Algebraic	$x \times y$	$x + y - x \times y$
Bounded	$\max(0, x + y - 1)$	$\min(1, x + y)$
Drastic	$\begin{cases} \min(x, y) \; if \; \max(x, y) = 1 \\ 0 \quad else \end{cases}$	$\begin{cases} \max(x, y) \; if \; \min(x, y) = 1 \\ 1 \quad else \end{cases}$
Einstein	$(x \times y) / (2 - (x + y - x \times y))$	$(x + y) / (1 + (x \times y))$
Hamacher	$(x \times y) / (x + y - x \times y)$	$(x + y - 2 \times x \times y) / (1 - (x \times y))$

x and *y* are MF values in [0,1].

Aggregation Operators

$$\textbf{Arithmetic Mean}: \frac{1}{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{n}} x_i$$

$$\textbf{Geometric Mean}: \left(\prod_{\mathrm{i}=1}^{\mathrm{n}} x_i \right)^{\frac{1}{n}}$$

$$\textbf{Harmonic Mean}: \frac{\mathrm{n}}{\sum_{i=1}^{n} \frac{1}{x_i}}$$

$$\textbf{Minimum}: \min\left(x_1, x_2, \Lambda, x_n\right)$$

$$\textbf{Maximum}: \max\left(x_1, x_2, \Lambda, x_n\right)$$

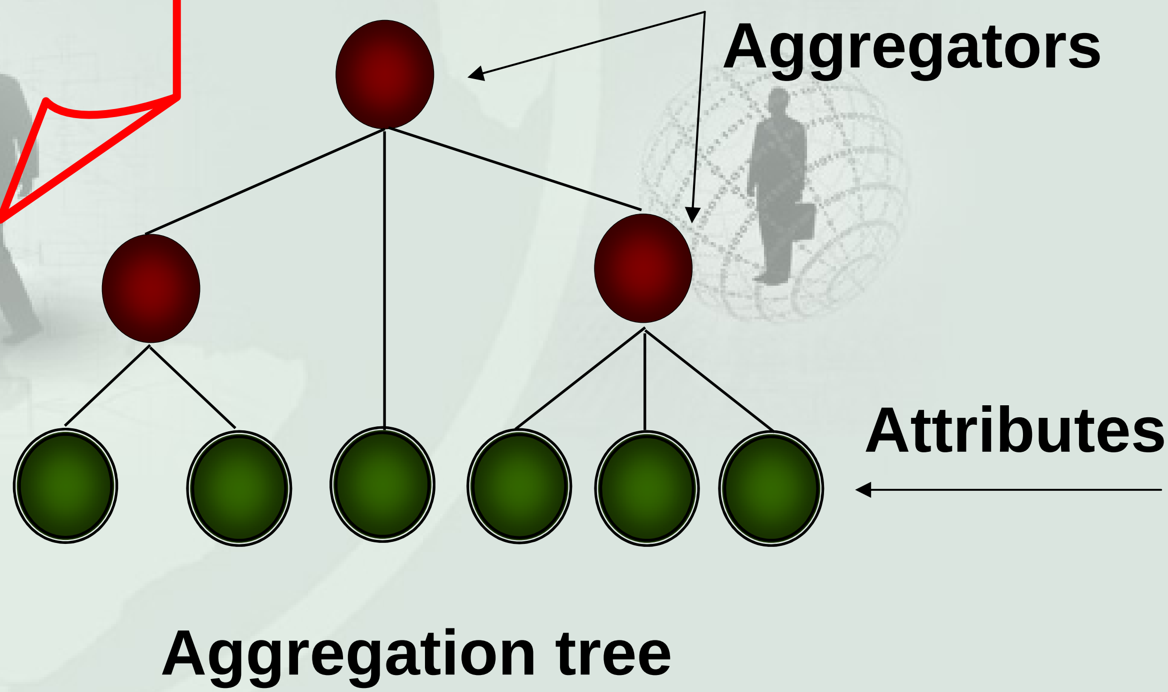
Weighted Aggregation Operators

$$\left.\begin{array}{l}
\textbf{Weighted Mean}: \sum_{i=1}^{n} w_i \times x_i \\[2ex]
\textbf{Weighted Geometric Mean}: \prod_{i=1}^{n} x_i^{\,w_i} \\[2ex]
\textbf{Weighted Harmonic Mean}: \dfrac{1}{\sum_{i=1}^{n} w_i \times \dfrac{1}{x_i}}
\end{array}\right\} \text{with}: \sum_{i=1}^{n} w_i = 1$$

$$\left.\begin{array}{l}
\textbf{Weighted Minimum}: \min_{i=1}^{n}\left(\max\left(1 - w_i, x_i\right)\right) \\[2ex]
\textbf{Weighted Maximum}: \max_{i=1}^{n}\left(\min\left(w_i, x_i\right)\right)
\end{array}\right\} \text{with}: \max_{i=1}^{n}\left(w_i\right) = 1$$

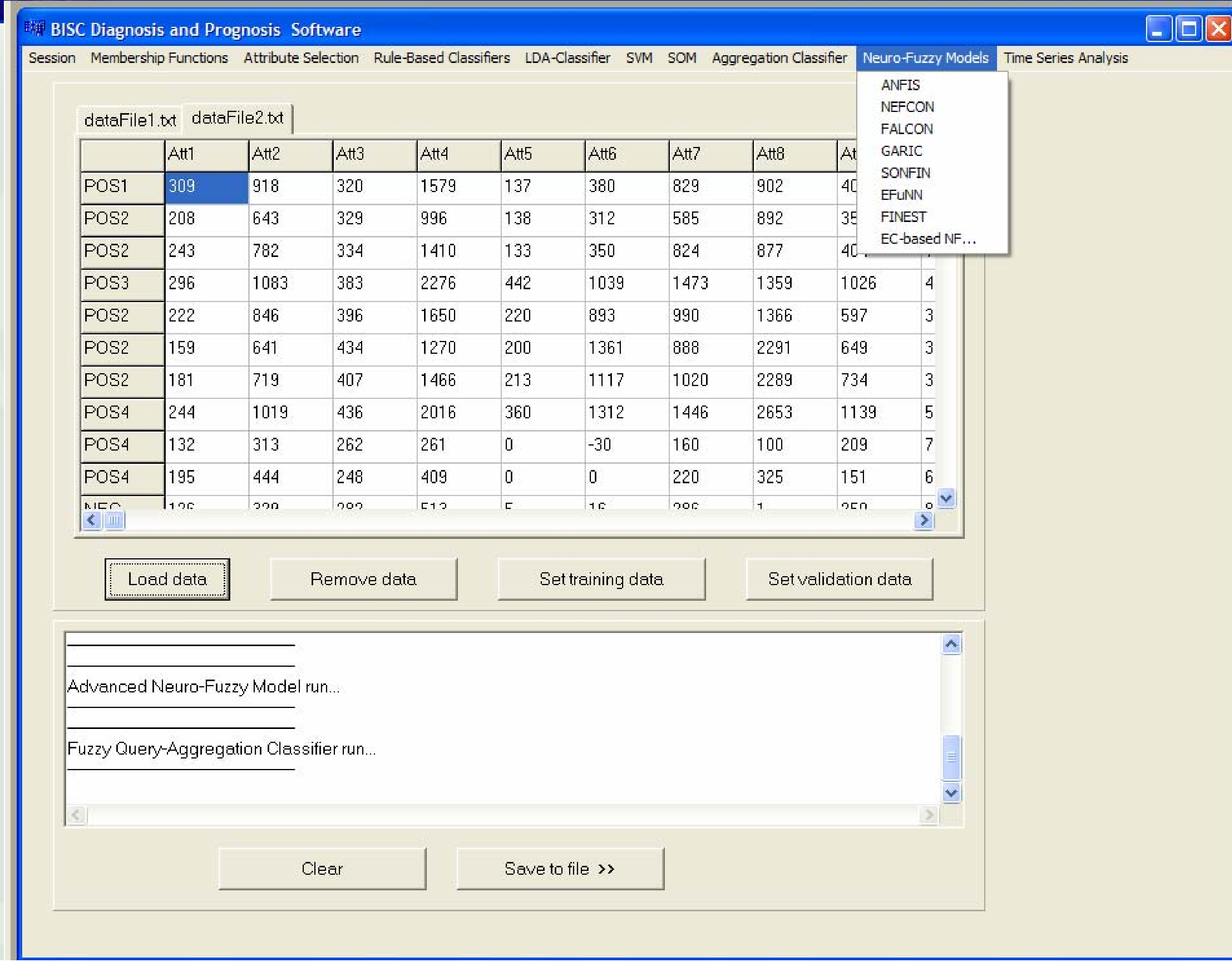
Advanced Multi-Aggregator Model

- **Parameters**
  - aggregators
  - weights
  - tree structure.



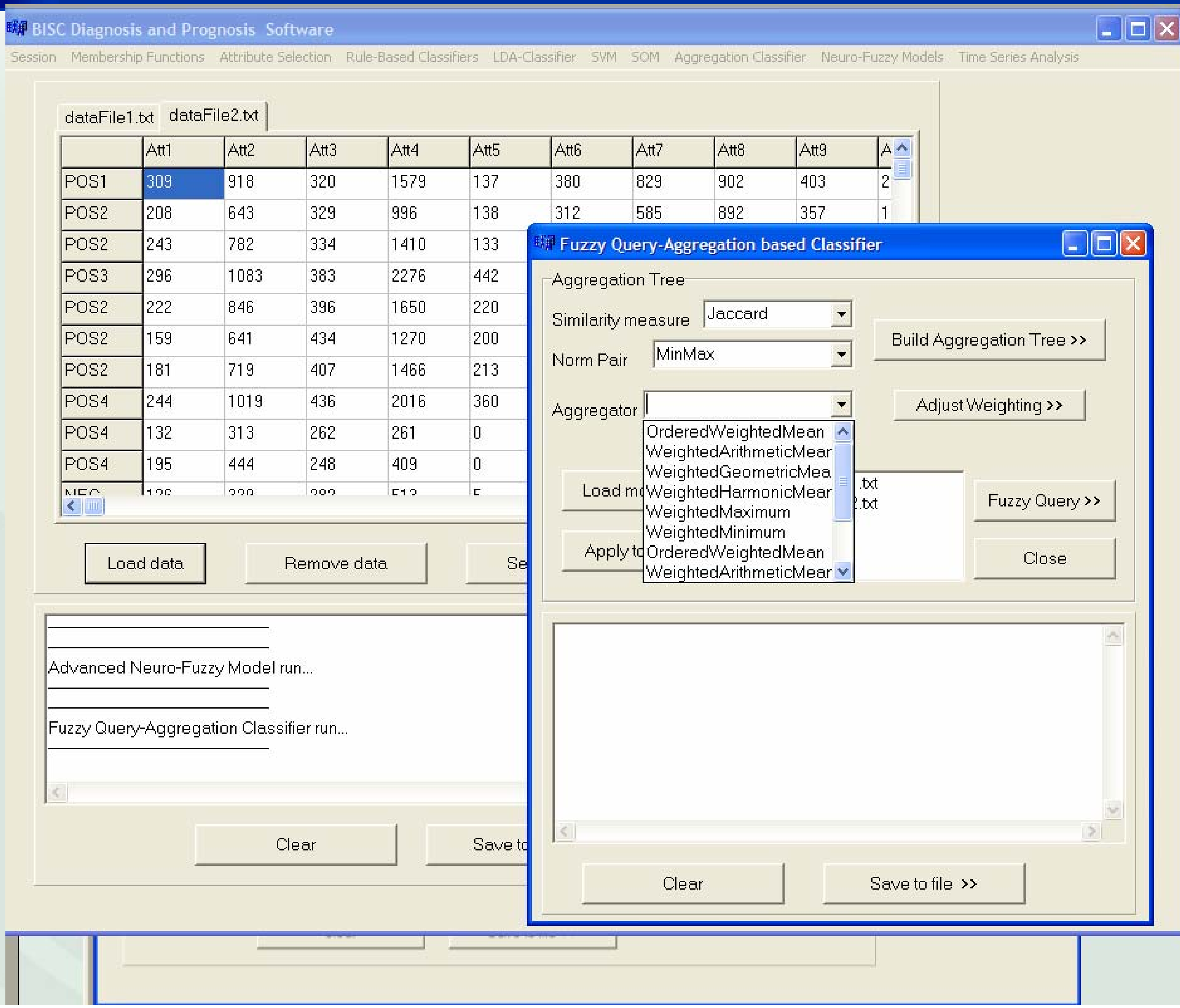
BISC - Decision Support System

BISC-DSS Software



BISC - Decision Support System

BISC-DSS Software



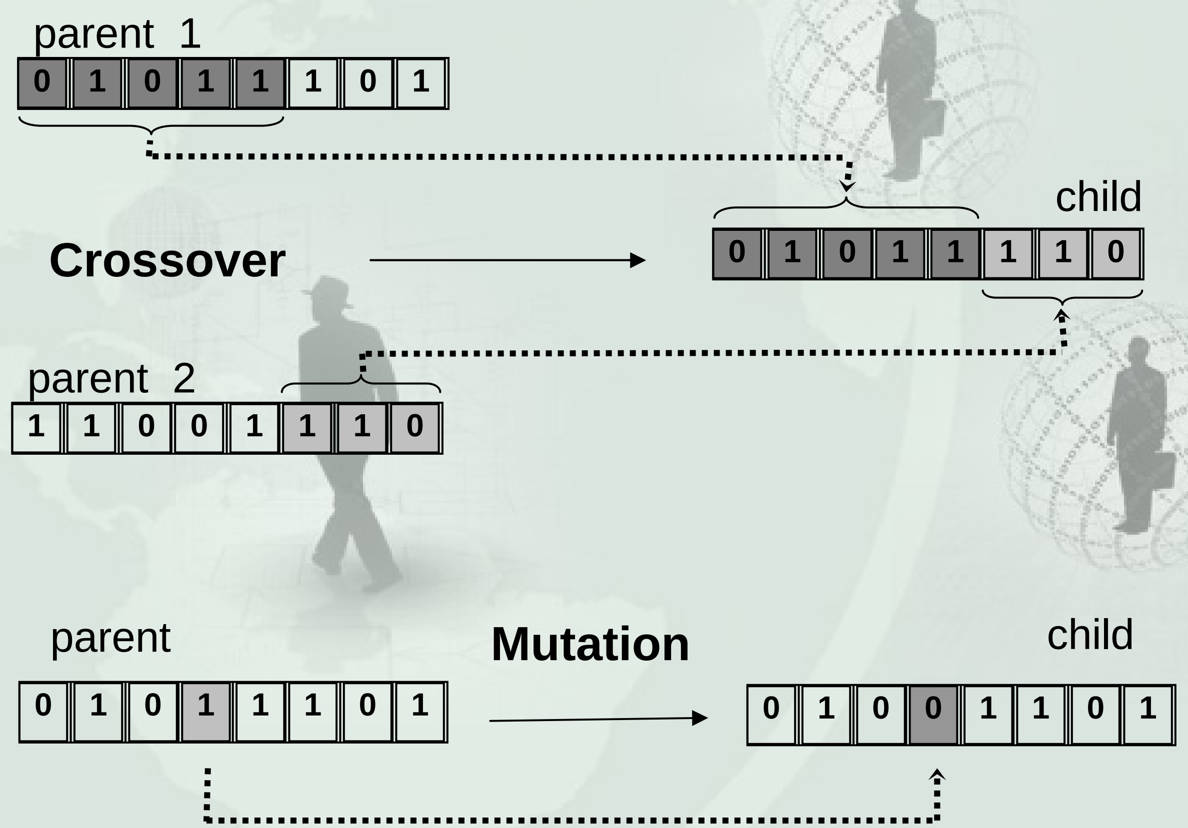
Requirements

- Individual :problem representation
- Fitness function: for evaluation
- Termination criterion

Principle:

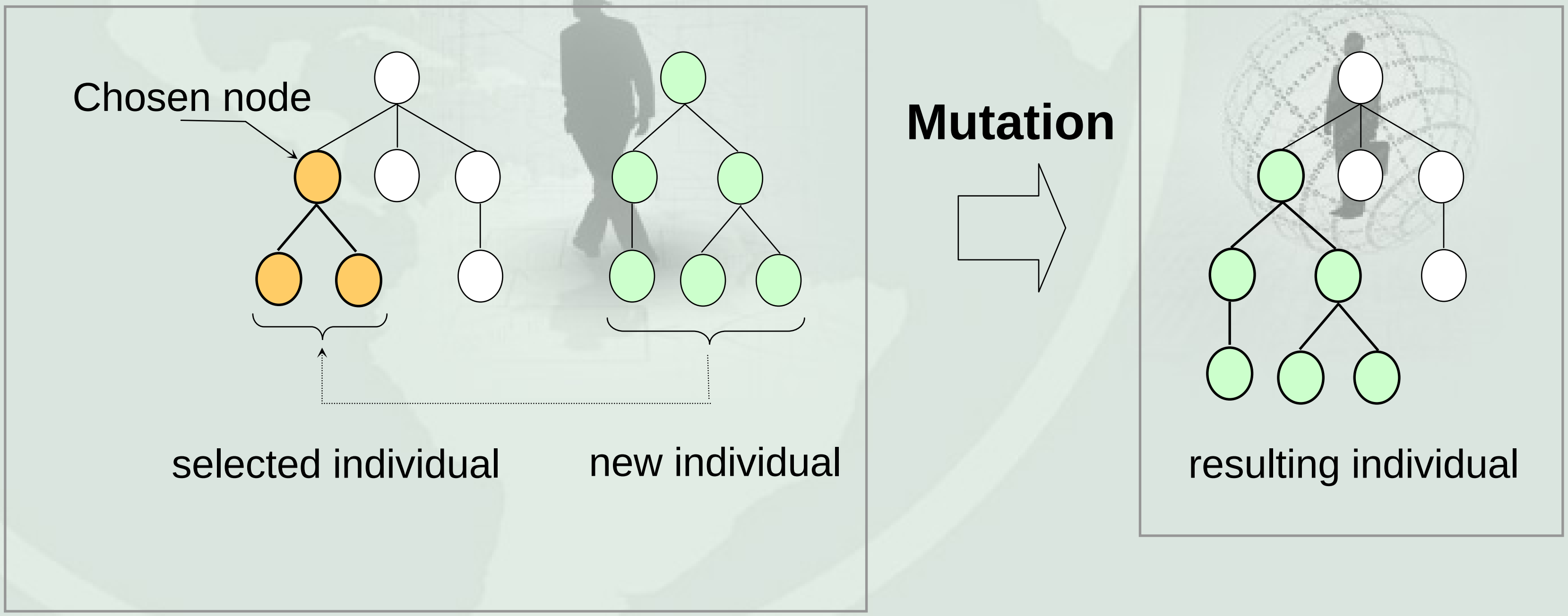
- Create randomly an initial population of individuals
- Evolve the population:
    - evaluate and select individuals
    - use them in genetic operators (crossover, mutation)
    - generate new generation
- Stop if termination criterion satisfied

Genetic Operators



EC: Genetic Programming

- Individual = Computer program
- Most common representation : tree encoding (nodes = functions, leaves = terminals)
- Fitness function = returned value by the root node



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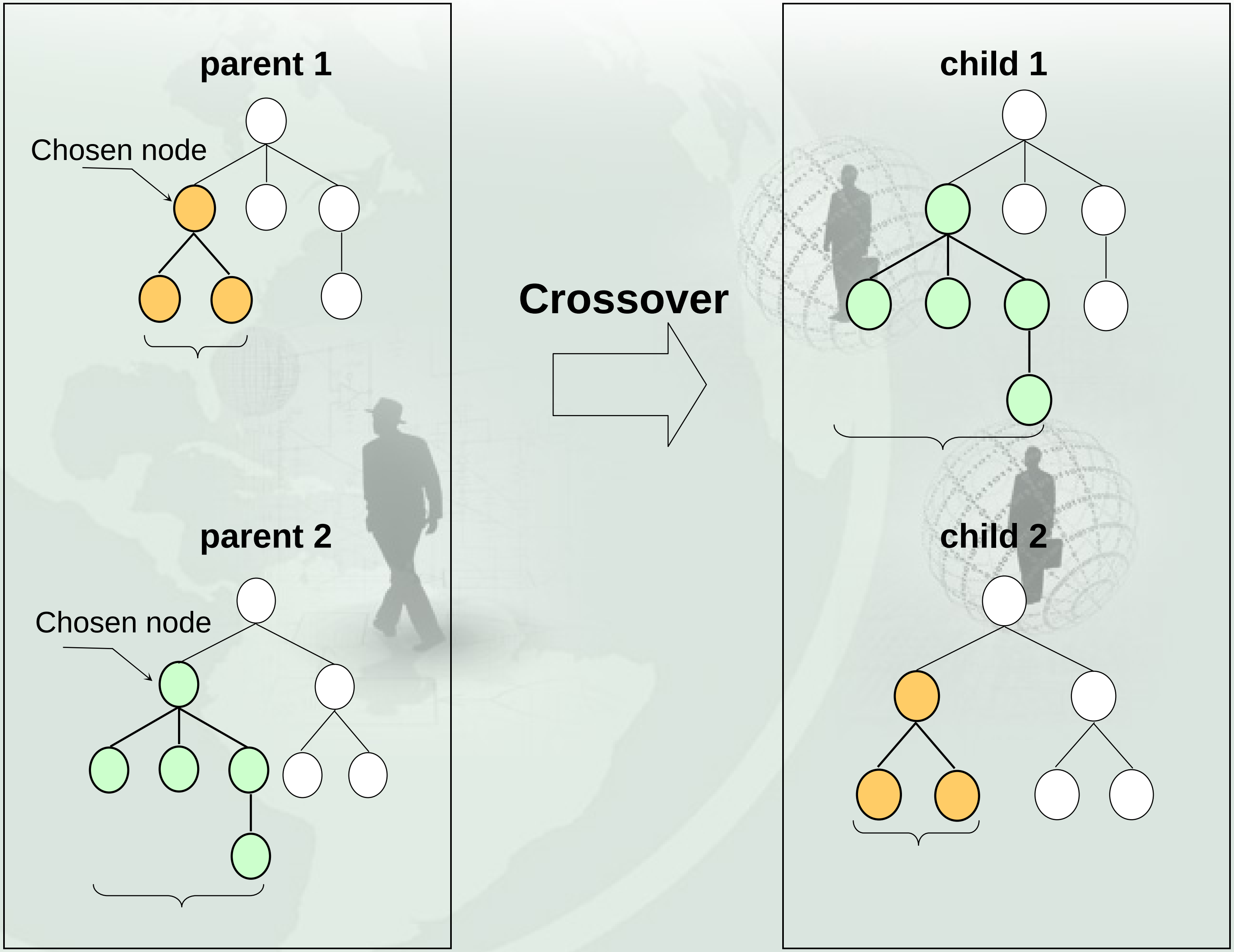
EC: Genetic Programming



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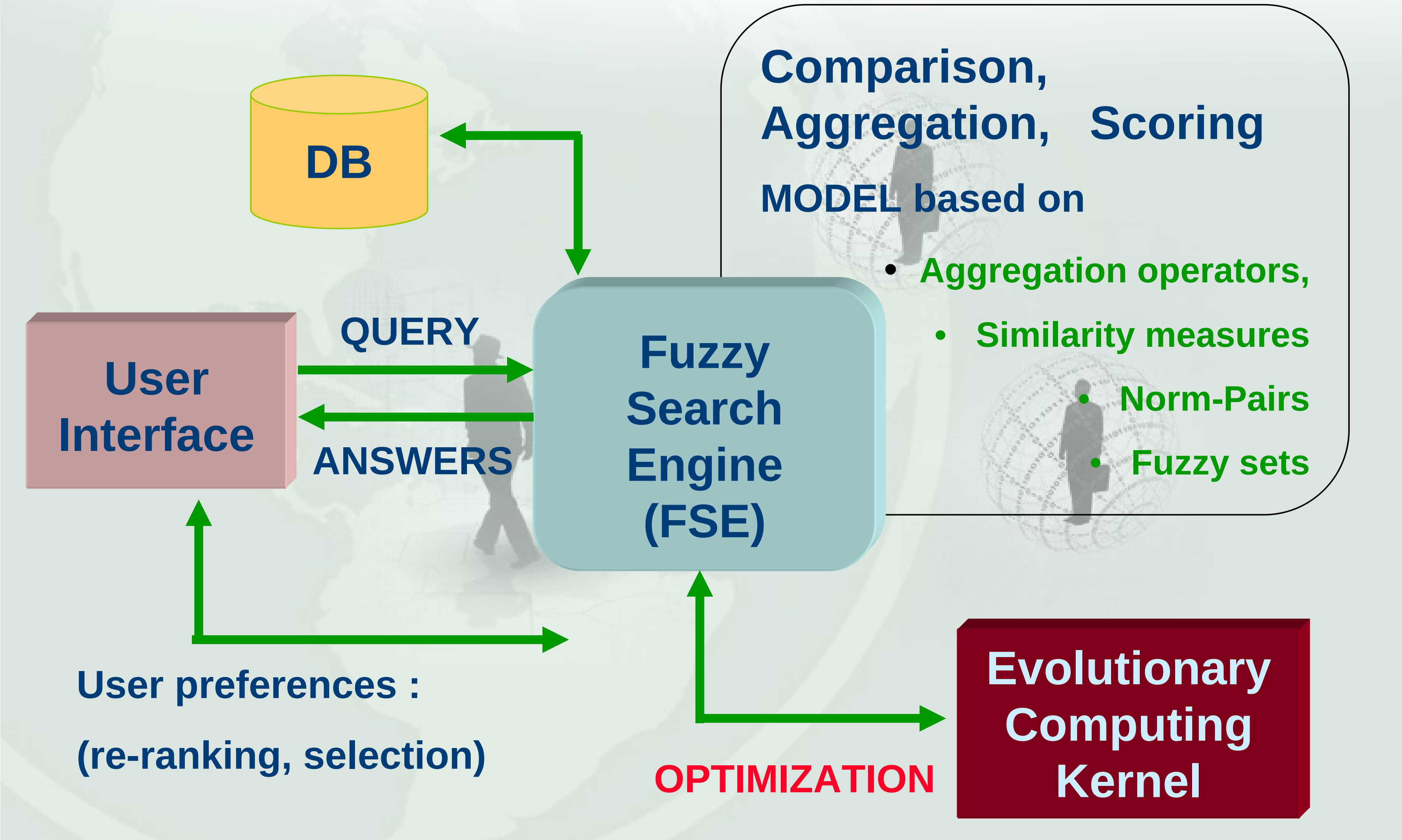
BISC-DSS: Interaction and Optimization



Multi-Criteria Decision Model (1)

Multi-Attribute Query: K attributes $A_1, A_2, \ldots, A_K$

Database

x_{11}	x_{12}	.....	x_{1K}
x_{21}	x_{22}	.....	x_{2K}
	⋮		
x_{N1}	x_{N2}	.....	x_{NK}

Similarity calculation

Query

y_1	y_2	.....	y_K

Scores

S_1
S_2
⋮
S_N

Query Answering

Ranking based
(criteria: number top answers)

Selection based
(criteria: threshold)

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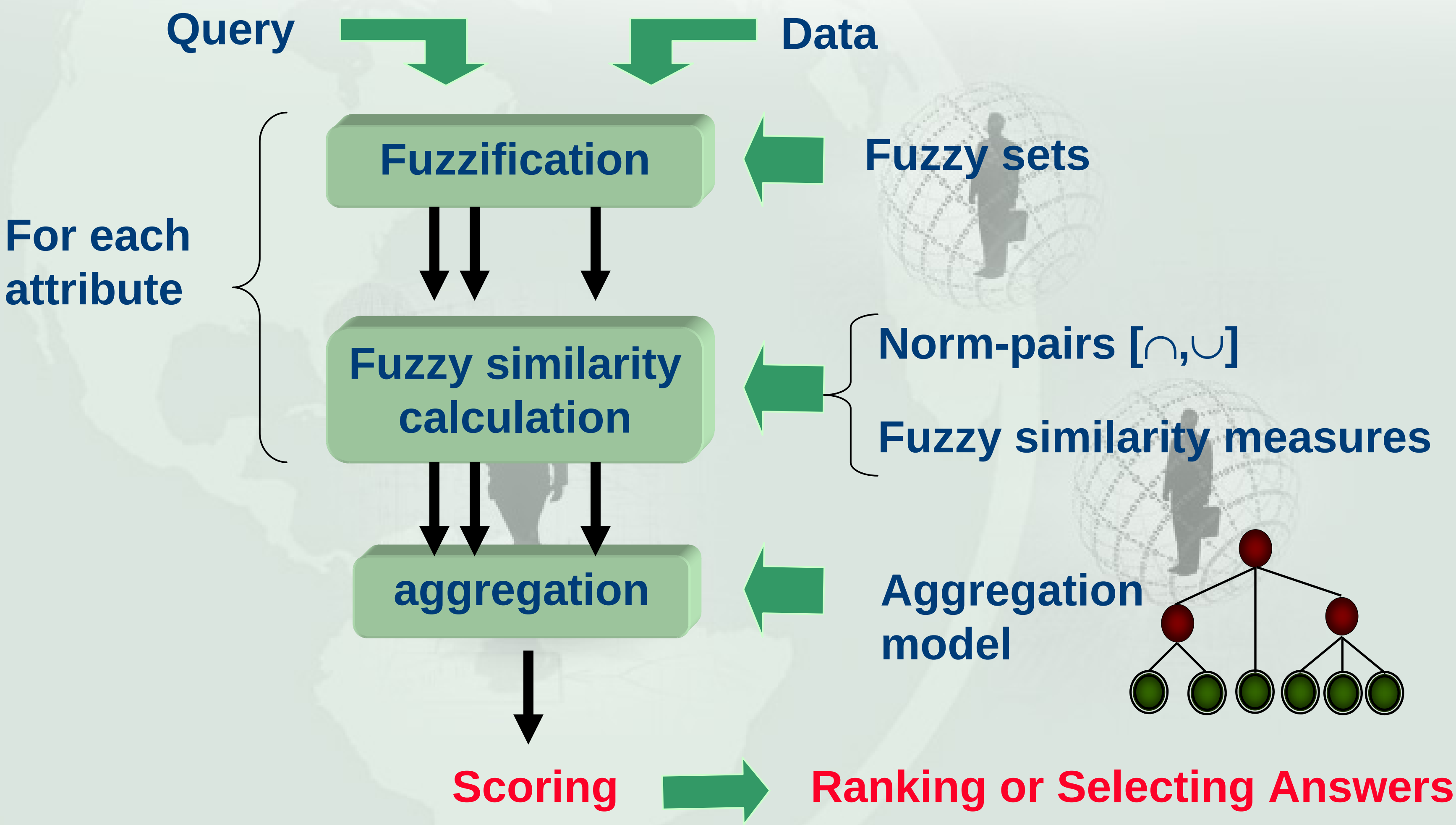
Multi-Criteria Decision Model (2)



Multi-Criteria Decision Model (3)

Data: $X_i = (x_{i1}, x_{i2}, \ldots, x_{iK})$, **Query:** $Q = (y_1, y_2, \ldots, y_k)$

K **attributes:** $A_1, A_2, \ldots, A_K$

For each attribute A_j ***:***

r_j ***fuzzy sets*** $\mu_1(Aj,.), \mu_2(A_j,.), \ldots, \mu_{rj}(A_j,.)$

$s_j = similarity(x_{ij}, y_j)$, $j = 1, 2, \ldots, K$

$$Score = SIM(Q,X_i) = Aggregation(s_1, s_2, \ldots, s_k)$$

First Order Aggregation Model (1)

- **Norm-pair: *Min/Max***
- **Fuzzy similarity measure: *Jaccard***
- **Aggregation operator: *Weighted Mean***

$$SIM(Q, X_i) = \sum_{j=1}^{M} w_j \times Jaccard(y_j, x_{ij}), \text{ with } \sum_{j=1}^{M} w_j = 1$$

$$Jaccard(y_j, x_{ij}) = \frac{\left| y_j \cap x_{ij} \right|}{\left| y_j \cup x_{ij} \right|}$$

$$y_j \cap x_{ij} = \left[Min(\mu_k(A_j, y_j), \mu_k(A_j, x_{ij})) \right]_{k=1,\ldots,r_j}$$

$$y_j \cup x_{ij} = \left[Max(\mu_k(A_j, y_j), \mu_k(A_j, x_{ij})) \right]_{k=1,\ldots,r_j}$$

First Order Aggregation Model (2)

Aggregation model = simple weighted aggregation operator

user preferences = attribute weighting

(Degree of importance of each attribute)

Aggregation model parameters = weighting vector

Optimization process : find the optimal weights Using GA.

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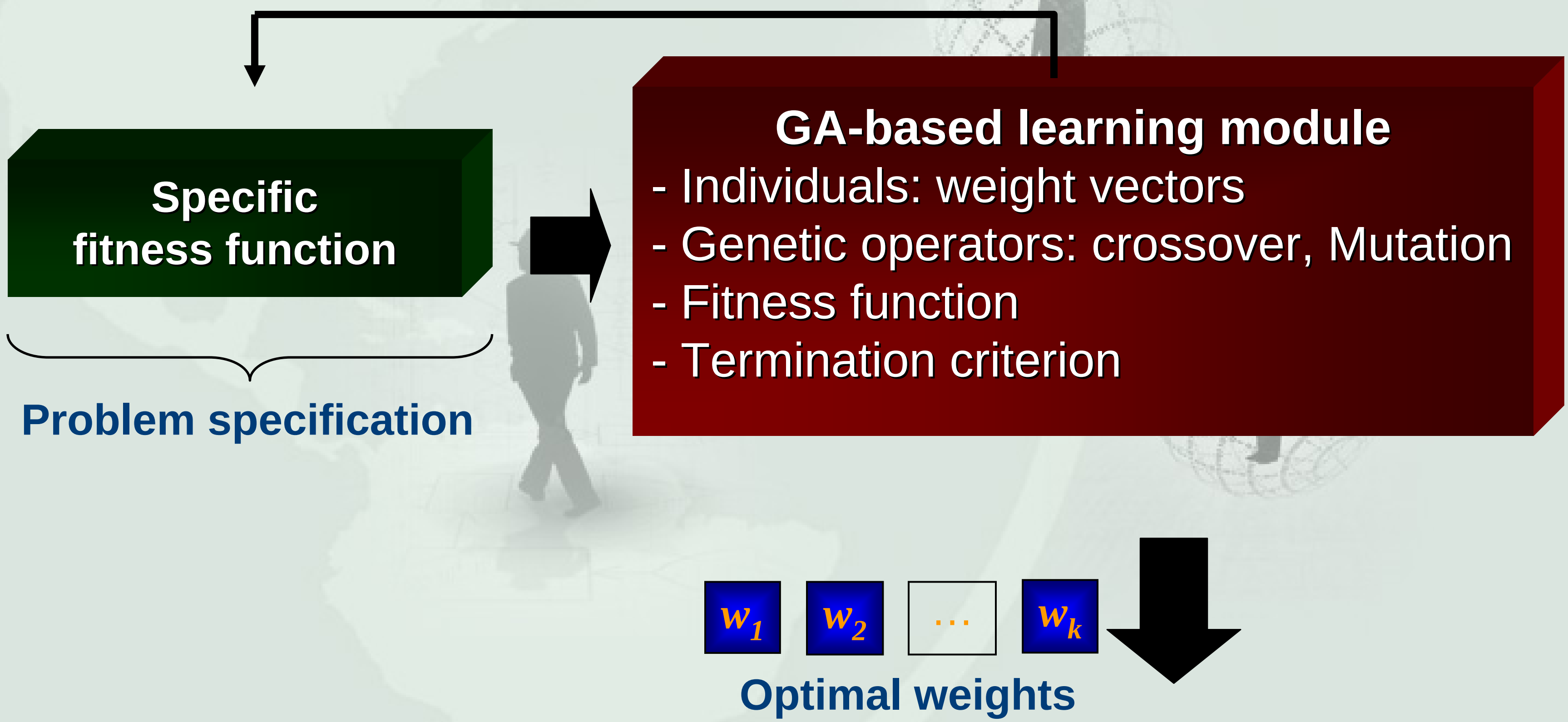
First Order Aggregation Model (3)

- **Model parameters learning using GA**



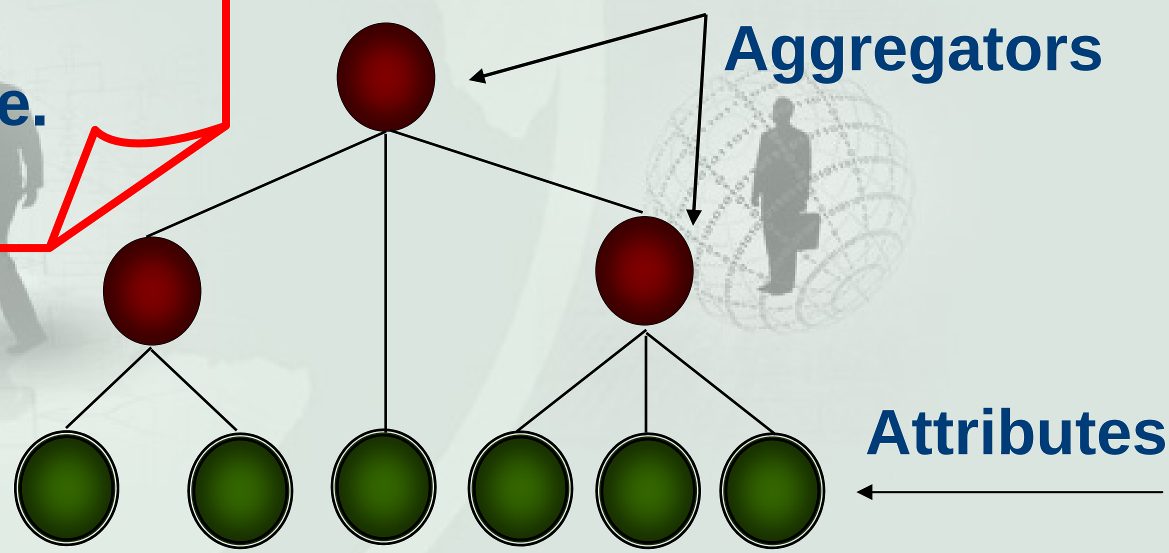
Advanced Multi-Aggregator Model (1)

- **parameters**
  - similarity measures
    - norm-pairs
  - aggregation operators
    - weights
  - aggregation model structure

Representation of user/expert preferences

Advanced Multi-Aggregator Model (2)

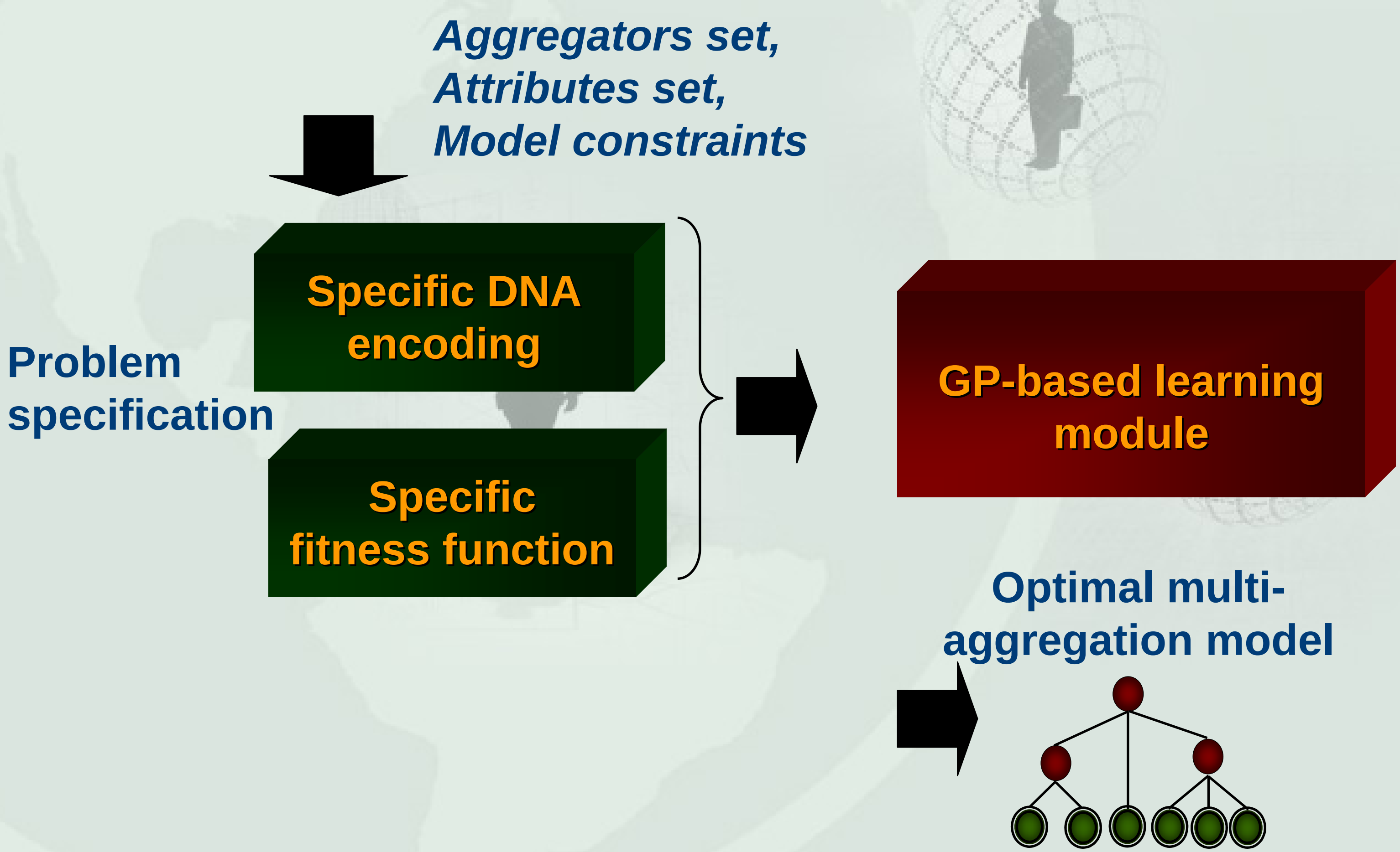
- Model description
  - Parameters
    - aggregators
    - weights
    - tree structure.



Aggregation tree

Advanced Multi-Aggregator Model (3)

- Model parameters learning using GP



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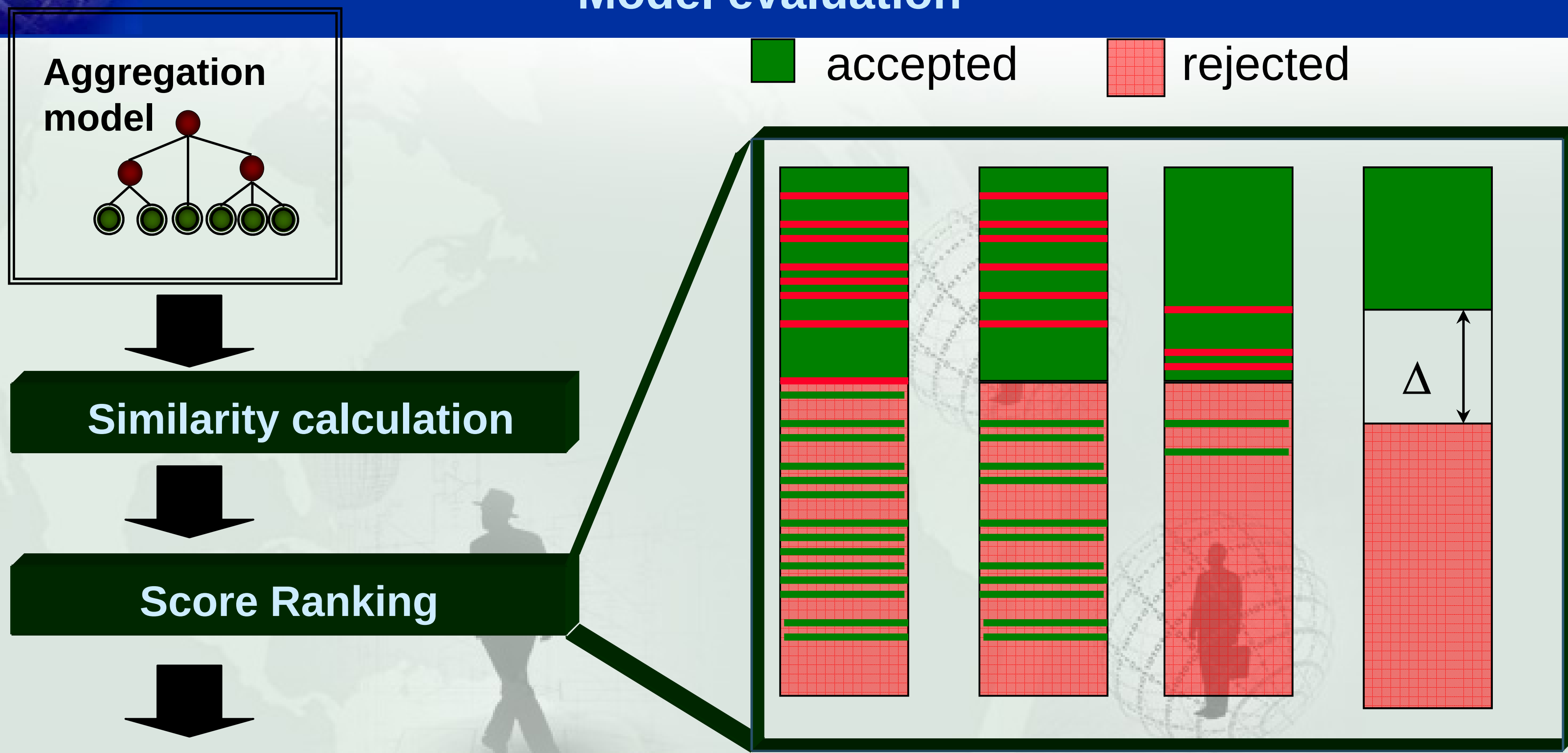
Model evaluation



Fitness function combining :

- **accuracy rates to <u>maximize</u>**
- **distance Δ to <u>maximize</u>**
- **model structure size to <u>minimize</u>**

Other Applications

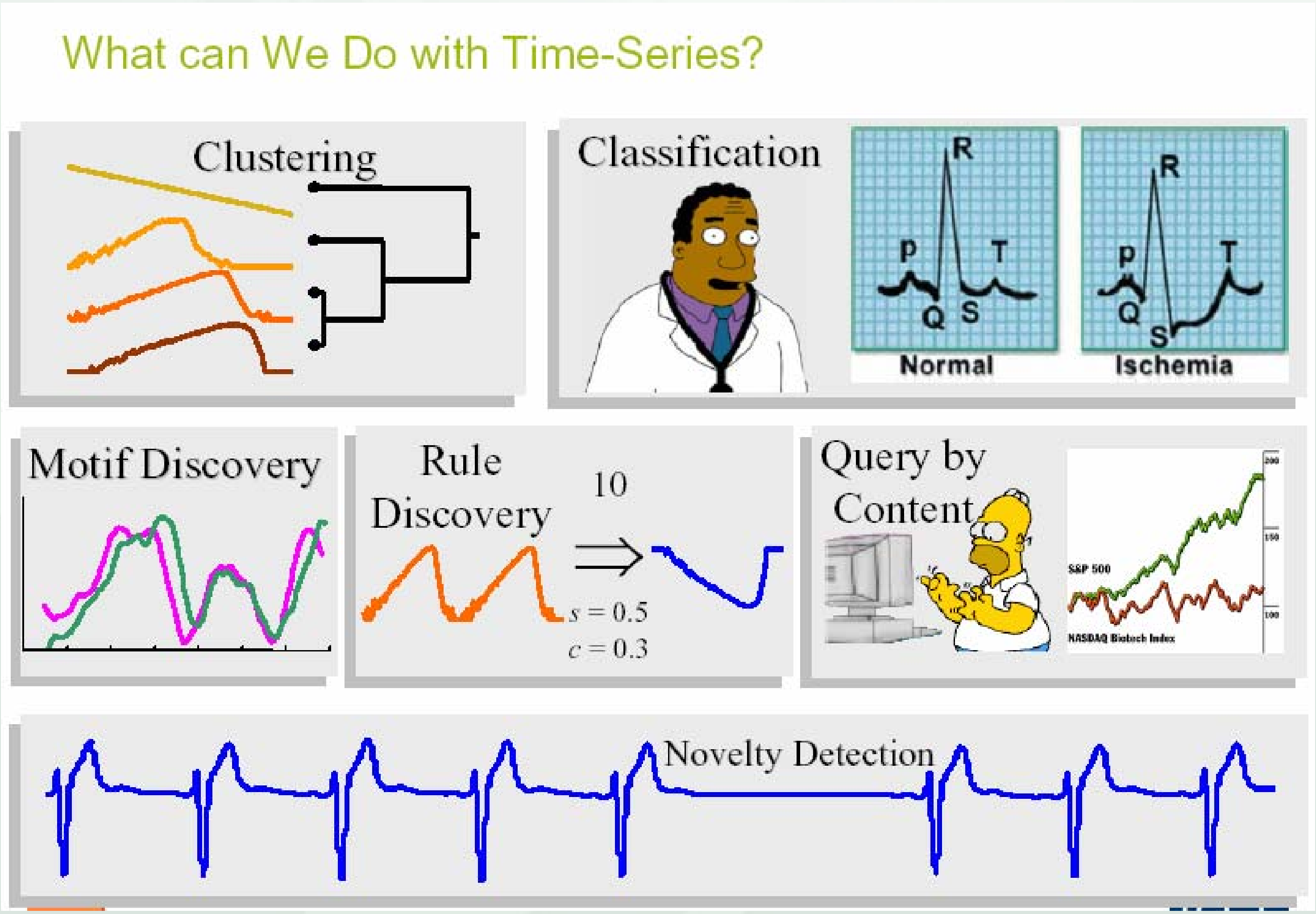
Application	Description
Finance	• stock prices and characteristics, credit scoring, credit card ranking
Military	• battlefield simulation and decision making
Medicine	• diagnosis
Marketing	• store and product display • electronic shopping
Internet	• provide knowledge and advice to large numbers of user
Education	• university admission
Banking	• fraud detection

Automated Sensory Inspection System

ASIS

BISC - Decision Support System

Applications



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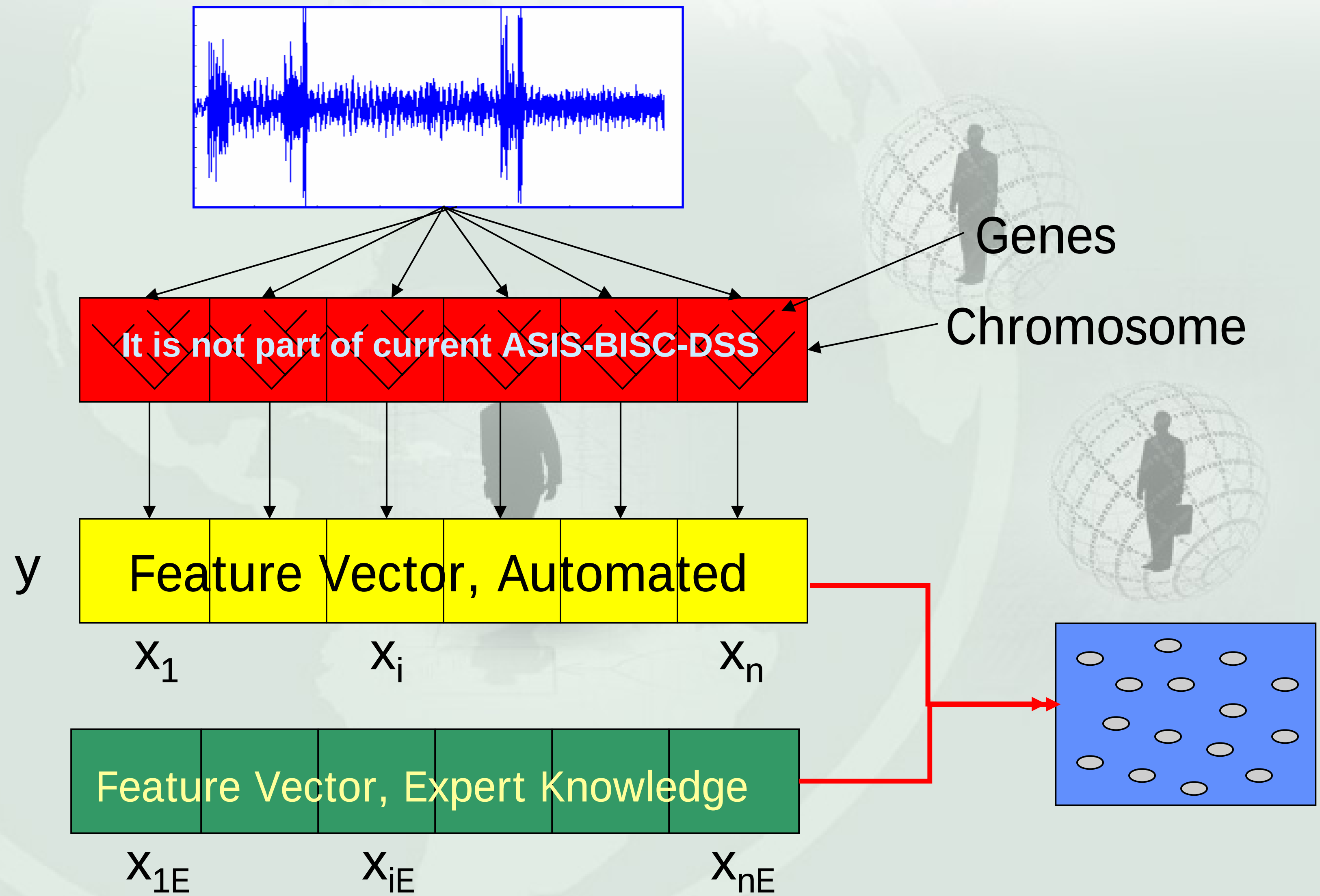
Chromosome Representation



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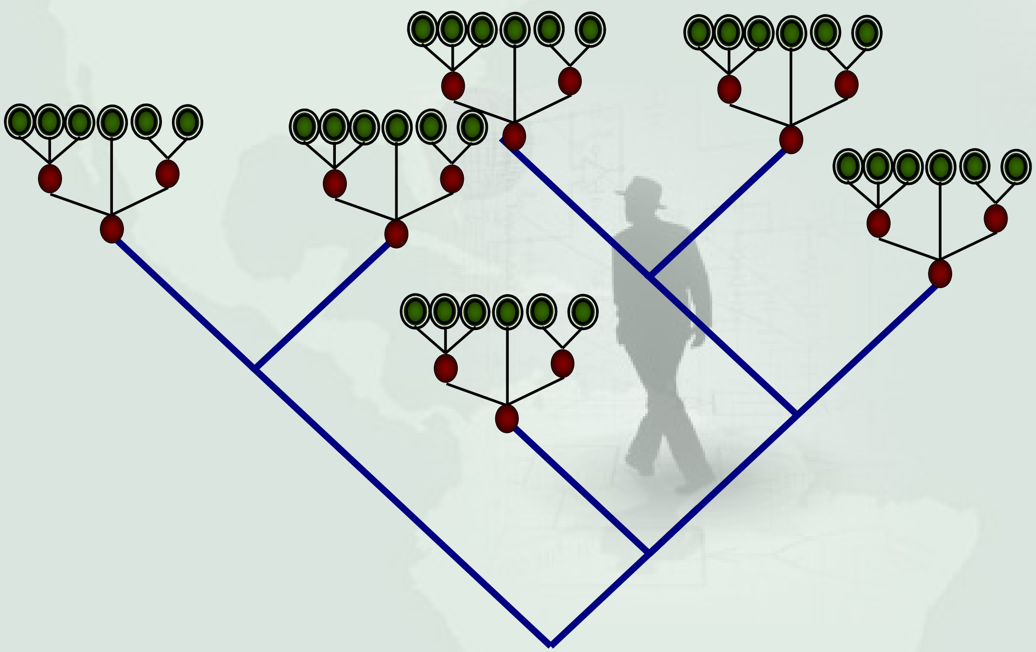
Chromosome Representation

Fuzzy Label, Set Value, Scalar & Series Input



Scalar & Fuzzy Label Features

- Composed of primitive statistical, fuzzy set, aggregator, similarity, arithmetic, and signal processing operators.
- Each gene (or algorithm) is represented as a tree, accepts both scalar and series input, and outputs scalar features.
- The chromosome produces a feature vector set.

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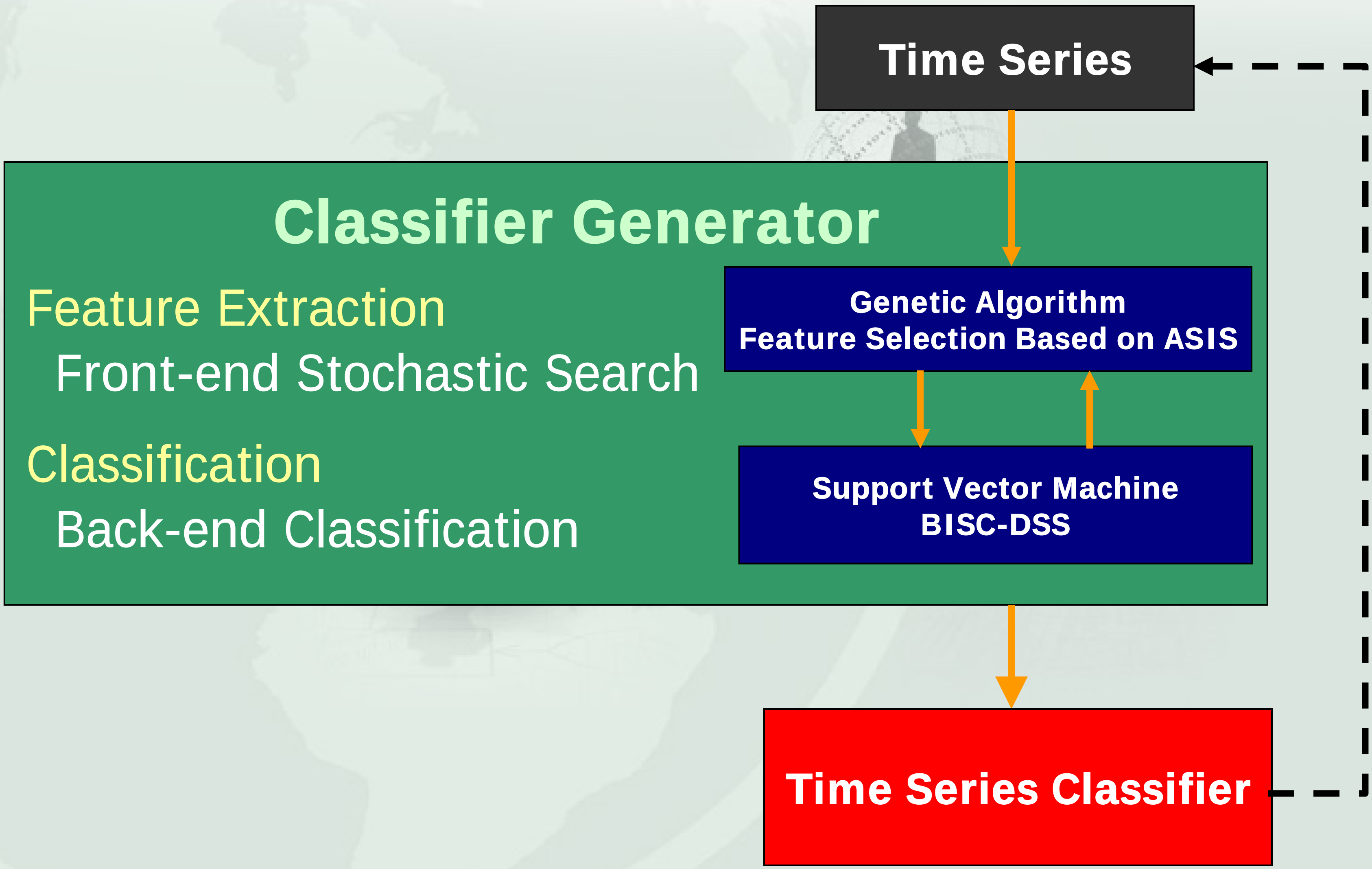
Front/Back-end Architecture



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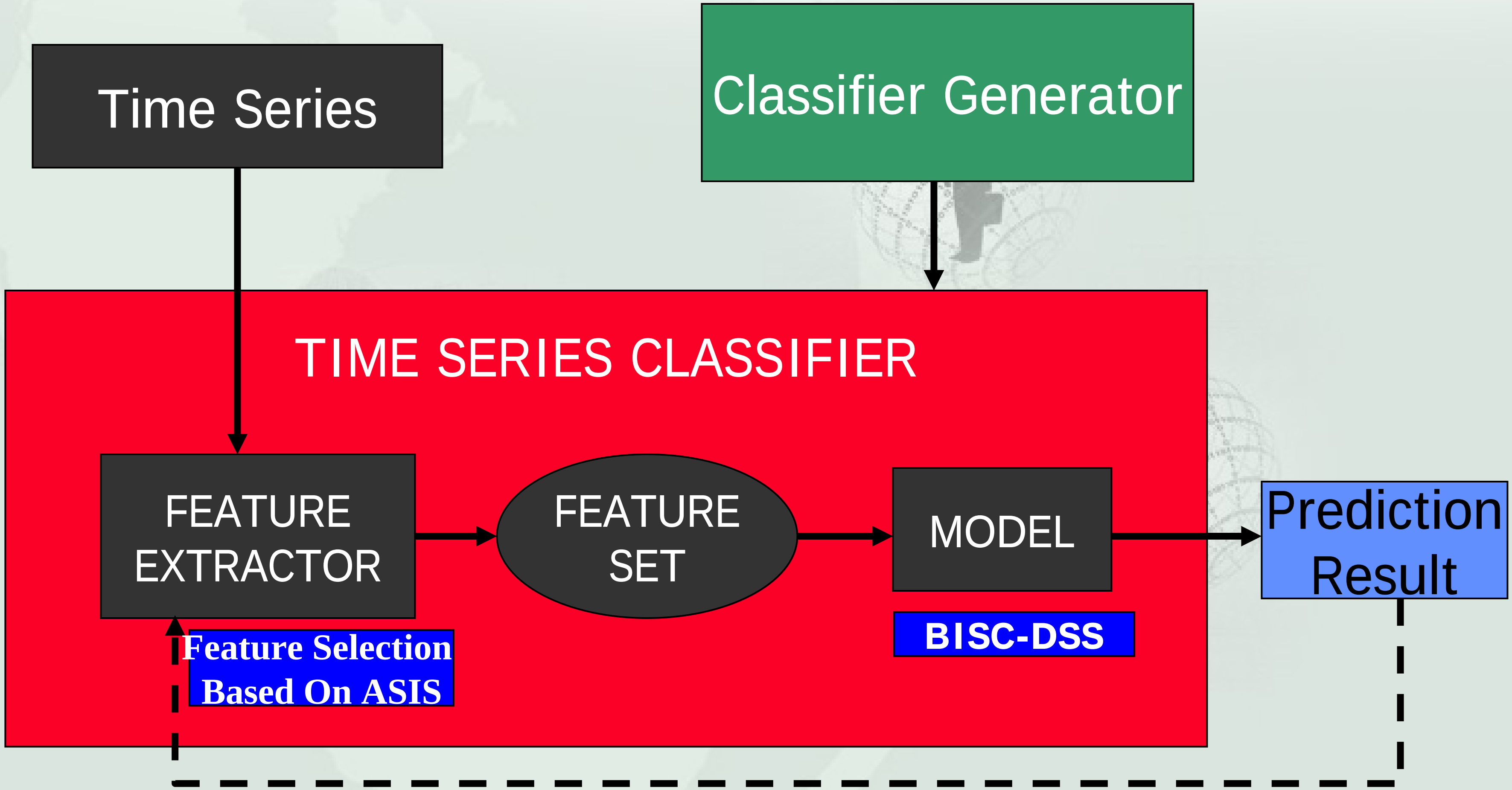
Classifier Architecture



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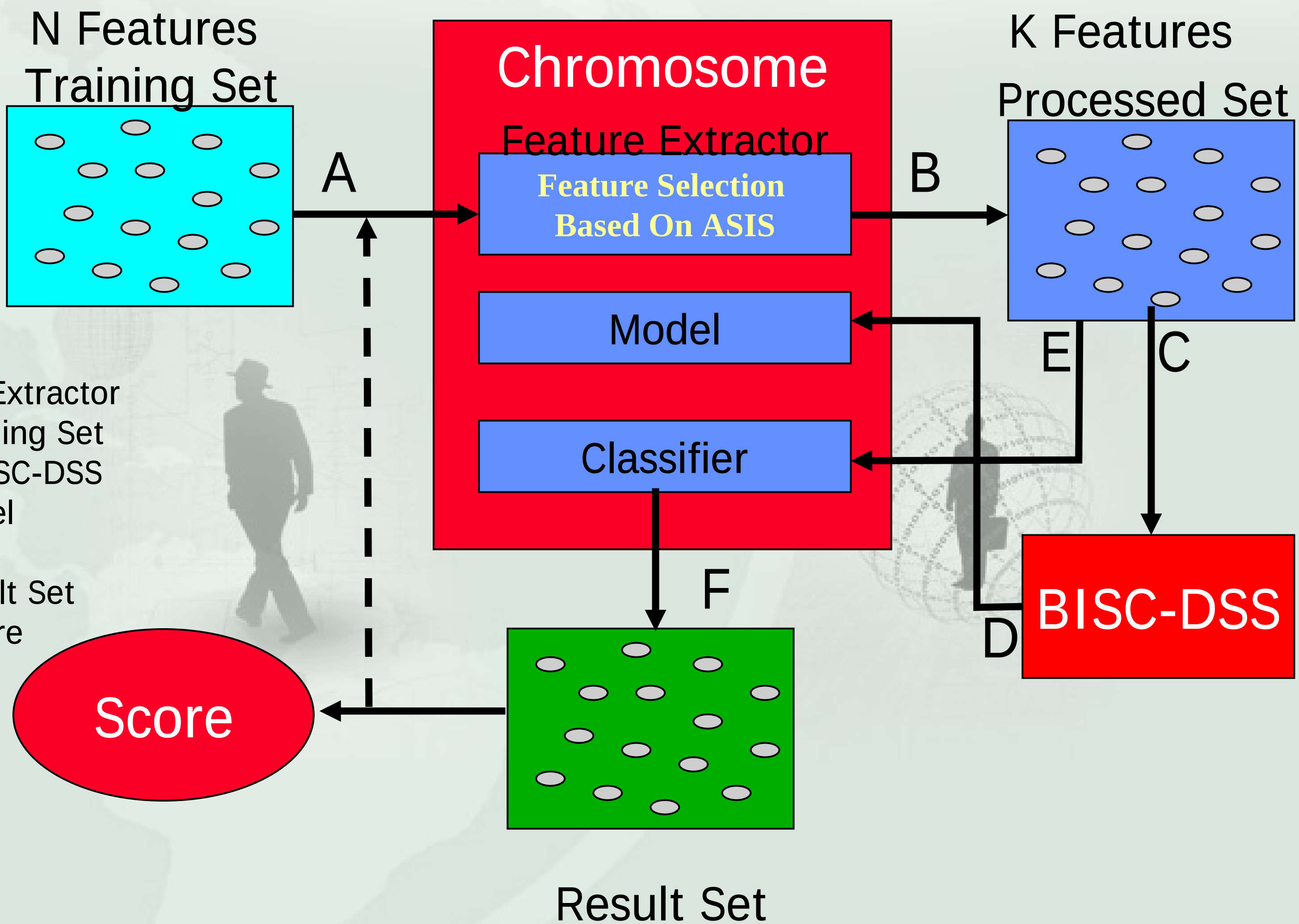
Fitness: In-sample Rate



Steps:

A. Run Feature Extractor
B. Produce Training Set
C. Train SVM/BISC-DSS
D. Produce Model
E. Run Classifier
F. Produce Result Set
G. Calculate Score

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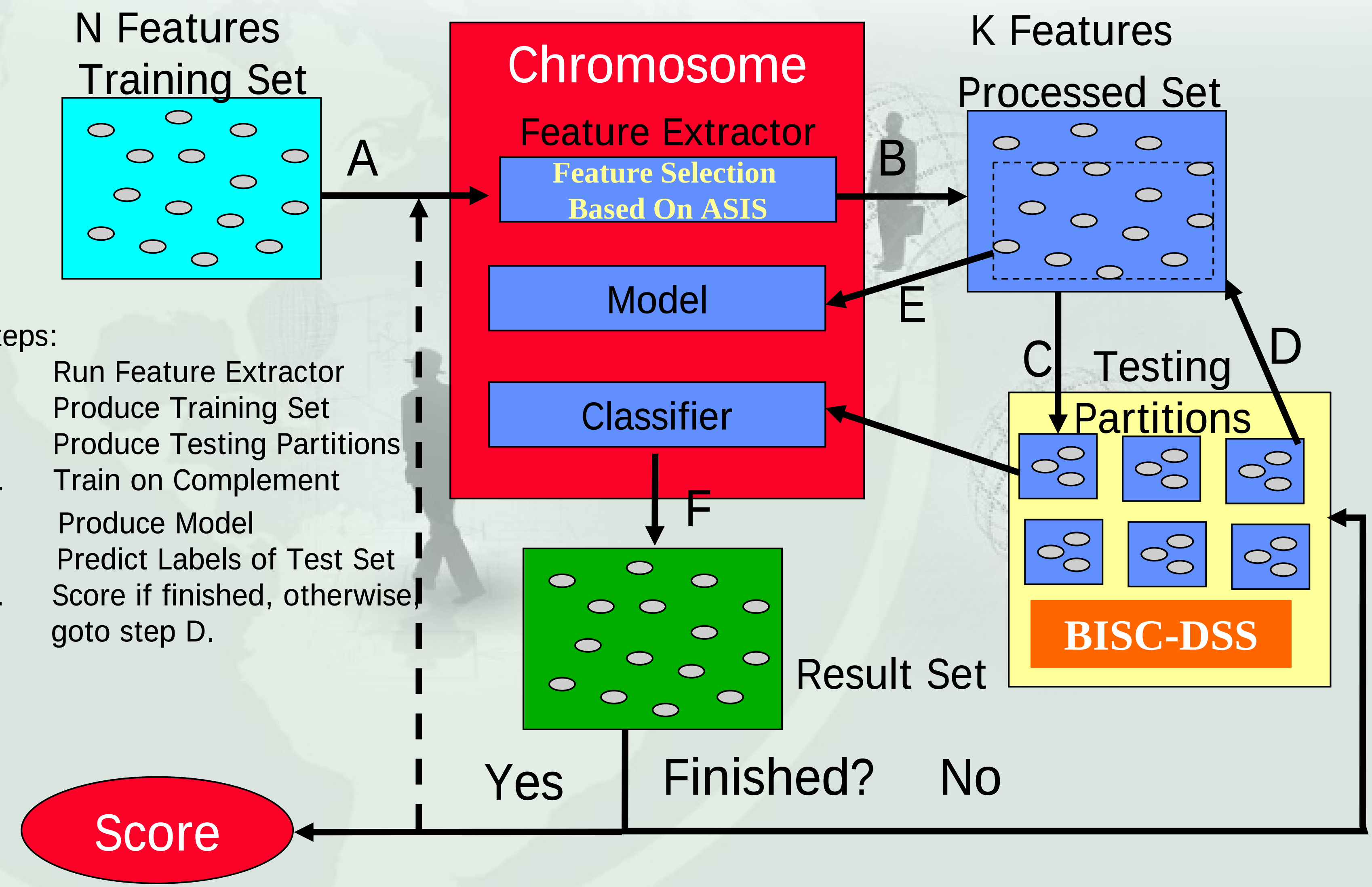
Fitness: N-Fold Cross Valid



Steps:

A. Run Feature Extractor
B. Produce Training Set
C. Produce Testing Partitions
D. Train on Complement
E. Produce Model
F. Predict Labels of Test Set
G. Score if finished, otherwise, goto step D.

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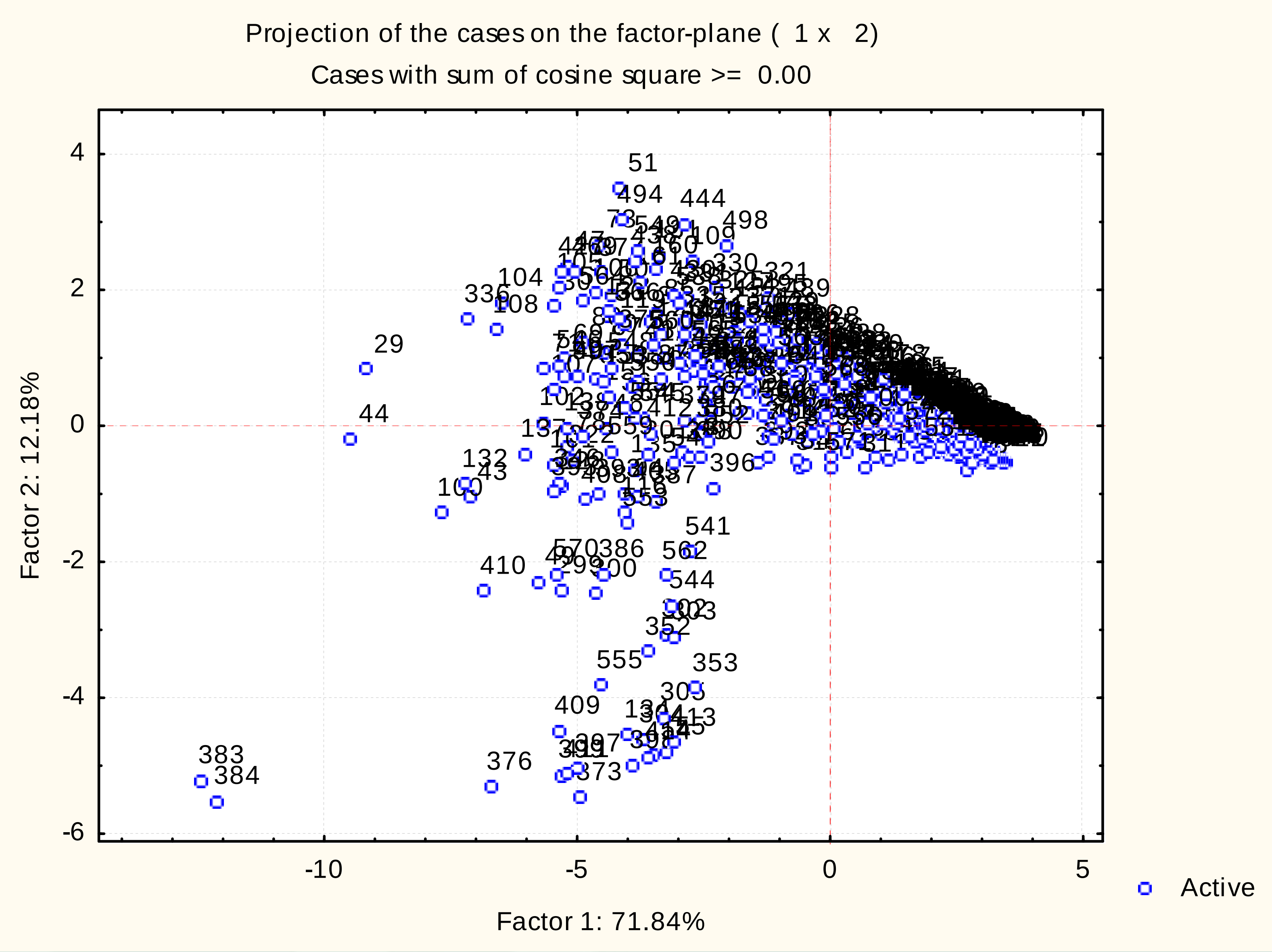

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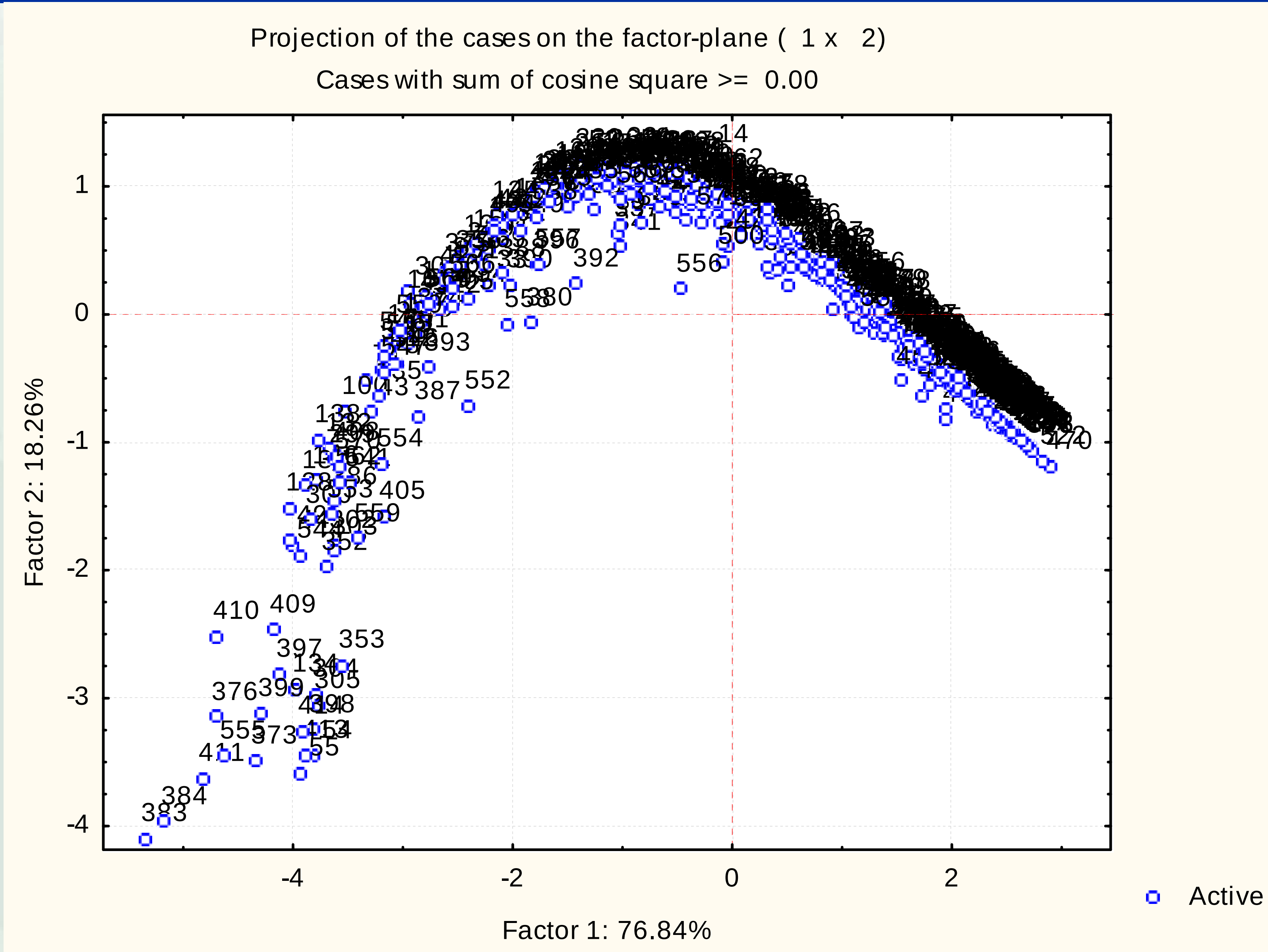
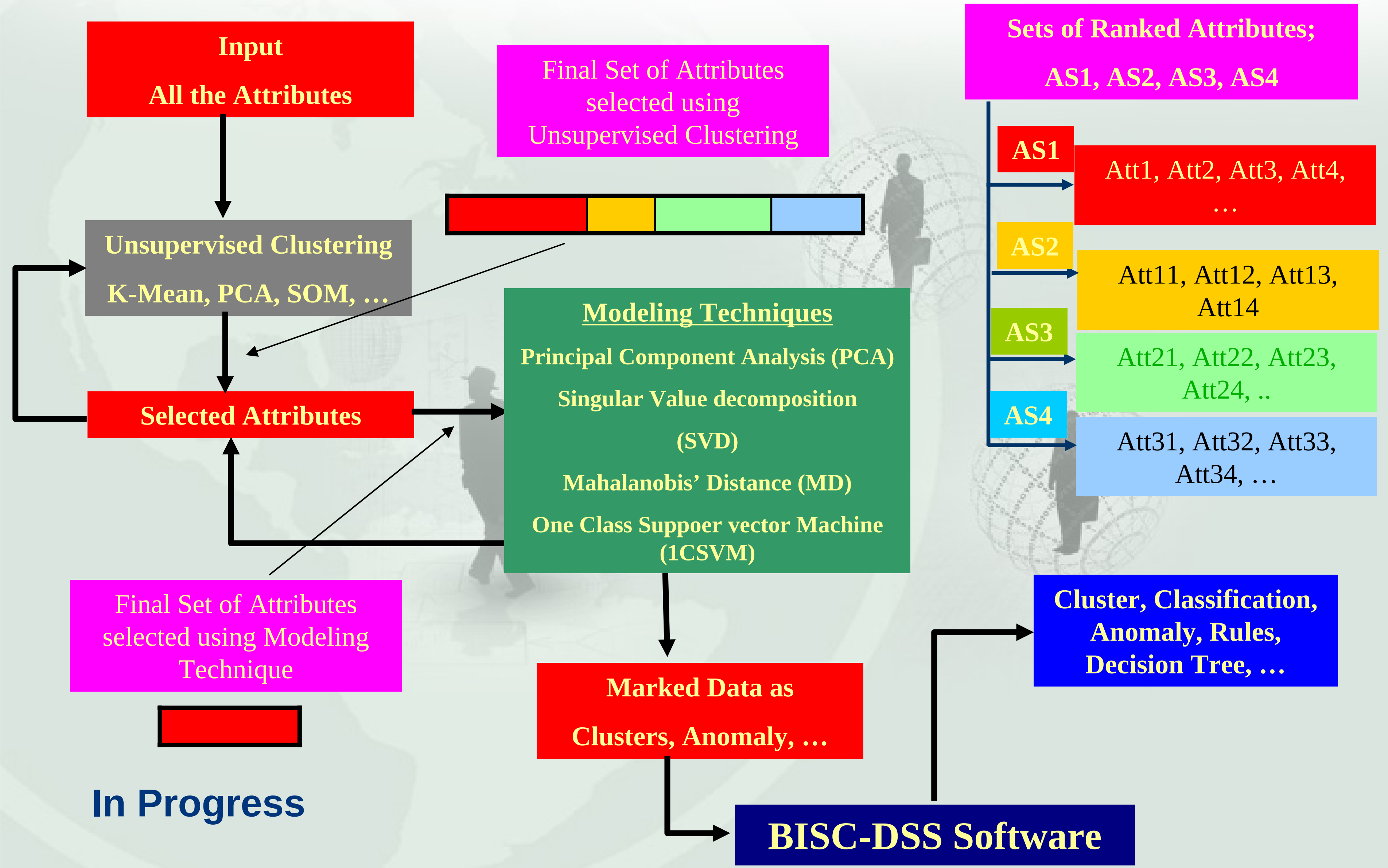


BISC - Decision Support System

BISC-DSS Clustering-Based ANSIS



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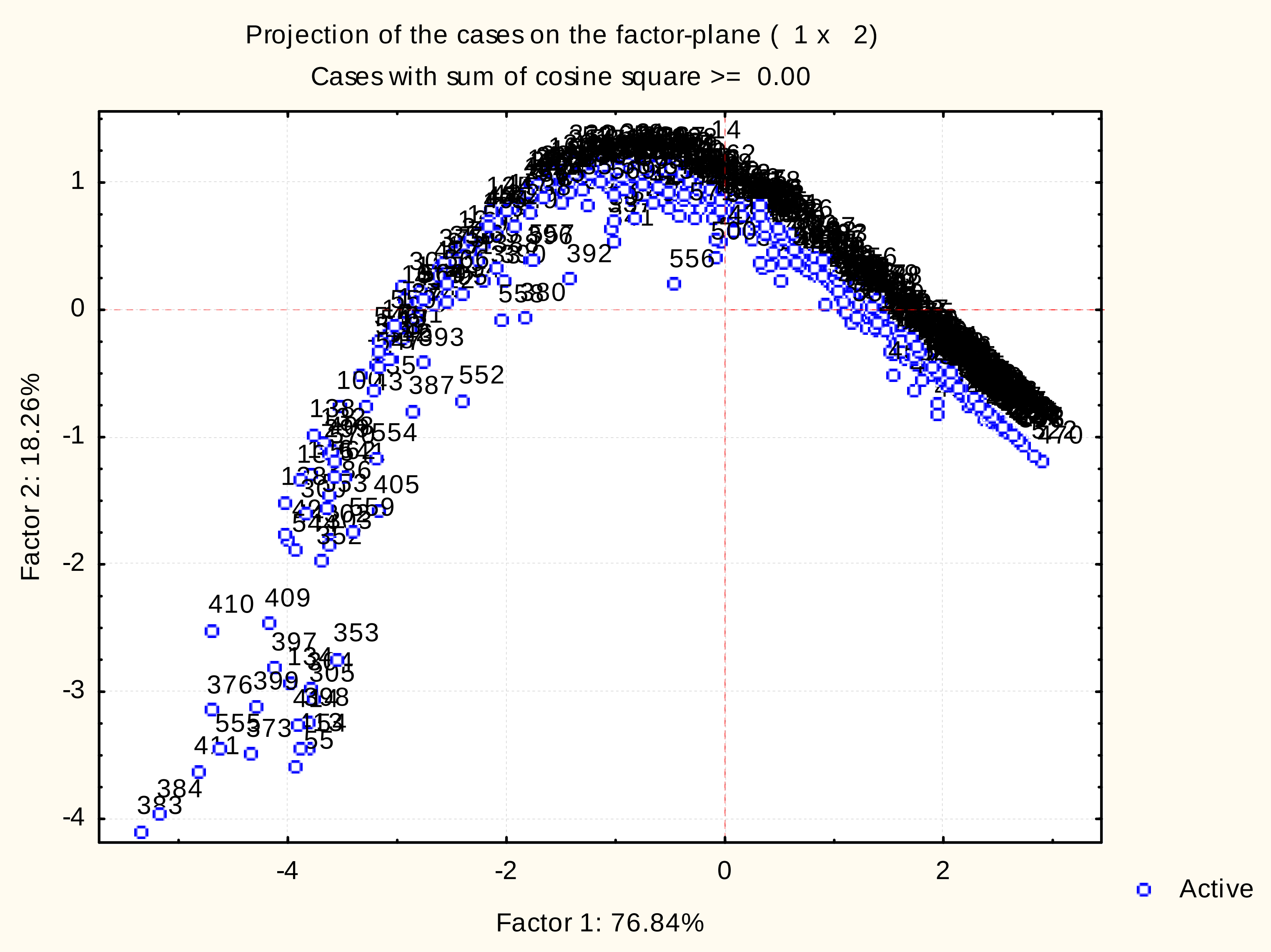

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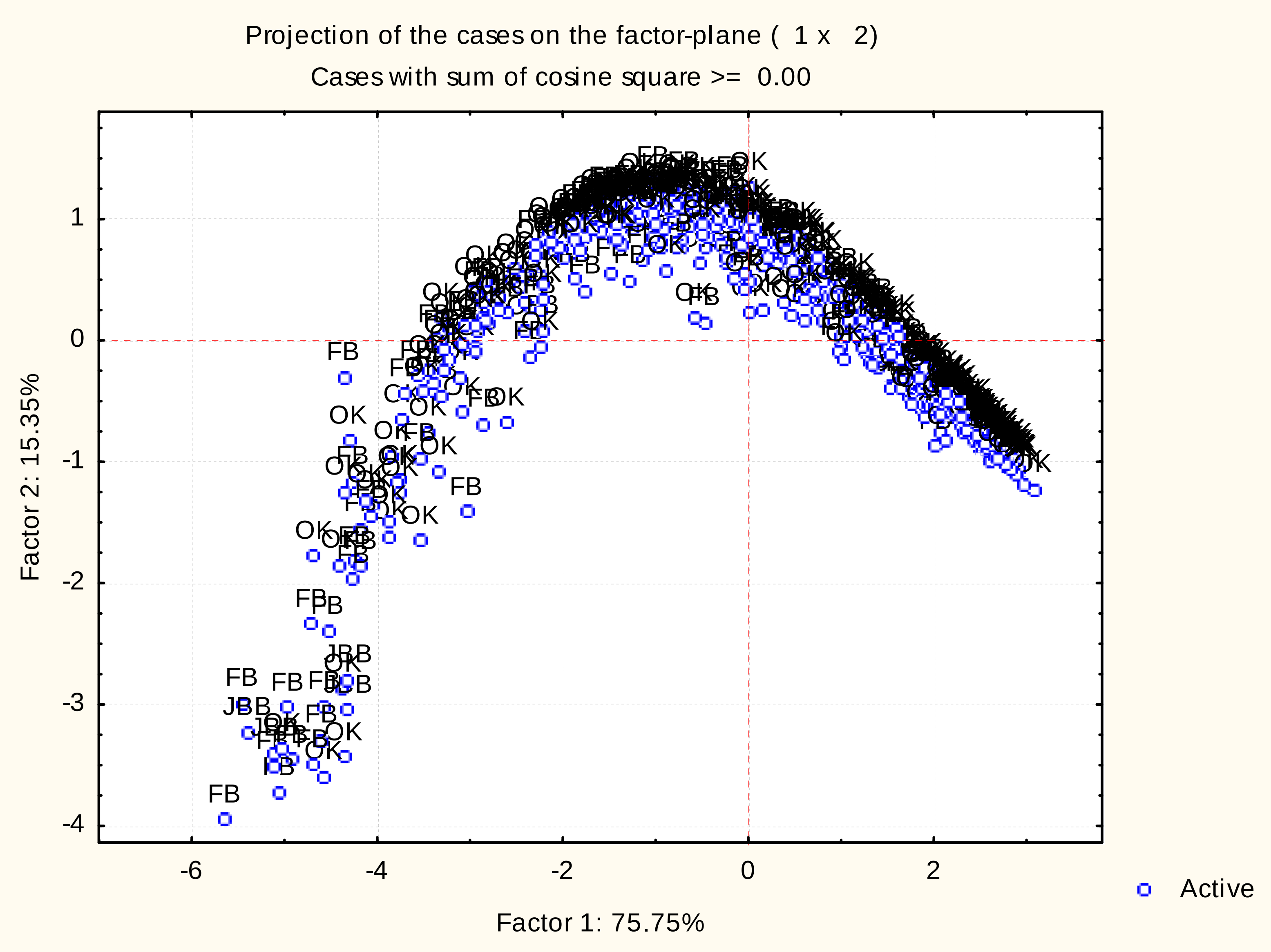

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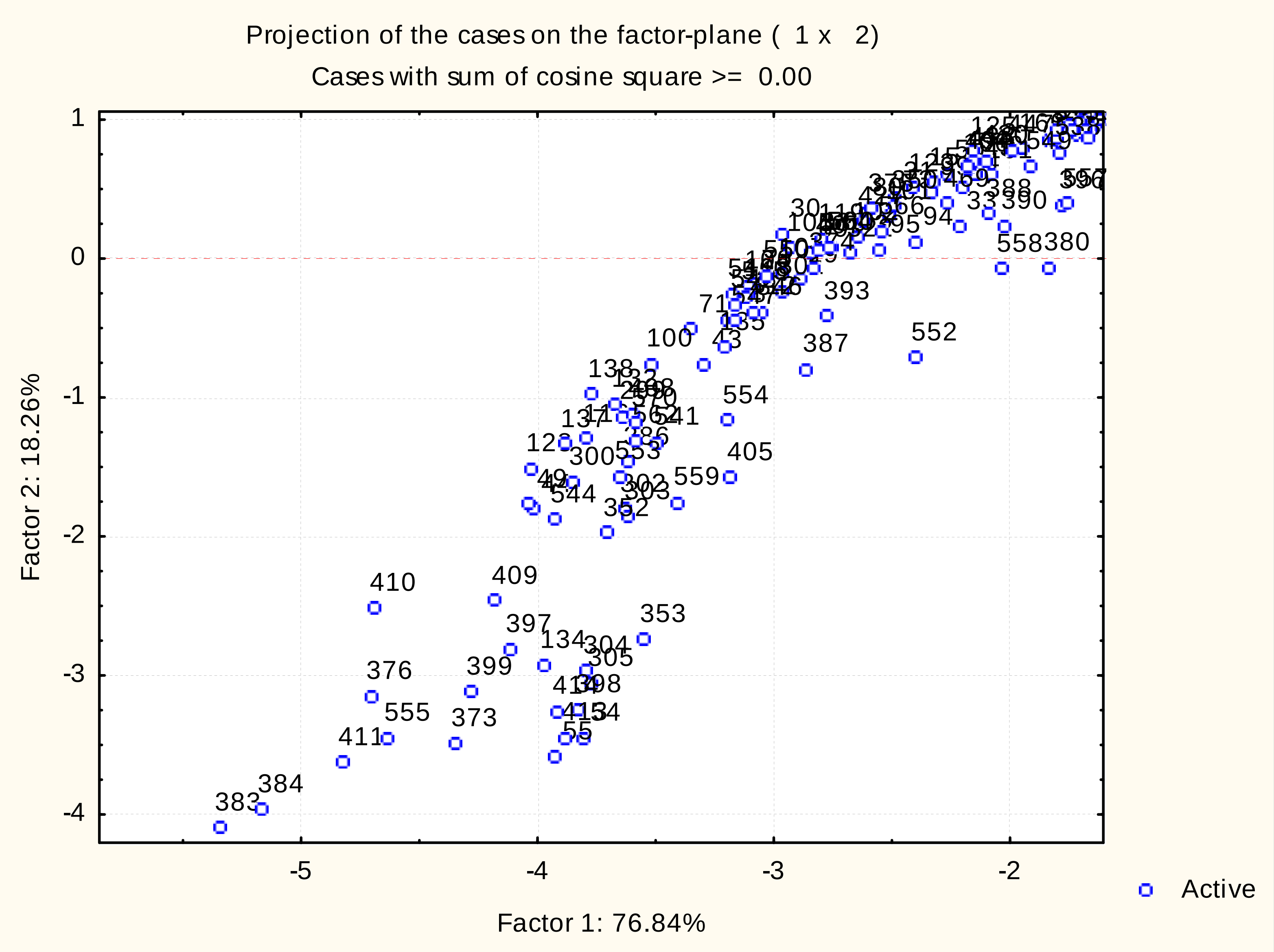

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