

# BISC - Decision Support System

## *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






Fuzzy Set: 1965 ... Fuzzy Logic: 1973 ... Soft Decision: 1981 ... BISC: 1990 ... Human-Machine Perception: 2000 - ...



# BISC - Decision Support System

## 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;**



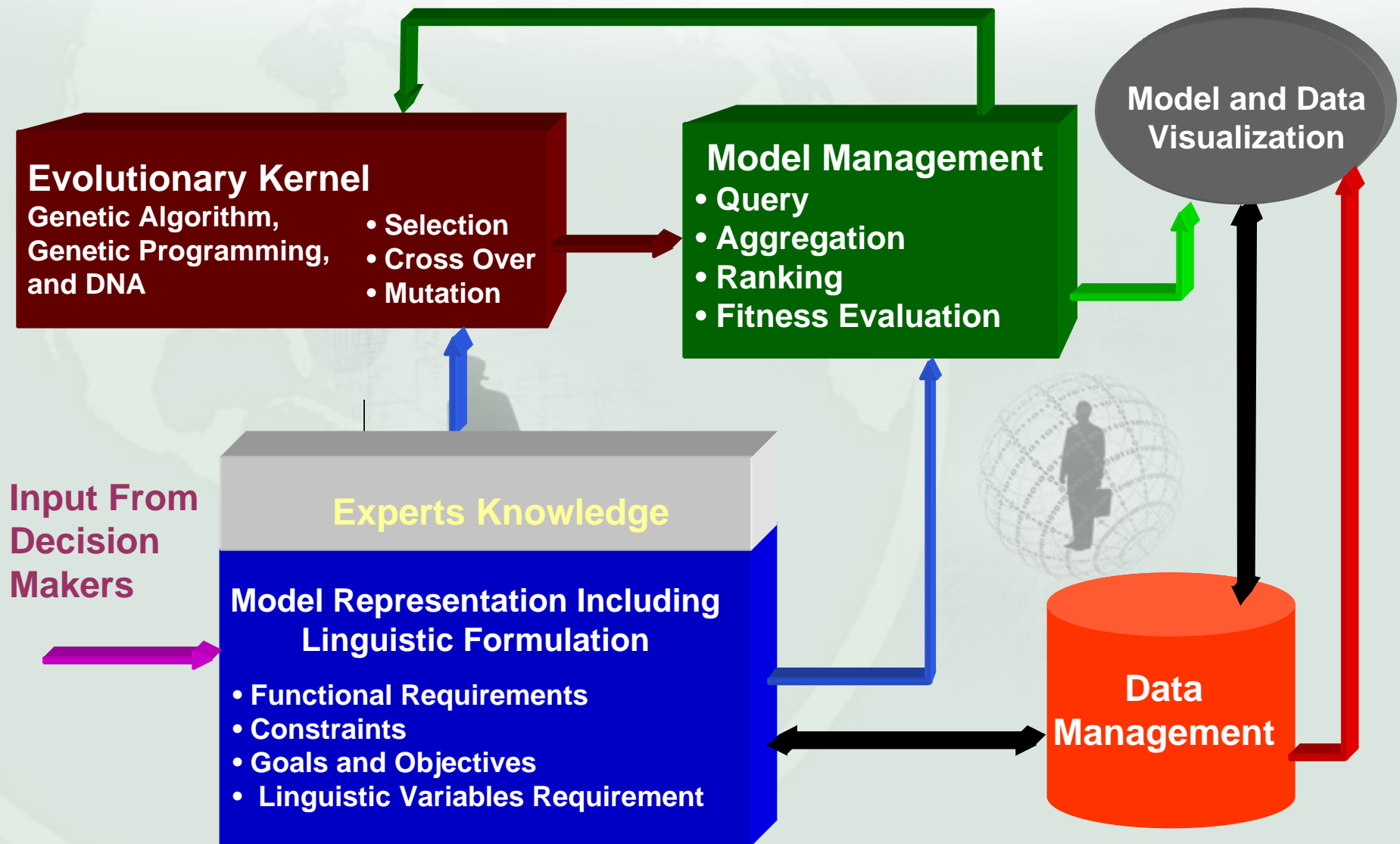
# BISC - Decision Support System

## 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

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

$v_i$  : Variables

$\mu_i$ : Degree in which  $v_i$  belong to a certain grade

$w_i$  : Preferences

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



## BISC - Decision Support System

Objective function: Cost Function/ Fitness Function

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

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





# BISC - Decision Support System

## BISC-DSS Software

### Neuro-Fuzzy-Evolutionary Computing

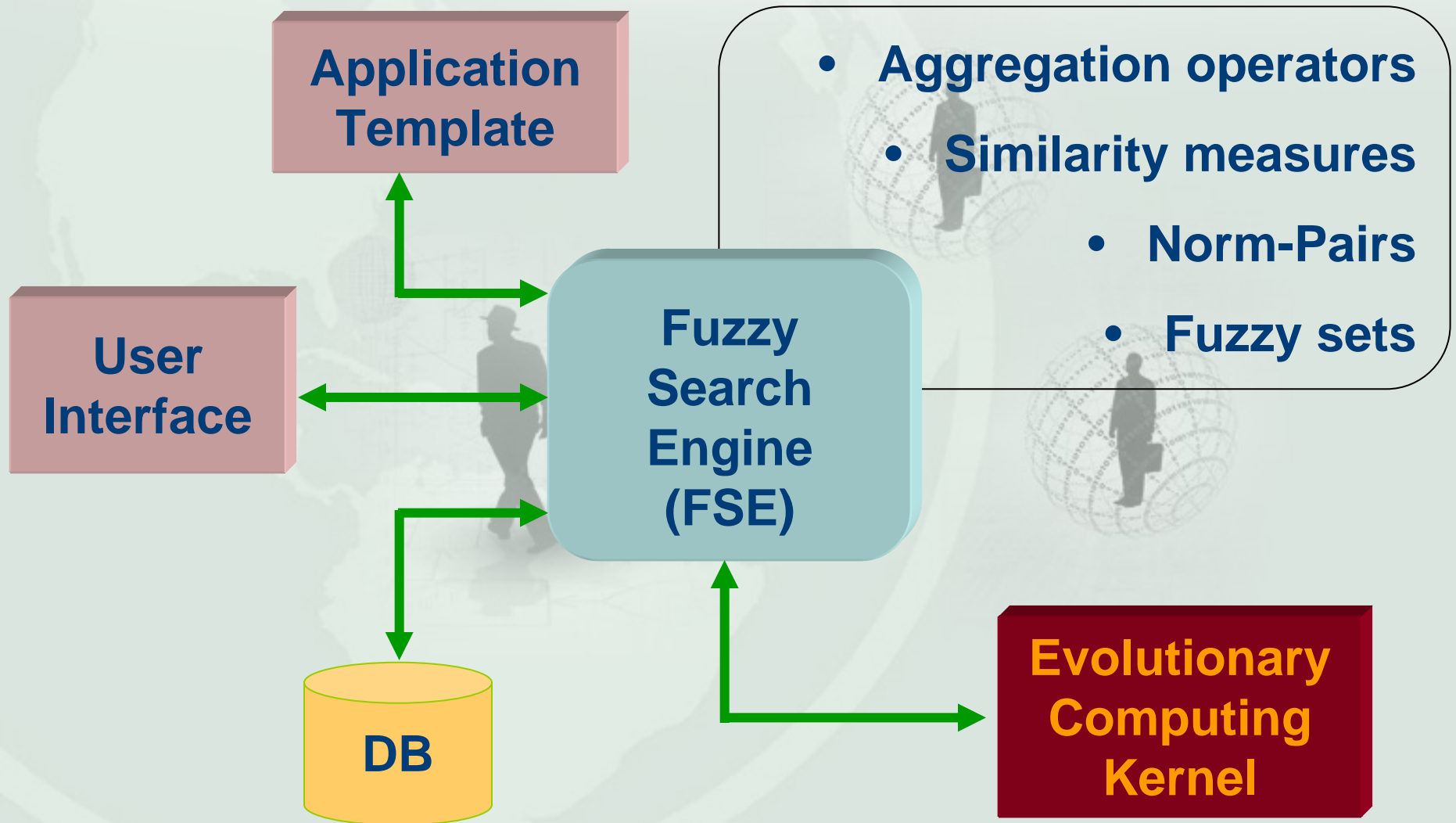
Multi-Criteria Decision Analysis with Uncertain and Incomplete Information



# *NeF-ECom*

# BISC - Decision Support System

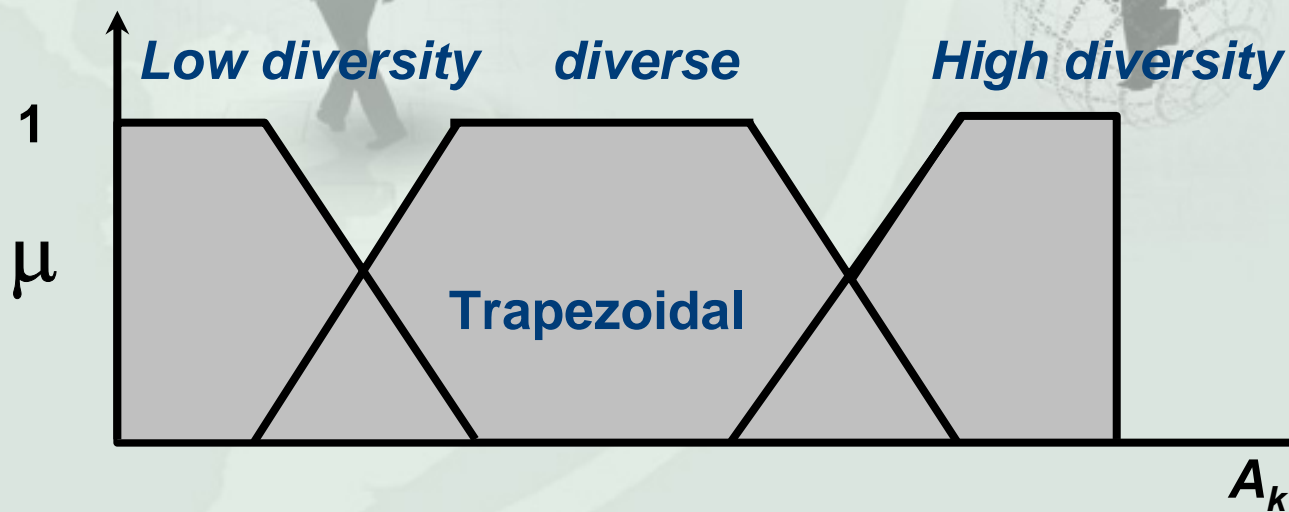
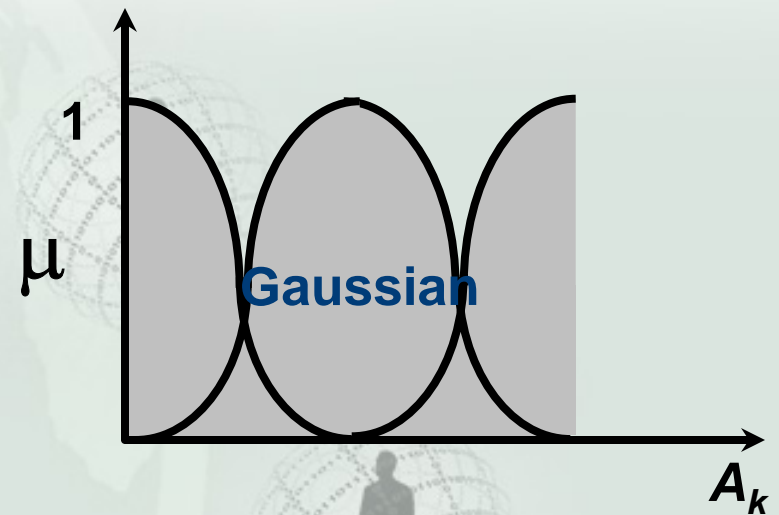
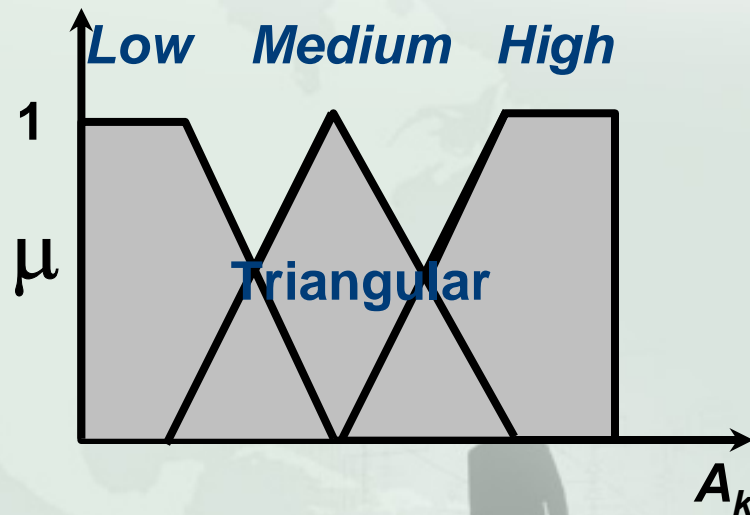
## BISC – DSS Software: Architecture



# BISC - Decision Support System

## Basic concepts

### Fuzzy sets/ Membership Functions (MFs)



### Fuzzy similarity measures

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:

$$\mu_1, \mu_2, \dots, \mu_m$$

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

# BISC - Decision Support System

## Basic concepts

### Norm-Pairs

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

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

### Aggregation Operators

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

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

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

$$\text{Minimum} : \min(x_1, x_2, \dots, x_n)$$

$$\text{Maximum} : \max(x_1, x_2, \dots, x_n)$$

### Weighted Aggregation Operators

**Weighted Mean :**  $\sum_{i=1}^n w_i \times x_i$

**Weighted Geometric Mean :**  $\prod_{i=1}^n x_i^{w_i}$

**Weighted Harmonic Mean :**  $\frac{1}{\sum_{i=1}^n w_i \times \frac{1}{x_i}}$

with :  $\sum_{i=1}^n w_i = 1$

**Weighted Minimum :**  $\min_{i=1}^n (\max(1 - w_i, x_i))$

**Weighted Maximum :**  $\max_{i=1}^n (\min(w_i, x_i))$

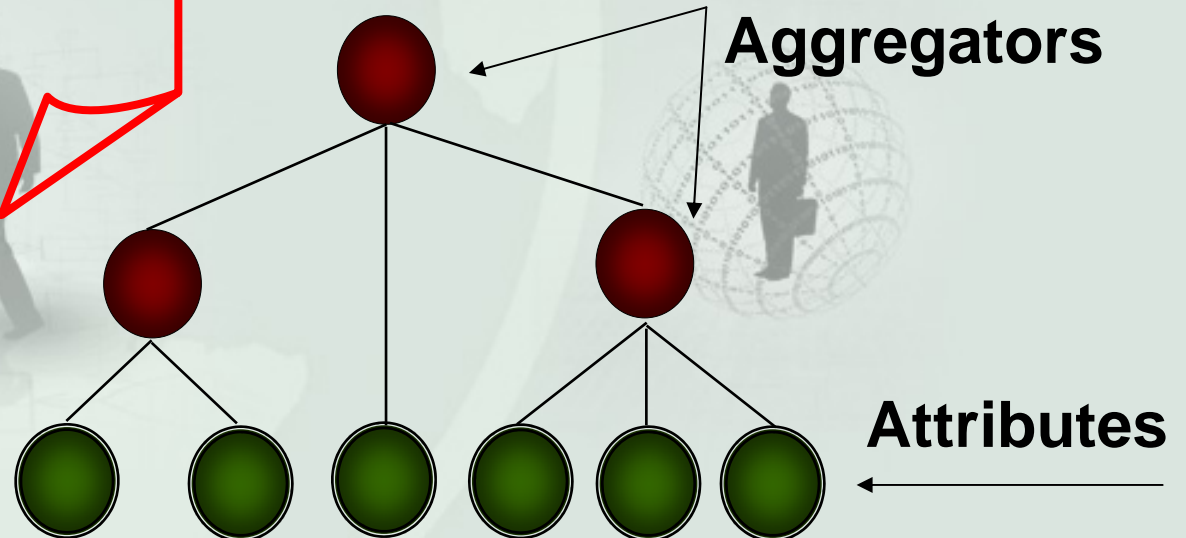
with :  $\max_{i=1}^n (w_i) = 1$



### Advanced Multi-Aggregator Model

#### Parameters

- aggregators
- weights
- tree structure.



Aggregation tree

# BISC - Decision Support System

## BISC-DSS Software

BISC Diagnosis and Prognosis Software

Session Membership Functions Attribute Selection Rule-Based Classifiers LDA-Classifer SVM SOM Aggregation Classifier **Neuro-Fuzzy Models** Time Series Analysis

dataFile1.txt dataFile2.txt

	Att1	Att2	Att3	Att4	Att5	Att6	Att7	Att8	Att9	Att10	Att11
POS1	309	918	320	1579	137	380	829	902	40		
POS2	208	643	329	996	138	312	585	892	35		
POS2	243	782	334	1410	133	350	824	877	40		
POS3	296	1083	383	2276	442	1039	1473	1359	1026	4	
POS2	222	846	396	1650	220	893	990	1366	597	3	
POS2	159	641	434	1270	200	1361	888	2291	649	3	
POS2	181	719	407	1466	213	1117	1020	2289	734	3	
POS4	244	1019	436	2016	360	1312	1446	2653	1139	5	
POS4	132	313	262	261	0	-30	160	100	209	7	
POS4	195	444	248	409	0	0	220	325	151	6	
NEFCON	126	220	282	512	5	16	286	1	250	0	

Load data Remove data Set training data Set validation data

Advanced Neuro-Fuzzy Model run...

Fuzzy Query-Aggregation Classifier run...

Clear Save to file >>

Neuro-Fuzzy Models dropdown menu:

- ANFIS
- NEFCON
- FALCON
- GARIC
- SONFIN
- EFuNN
- FINEST
- EC-based NF...

# BISC - Decision Support System

## BISC-DSS Software

BISC Diagnosis and Prognosis Software

Session Membership Functions Attribute Selection Rule-Based Classifiers LDA-Classifer SVM SOM Aggregation Classifier Neuro-Fuzzy Models Time Series Analysis

dataFile1.txt dataFile2.txt

	Att1	Att2	Att3	Att4	Att5	Att6	Att7	Att8	Att9	A
POS1	309	918	320	1579	137	380	829	902	403	2
POS2	208	643	329	996	138	312	585	892	357	1
POS2	243	782	334	1410	133					
POS3	296	1083	383	2276	442					
POS2	222	846	396	1650	220					
POS2	159	641	434	1270	200					
POS2	181	719	407	1466	213					
POS4	244	1019	436	2016	360					
POS4	132	313	262	261	0					
POS4	195	444	248	409	0					
NEG	126	228	282	512	5					

Load data Remove data

Advanced Neuro-Fuzzy Model run...

Fuzzy Query-Aggregation Classifier run...

Clear Save to

Fuzzy Query-Aggregation based Classifier

Aggregation Tree

Similarity measure Jaccard

Norm Pair MinMax

Aggregator

OrderedWeightedMean  
WeightedArithmeticMean  
WeightedGeometricMean  
WeightedHarmonicMean  
WeightedMaximum  
WeightedMinimum  
Apply to OrderedWeightedMean  
WeightedArithmeticMean

Build Aggregation Tree >>

Adjust Weighting >>

Load m... .txt  
Apply to... .txt

Fuzzy Query >>

Close

Clear Save to file >>




# BISC - Decision Support System

## EC: Genetic Algorithms

### Requirements

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

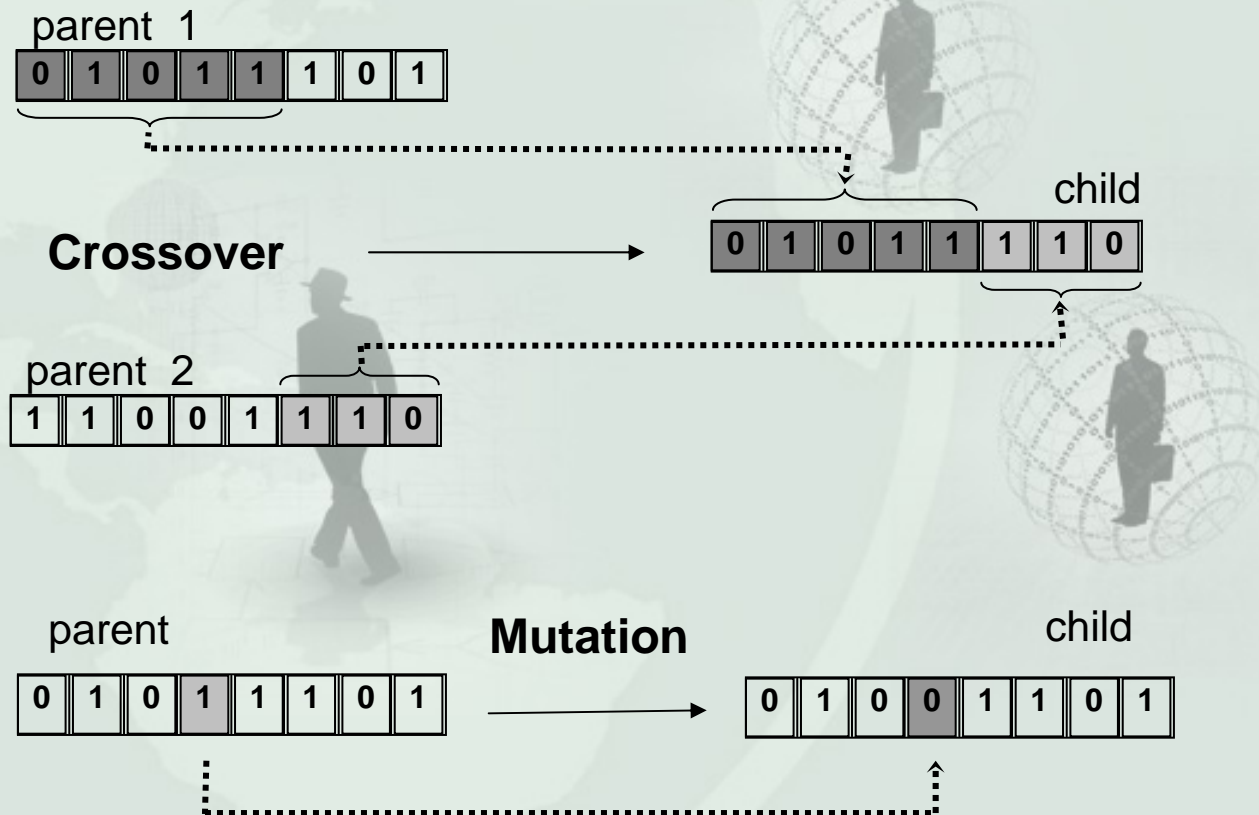
### Principle:

- 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
- 

# BISC - Decision Support System

## EC: Genetic Algorithms

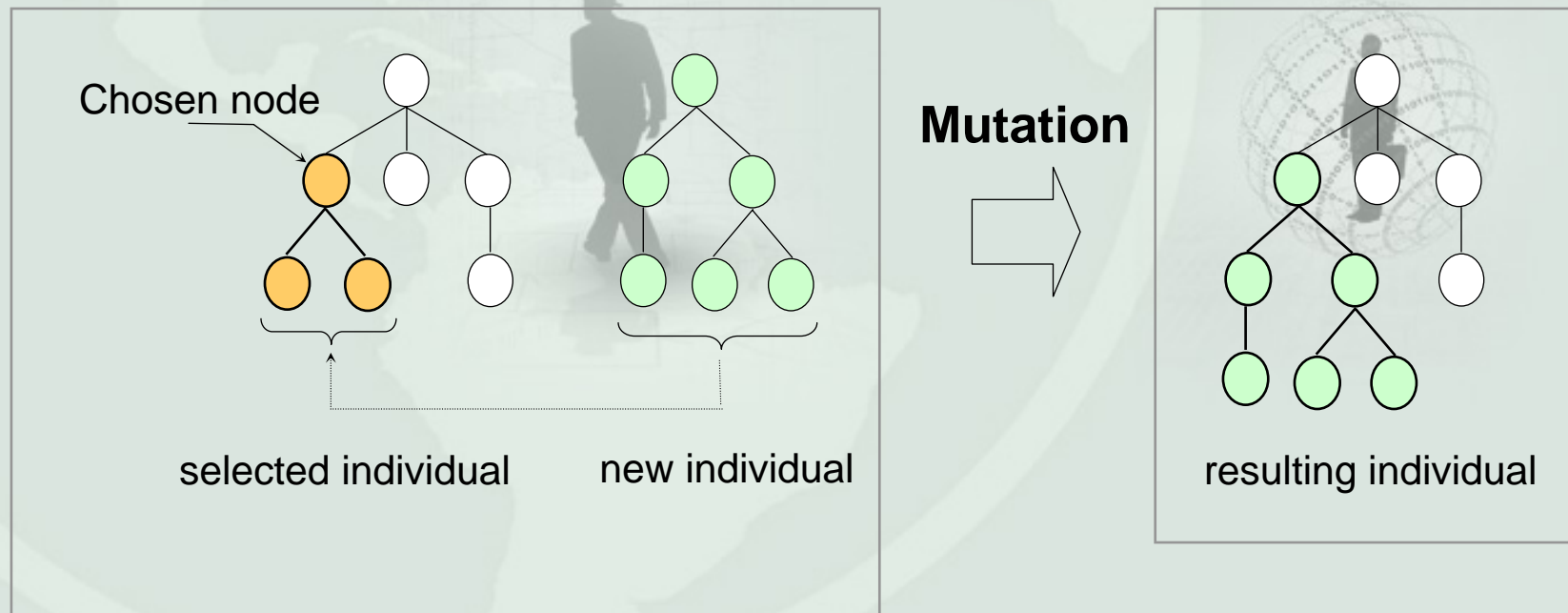
### Genetic Operators



# BISC - Decision Support System

## EC: Genetic Programming

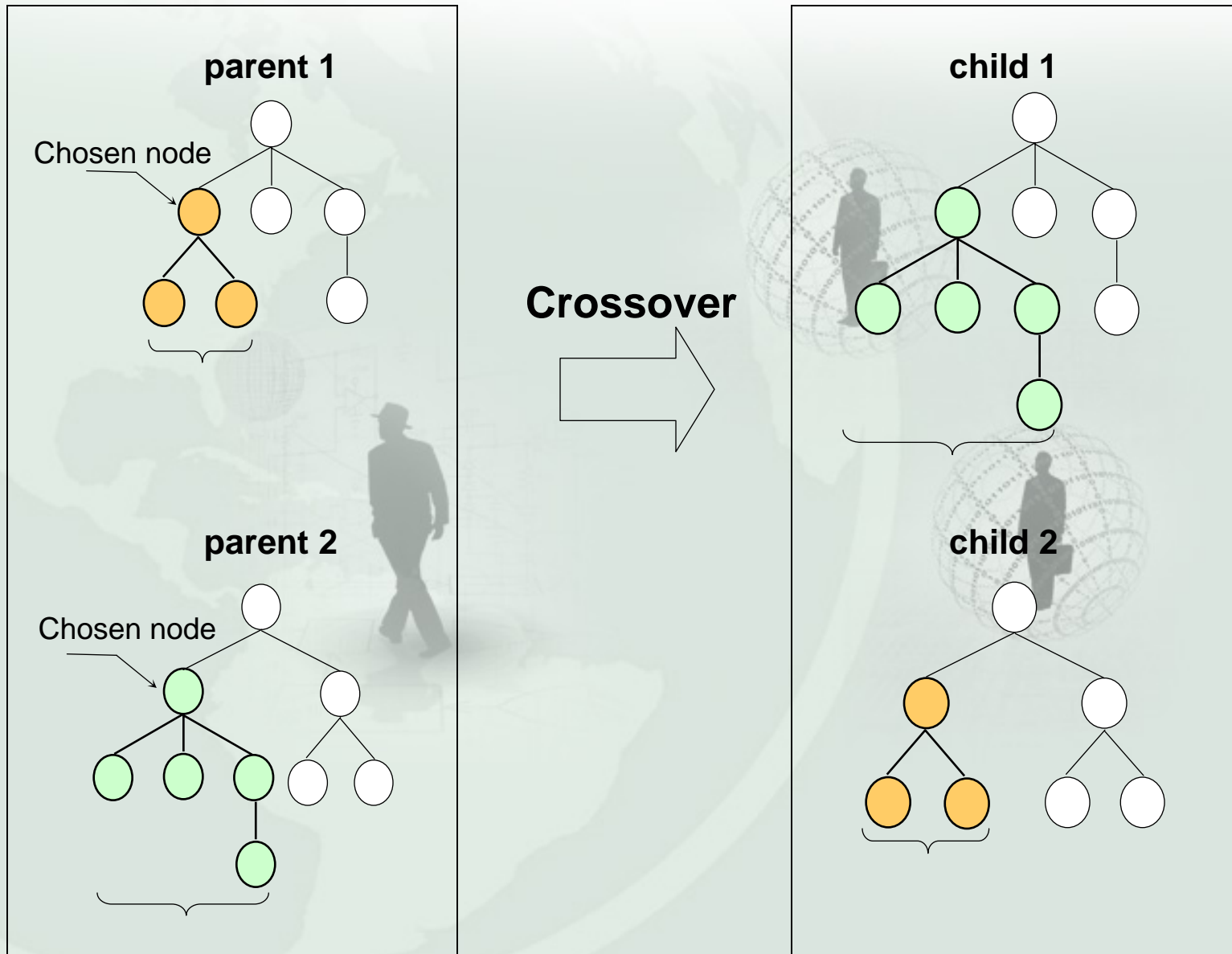
- Individual = Computer program
- Most common representation : tree encoding (nodes = functions, leaves = terminals)
- Fitness function = returned value by the root node





# BISC - Decision Support System

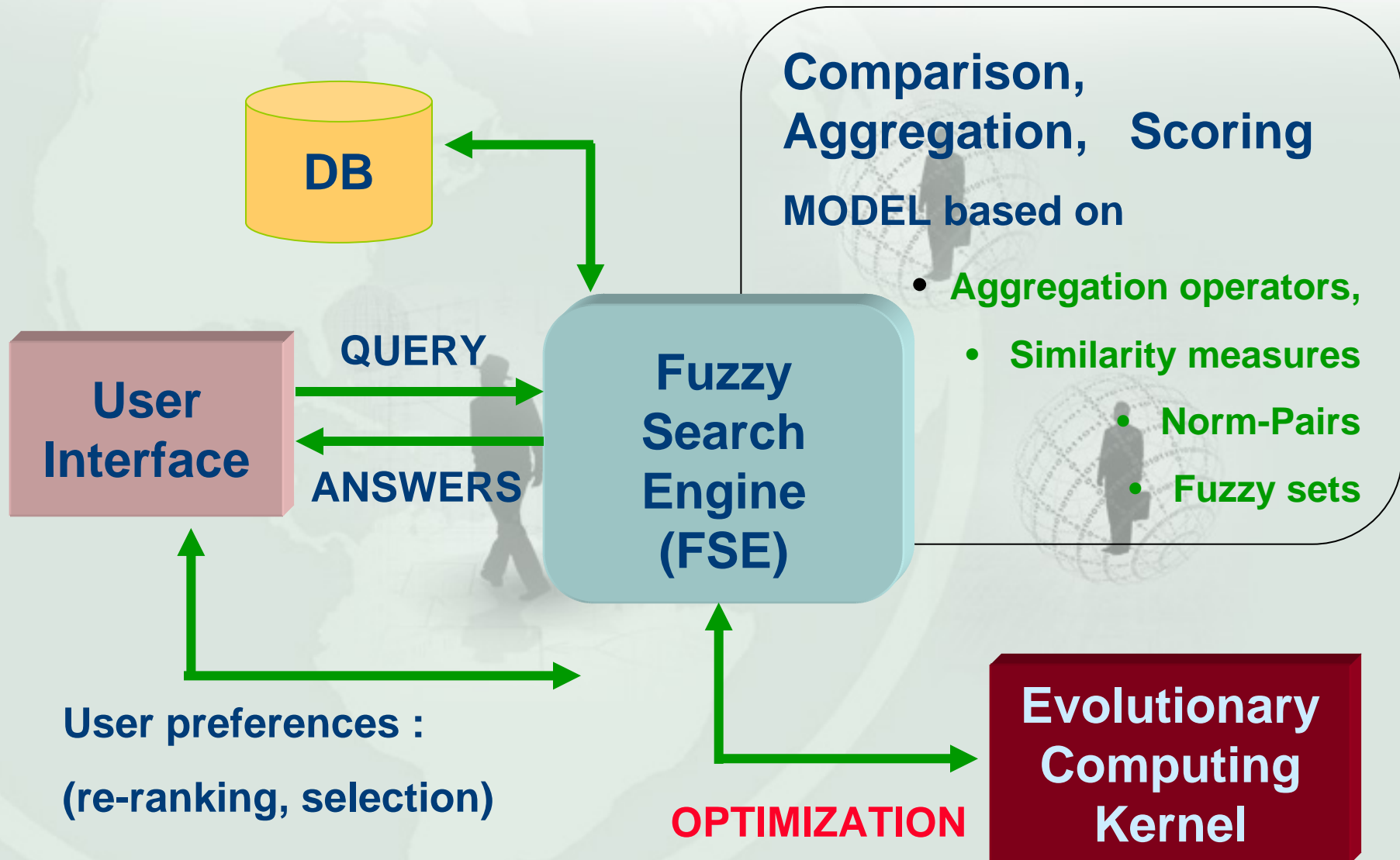
## EC: Genetic Programming





# BISC - Decision Support System

## BISC-DSS: Interaction and Optimization



# BISC - Decision Support System

## Multi-Criteria Decision Model (1)

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

### Database

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



Similarity  
calculation



### Scores

$S_1$
$S_2$
⋮
$S_N$

### Query

$y_1$	$y_2$	.....	$y_K$
-------	-------	-------	-------



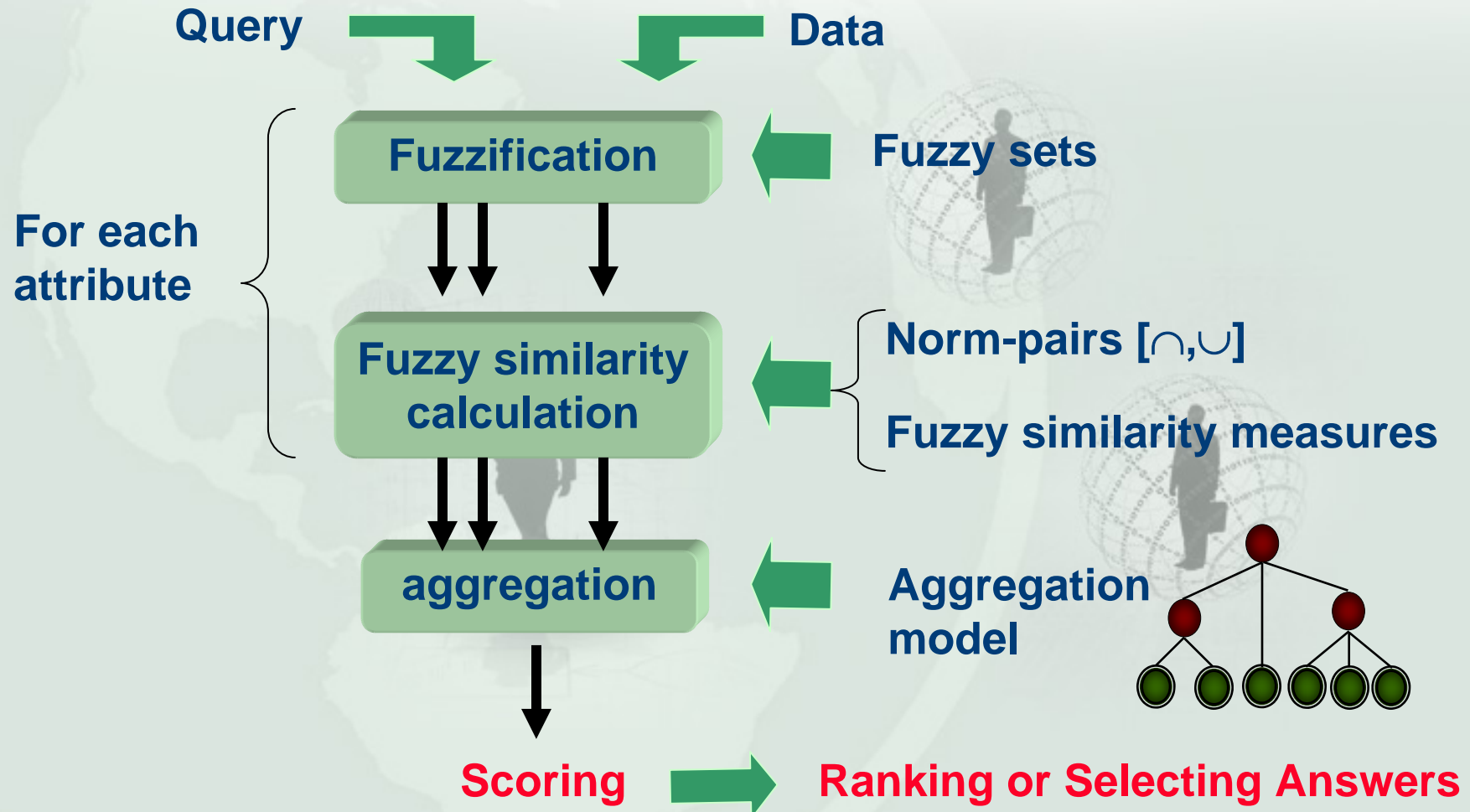
## Query Answering

Ranking based  
(criteria: number top answers)

Selection based  
(criteria: threshold)

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## Multi-Criteria Decision Model (2)



# BISC - Decision Support System

## Multi-Criteria Decision Model (3)

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

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

**For each attribute  $A_j$  :**

**$r_j$  fuzzy sets  $\mu_1(A_j, \cdot), \mu_2(A_j, \cdot), \dots, \mu_{r_j}(A_j, \cdot)$**

**$s_j = \text{similarity}(x_{ij}, y_j), \quad j = 1, 2, \dots, K$**

**$\text{Score} = \text{SIM}(Q, X_i) = \text{Aggregation}(s_1, s_2, \dots, s_k)$**

# BISC - Decision Support System

## First Order Aggregation Model (1)

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

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

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

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

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



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## First Order Aggregation Model (2)

Aggregation model = simple weighted aggregation operator

user preferences = attribute weighting  
(Degree of importance of each attribute)

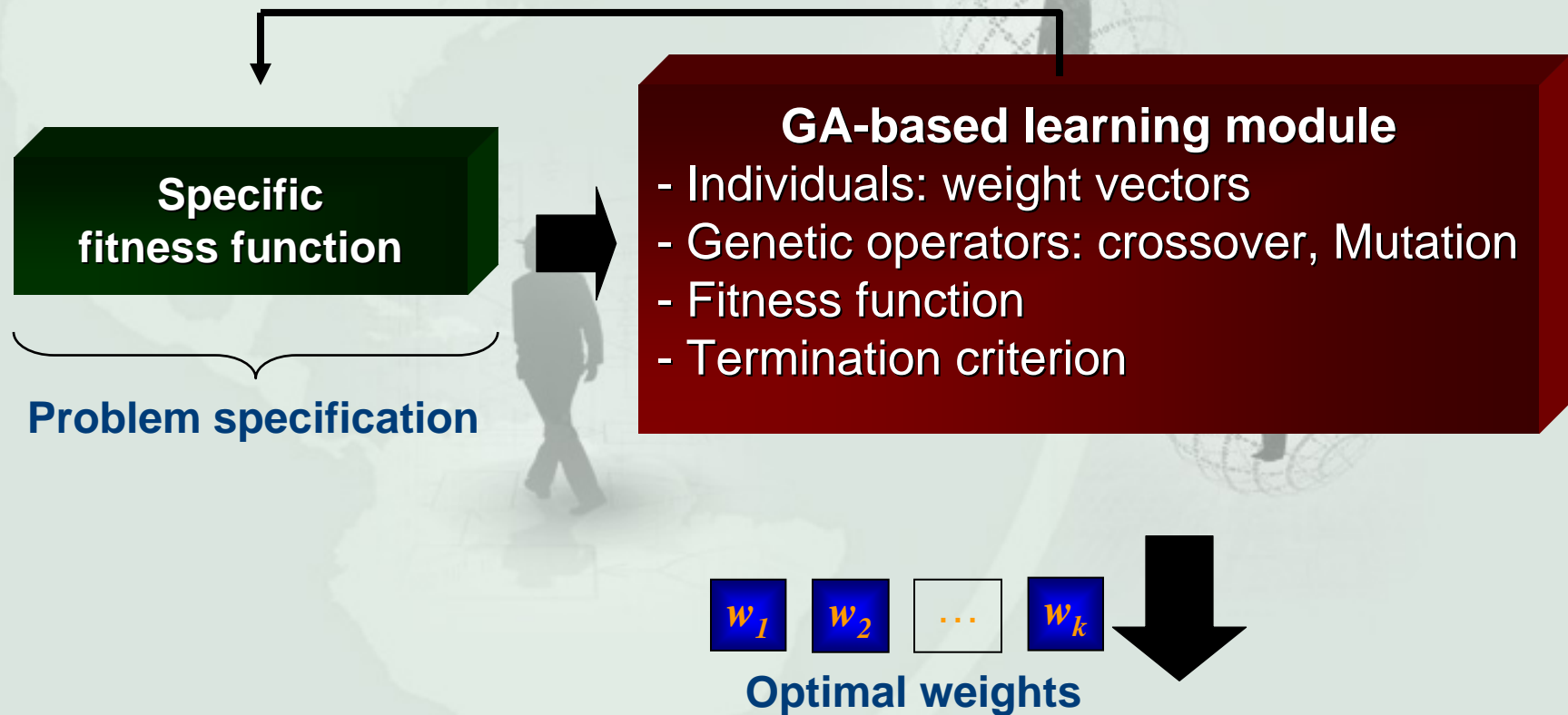
Aggregation model parameters = weighting vector

Optimization process : find the optimal weights Using GA.

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## First Order Aggregation Model (3)

### ● Model parameters learning using GA





# BISC - Decision Support System

## Advanced Multi-Aggregator Model (1)

- **parameters**

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



**Representation  
of user/expert  
preferences**

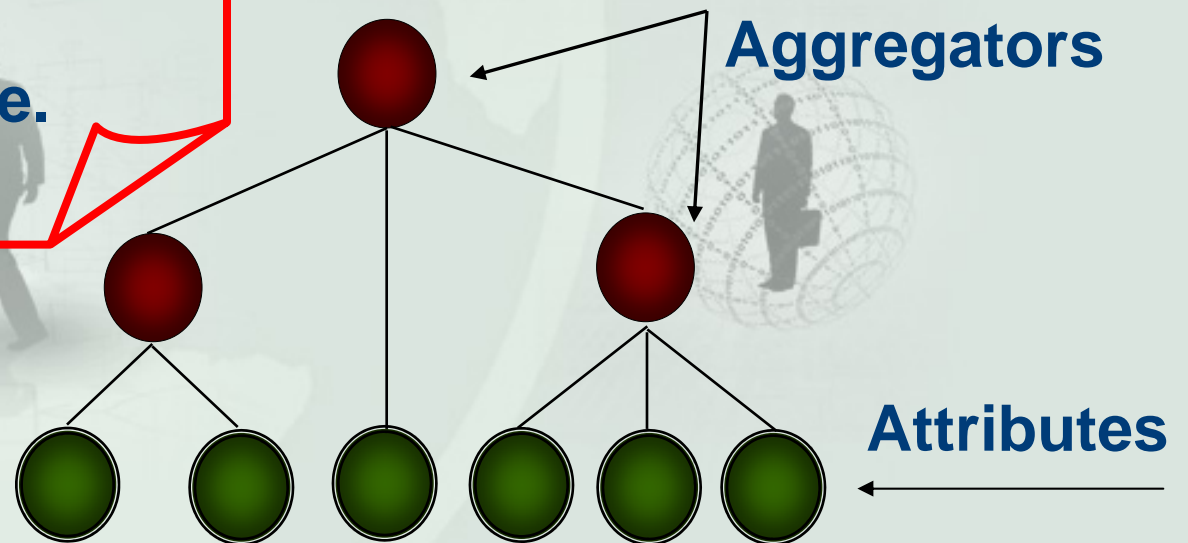
# BISC - Decision Support System

## Advanced Multi-Aggregator Model (2)

### ● Model description

#### ● Parameters

- aggregators
- weights
- tree structure.

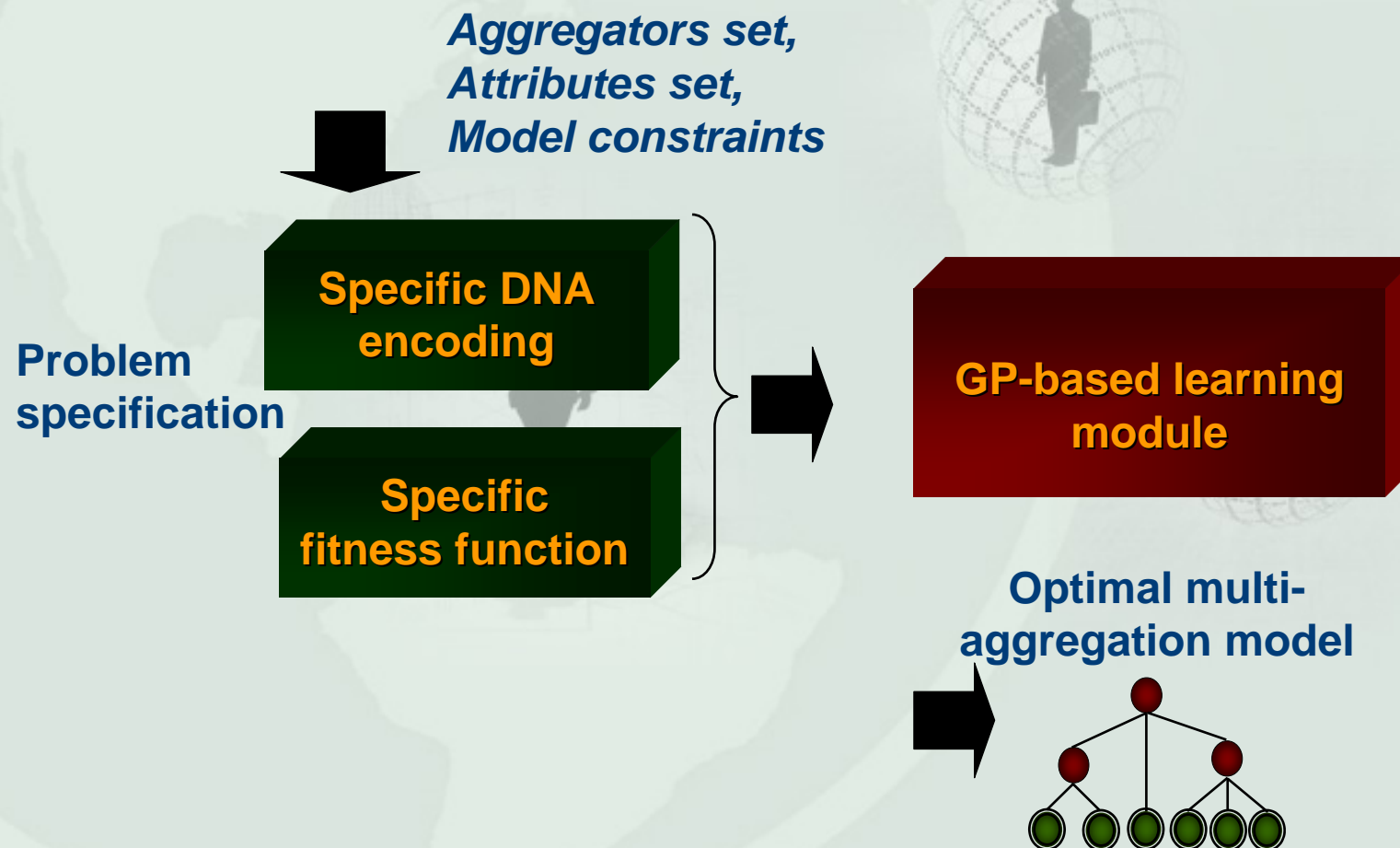


Aggregation tree

# BISC - Decision Support System

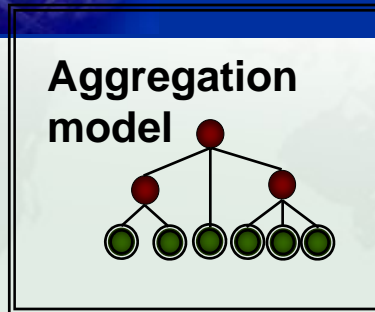
## Advanced Multi-Aggregator Model (3)

### Model parameters learning using GP



# BISC - Decision Support System

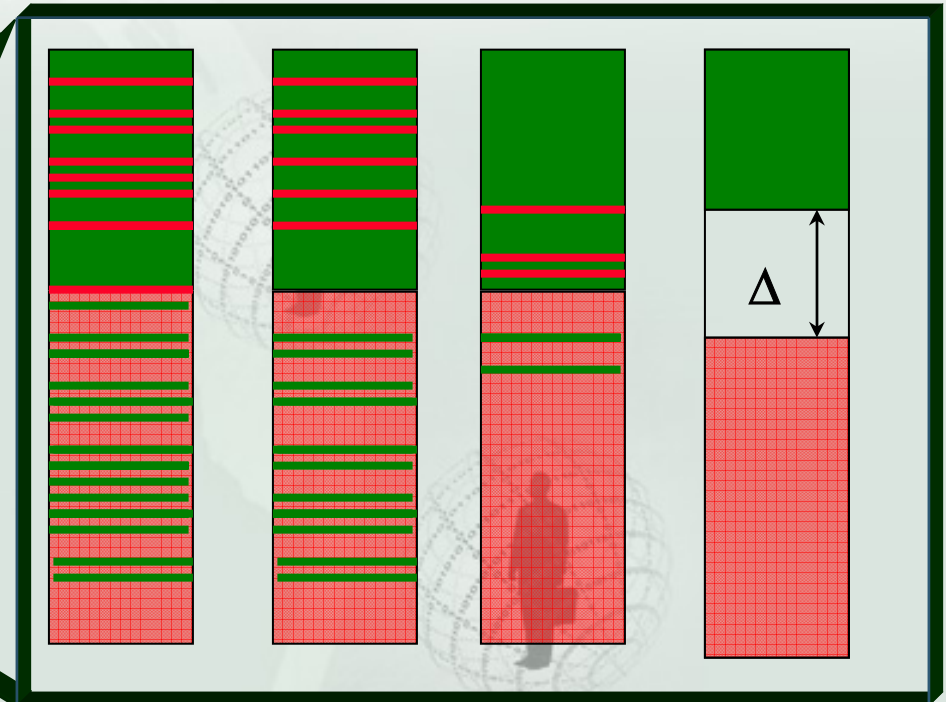
## Model evaluation



Similarity calculation

Score Ranking

■ accepted ■ rejected



Fitness function combining :

- accuracy rates to maximize
- distance  $\Delta$  to maximize
- model structure size to minimize



# BISC - Decision Support System

## 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



# BISC - Decision Support System

BISC-DSS-ASIS Software

Automated Sensory Inspection System



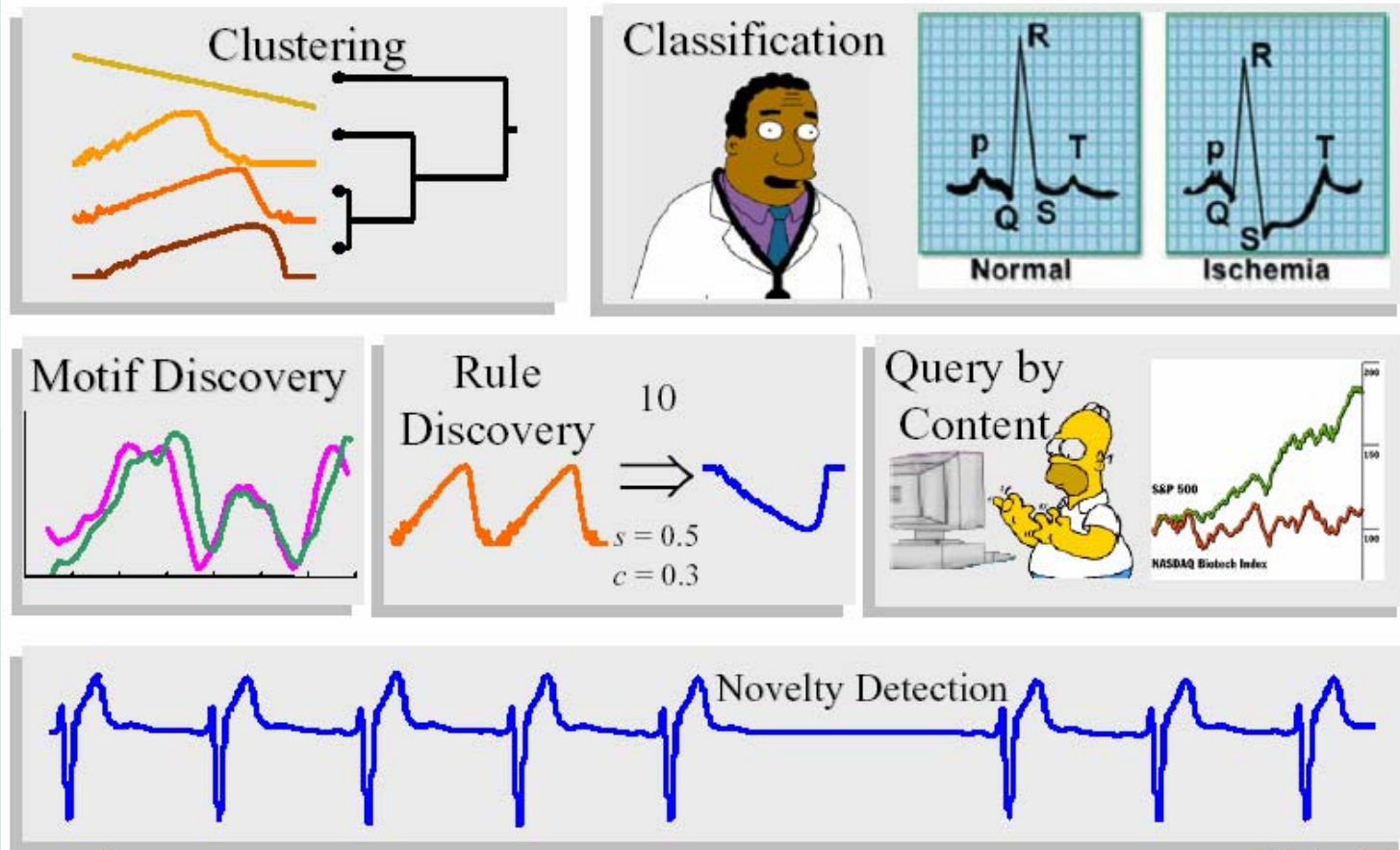
# ASIS

The ASIS logo is rendered in a large, bold, yellow-to-brown gradient font. It features a 3D effect with a dark shadow beneath the letters. The background of the slide includes a faint world map and several wireframe globe icons, some of which have a small human silhouette standing on them.

# BISC - Decision Support System

## Applications

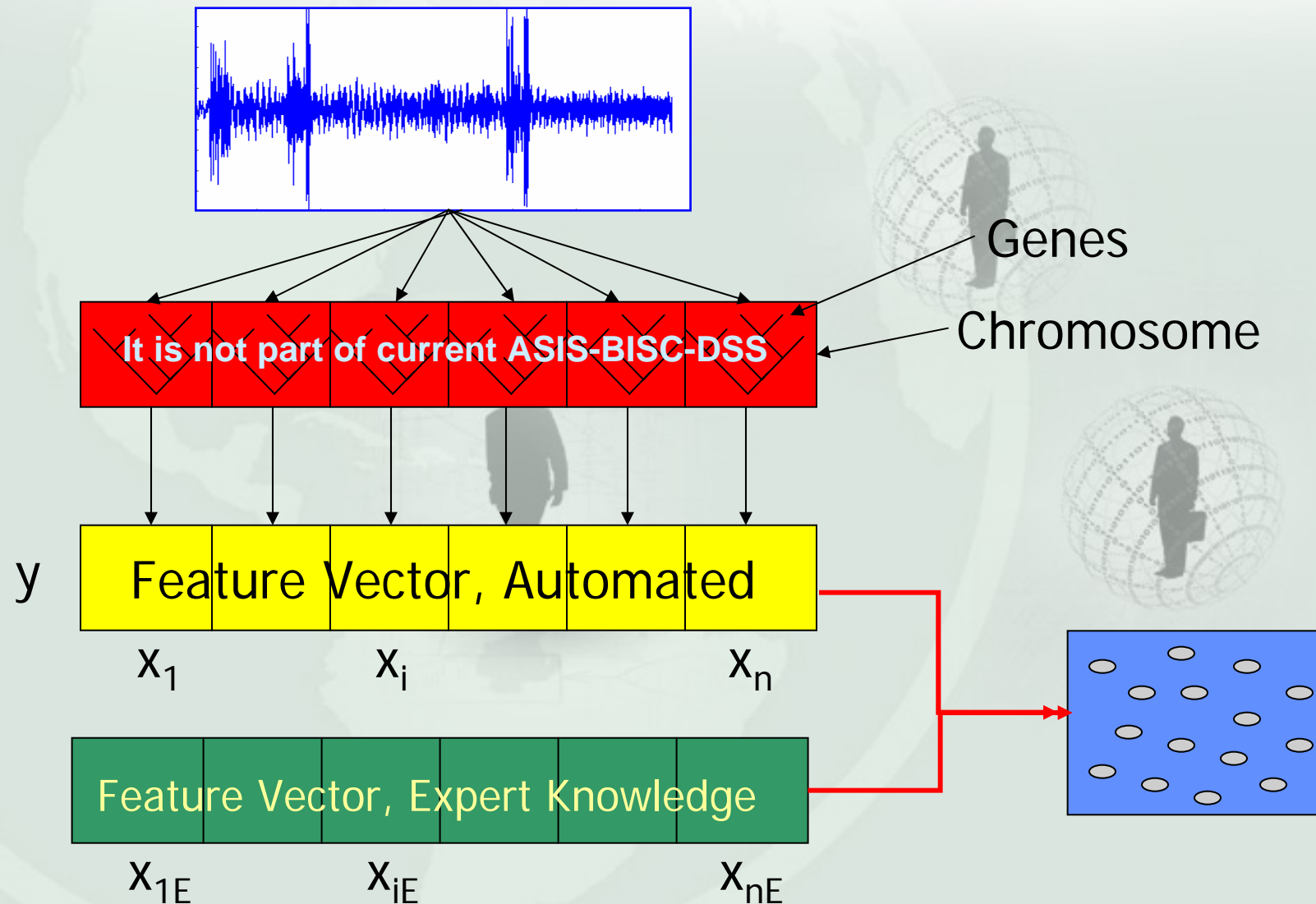
### What can We Do with Time-Series?





# BISC - Decision Support System

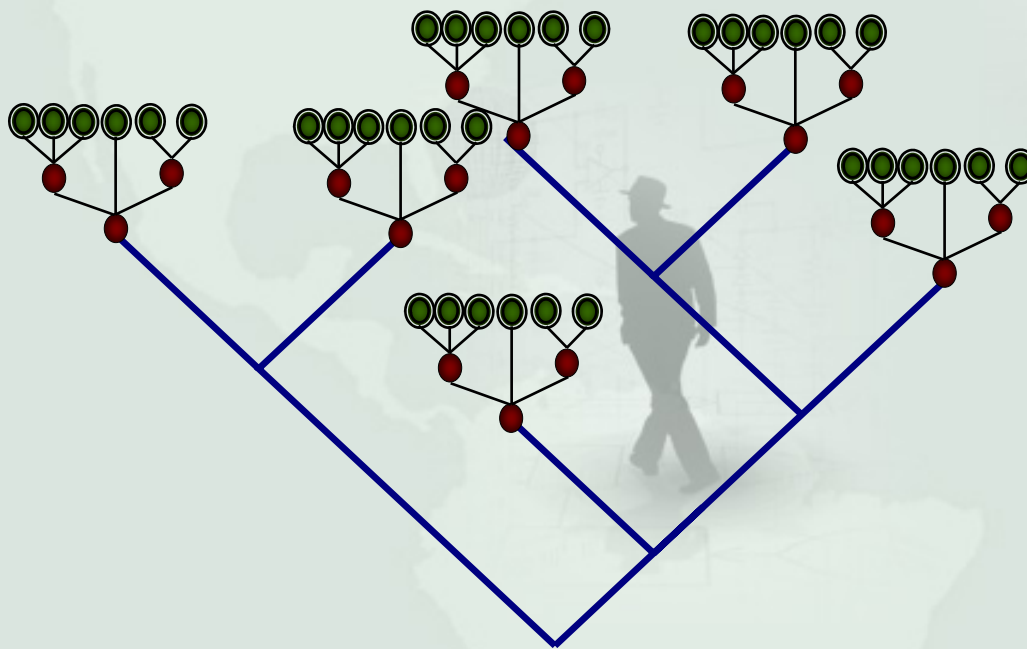
## Chromosome Representation



# BISC - Decision Support System

## Chromosome Representation

**Fuzzy Label, Set Value,  
Scalar & Series Input**

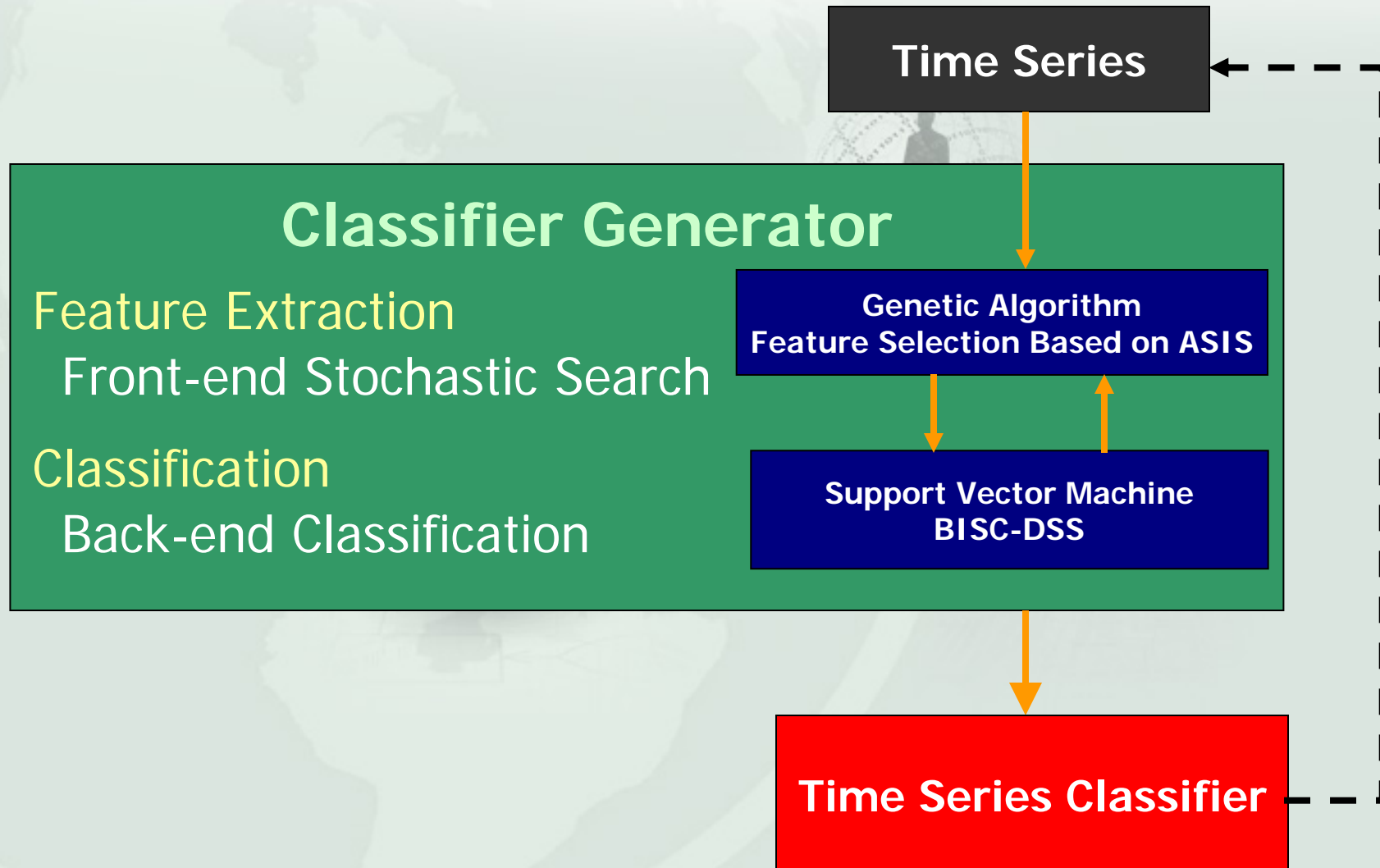


- Composed of primitive statistical, fuzzy set, aggregator, similarity, arithmetic, and signal processing operators.
- Each gene (or algorithm) is represented as a tree, accepts both scalar and series input, and outputs scalar features.
- The chromosome produces a feature vector set.

**Scalar & Fuzzy Label Features**

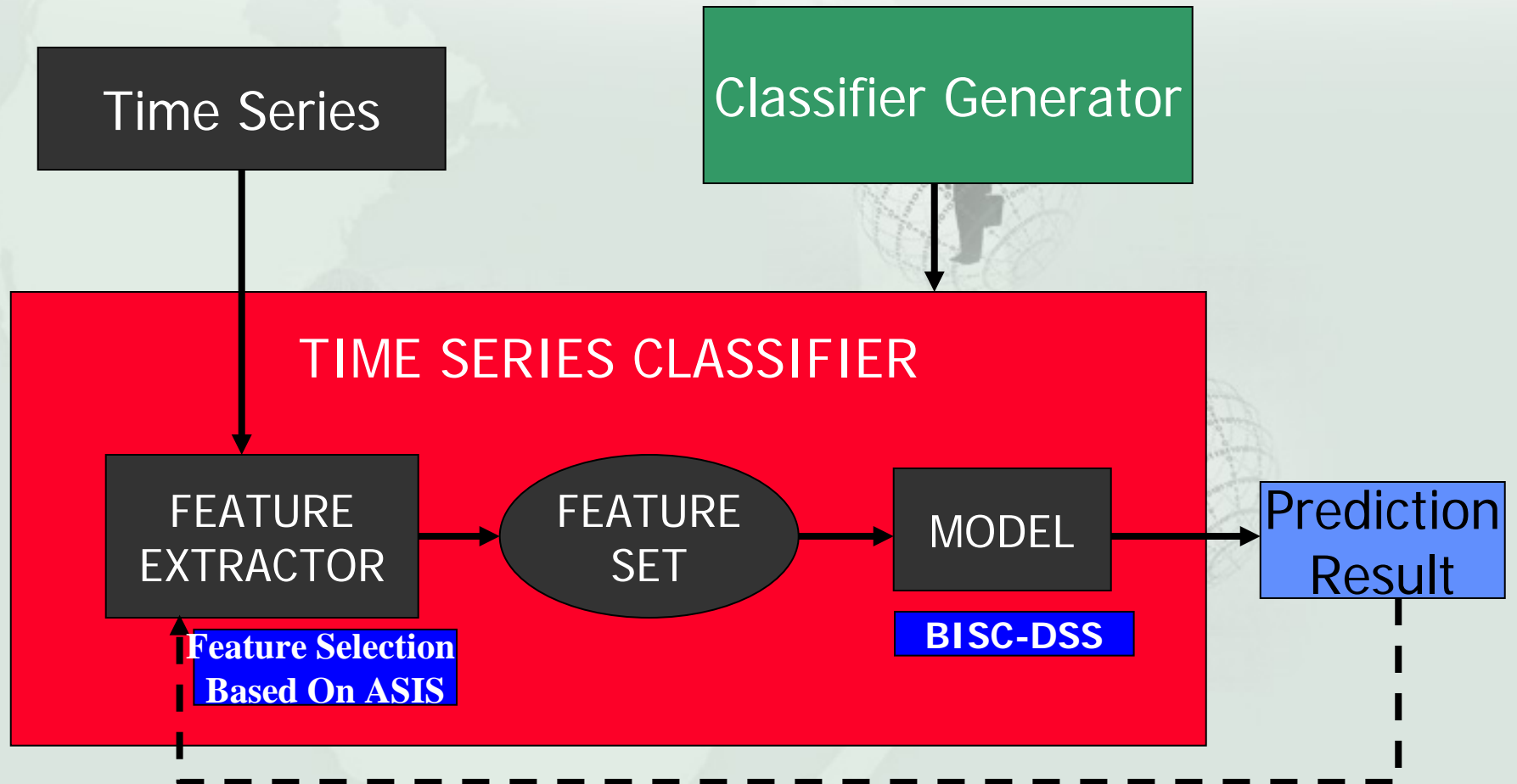
# BISC - Decision Support System

## Front/Back-end Architecture



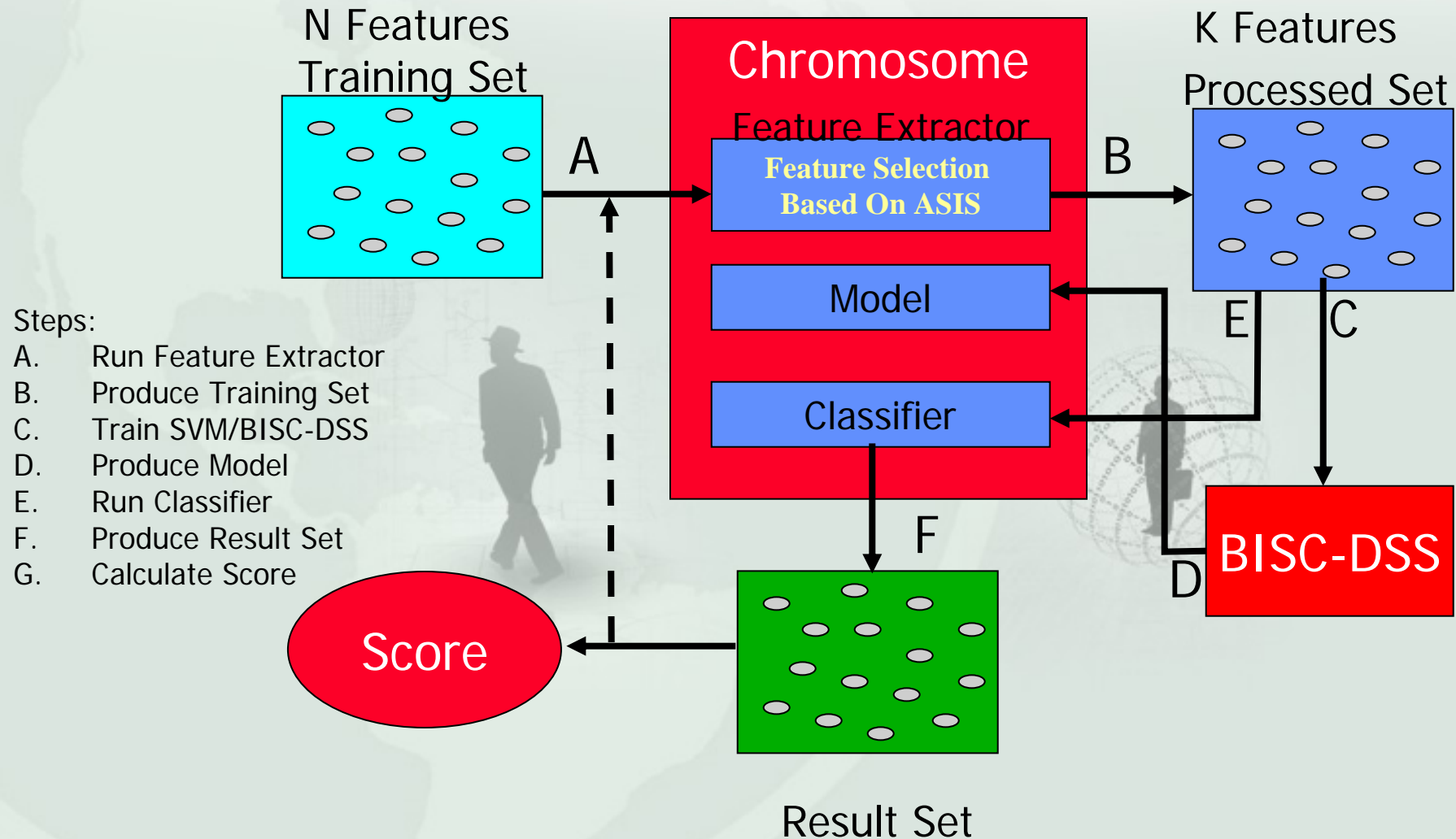
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## Classifier Architecture



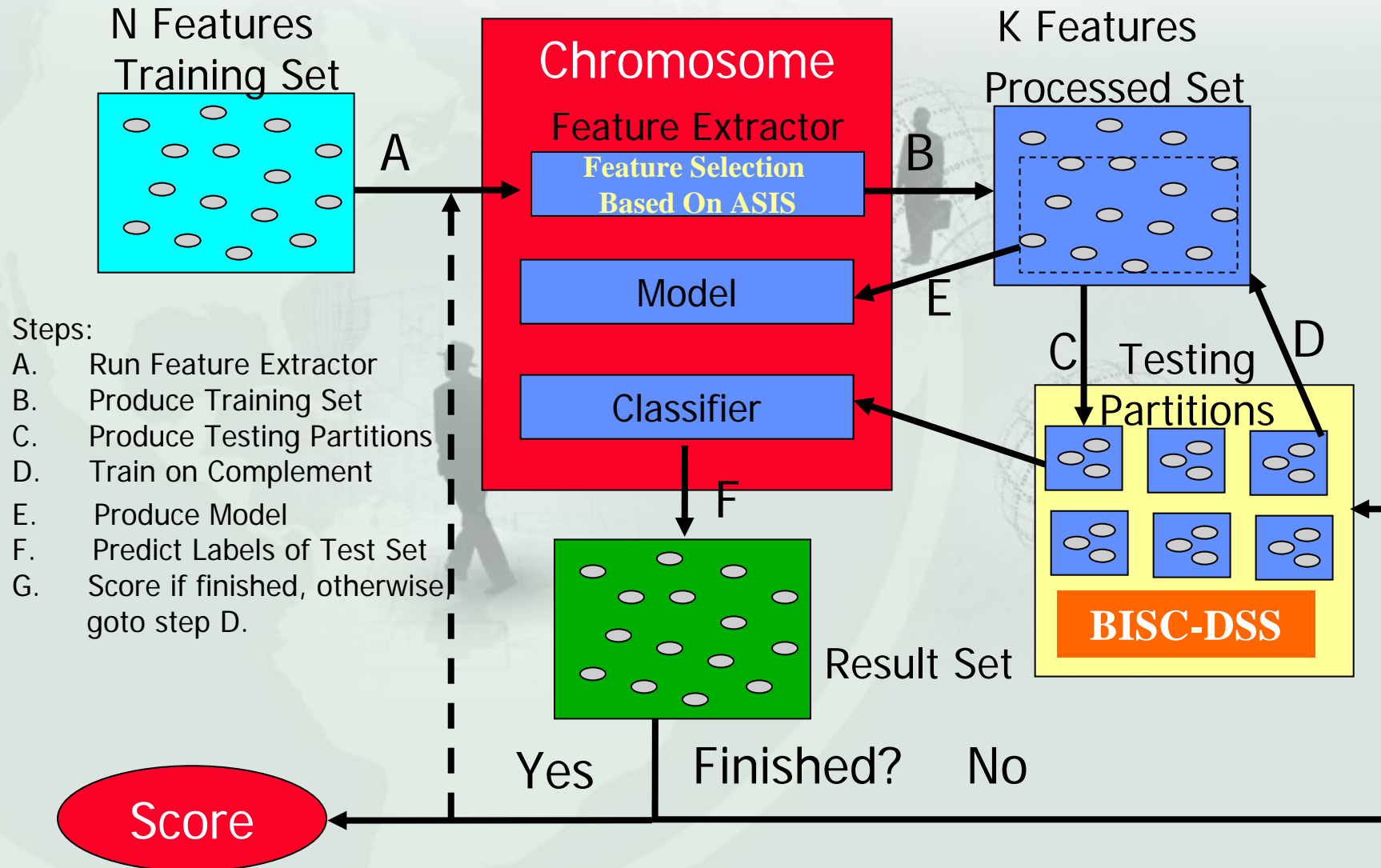
# BISC - Decision Support System

Fitness: In-sample Rate



# BISC - Decision Support System

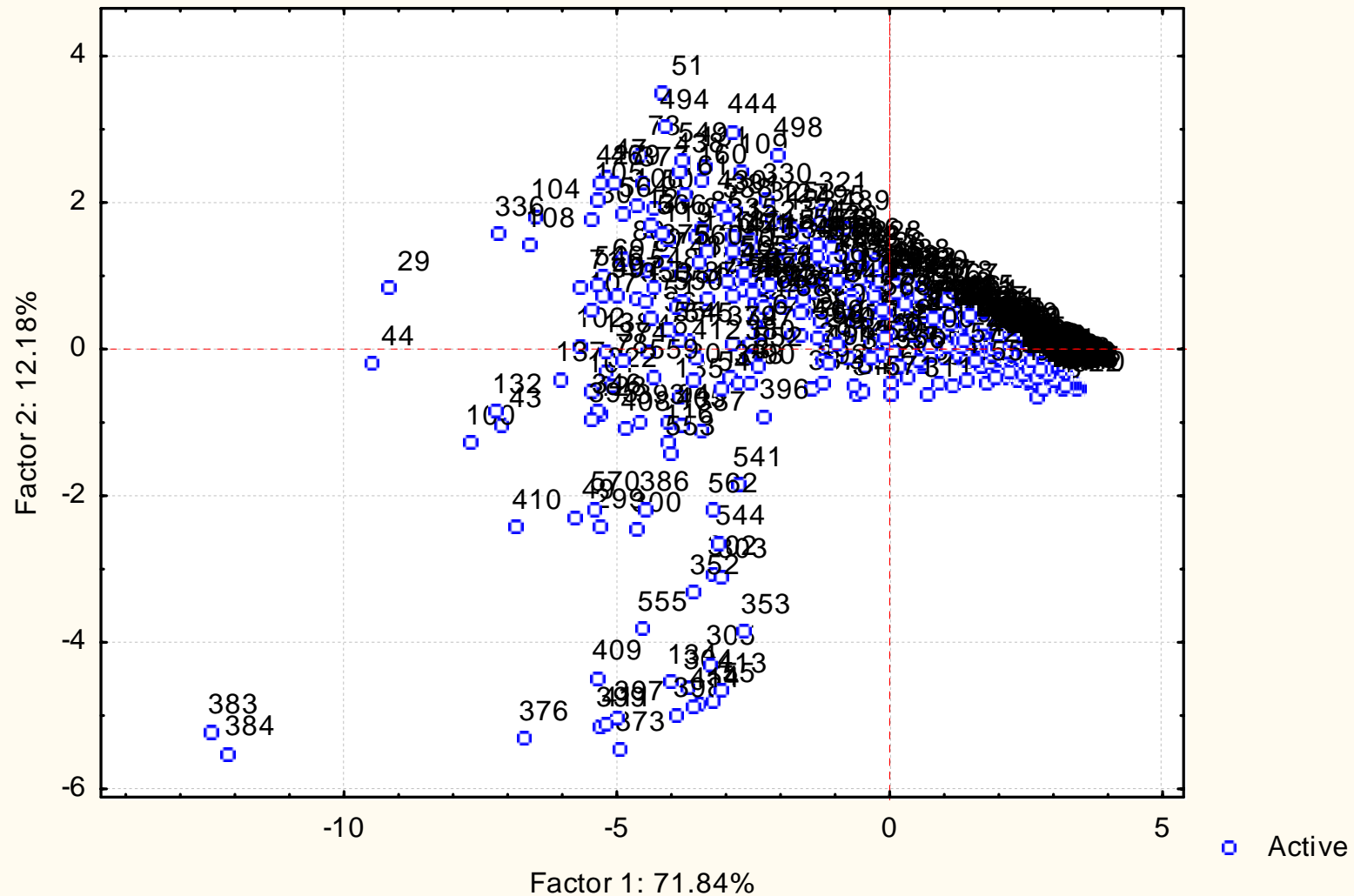
Fitness: N-Fold Cross Valid



# BISC - Decision Support System

Projection of the cases on the factor-plane ( 1 x 2 )

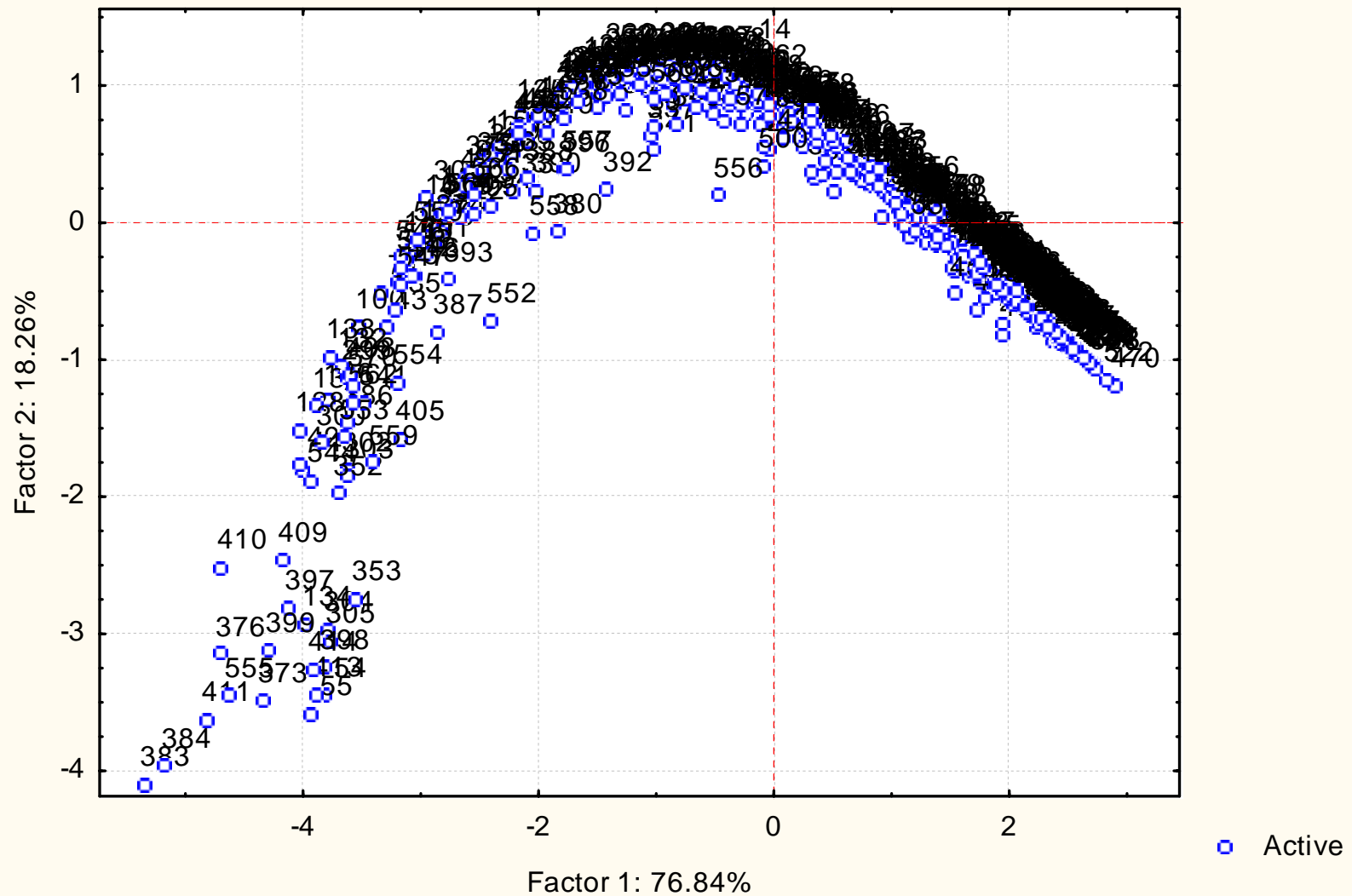
Cases with sum of cosine square  $\geq 0.00$



# BISC - Decision Support System

Projection of the cases on the factor-plane ( 1 x 2)

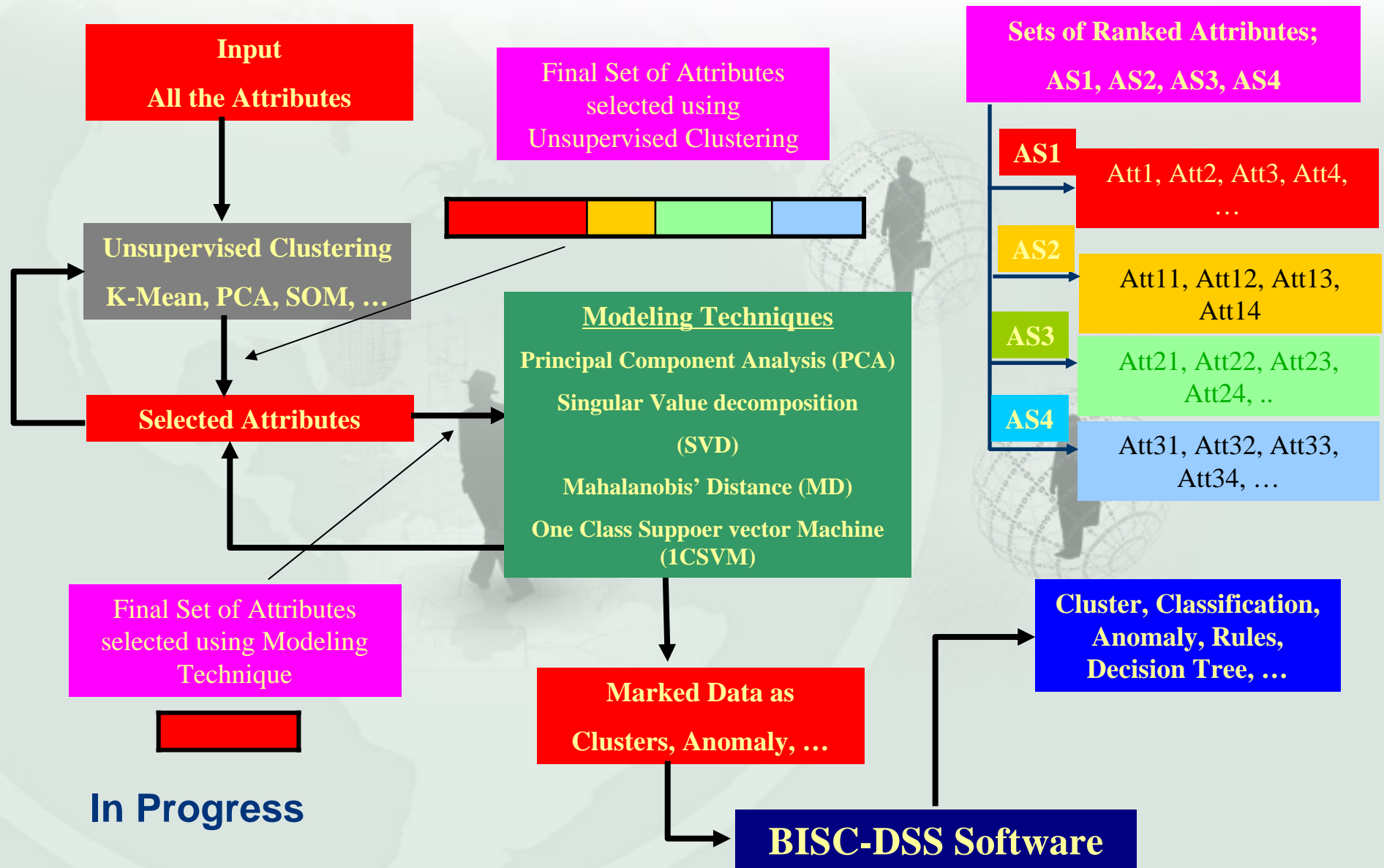
Cases with sum of cosine square  $\geq 0.00$



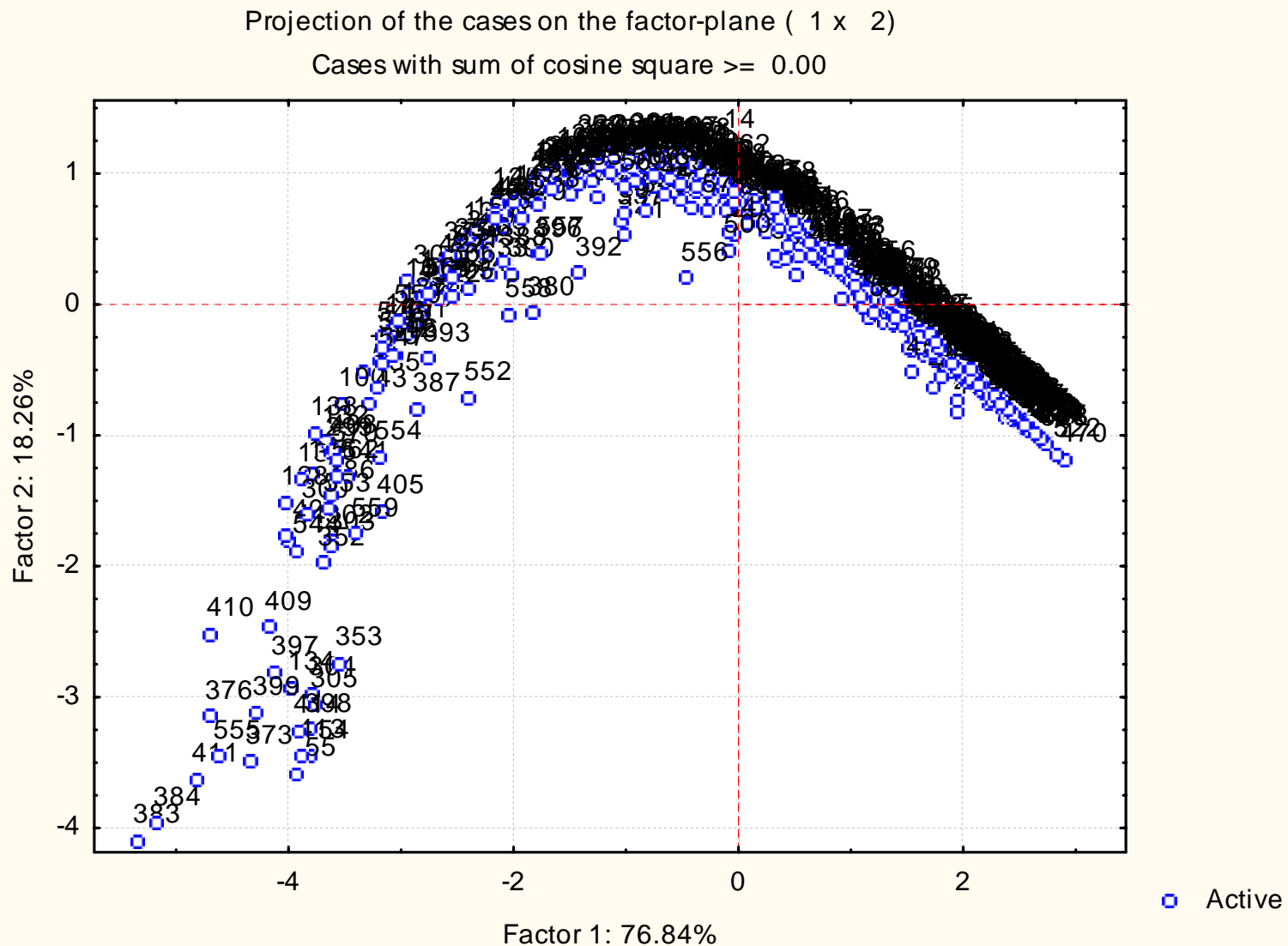


# BISC - Decision Support System

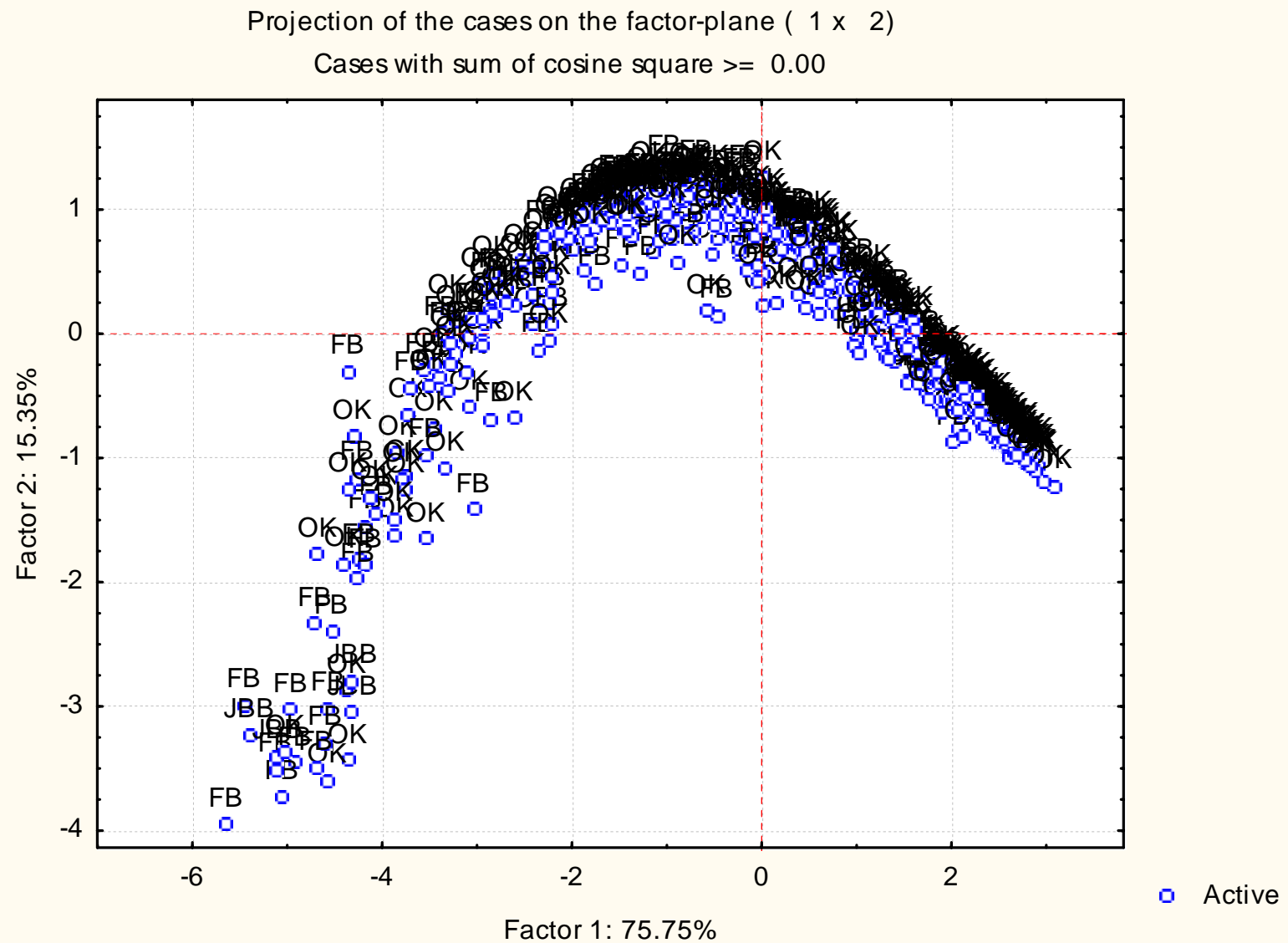
## BISC-DSS Clustering-Based ANSIS



# BISC - Decision Support System



# BISC - Decision Support System





# BISC - Decision Support System

