APPLYING FUZZY LOGIC AND GENETIC ALGORITHM FOR MULTI CRITERIA LAND VALORIZATION

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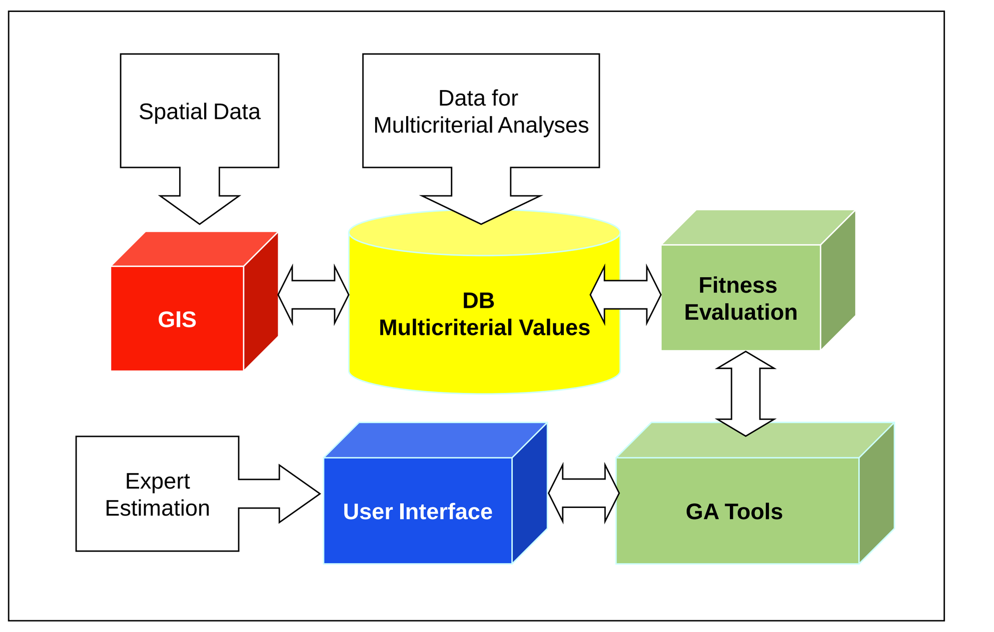
Abstract This chapter investigates possibility of multicriterial land valorization by application of genetic algorithm and fuzzy logic. One of the key tools for design of the decision support system based on this methodology is geographic information system which serves to quantify multicriterial data and represent resulting spatial data. The methodology and the algorithm are applied to a specific problem of spatial planning in Tuzla Canton, Bosnia and Herzegovina. In spatial multi criteria analyses geographic information systems are used to identify alternatives, present them and give information to decision makers for evaluating, comparing and ordering of alternatives. Limitations of multi criteria analyses in standard GIS are necessity to define all steps in advance and inability to simple change criteria or thresholds later. Fuzzy set methodologies and GA optimization could be excellent for designing efficient tools to support the spatial decision making process. Here is examined the incorporation of these methodologies into a DBMS repository for the application domain of GIS. It is shown how the useful concepts of fuzzy set theory and GA may be adopted for the representation and analysis of geographic data, whose uncertainty is an inherent characteristic.

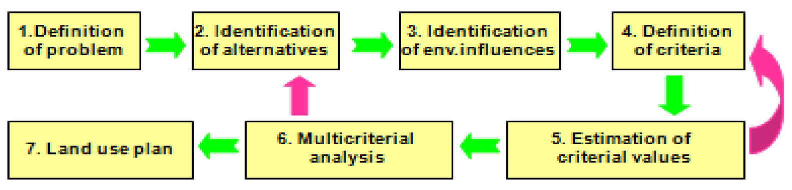
Land Use Multicriterial Analyses and DSS Structure



Multicrterial Optimization Problem in Spatial Planning

Spatial planning methodology: analysis, synthesis and planning phase

Multicriterial analysis process:



More alternatives - problem of multicriterial optimization – to find most suitable solution

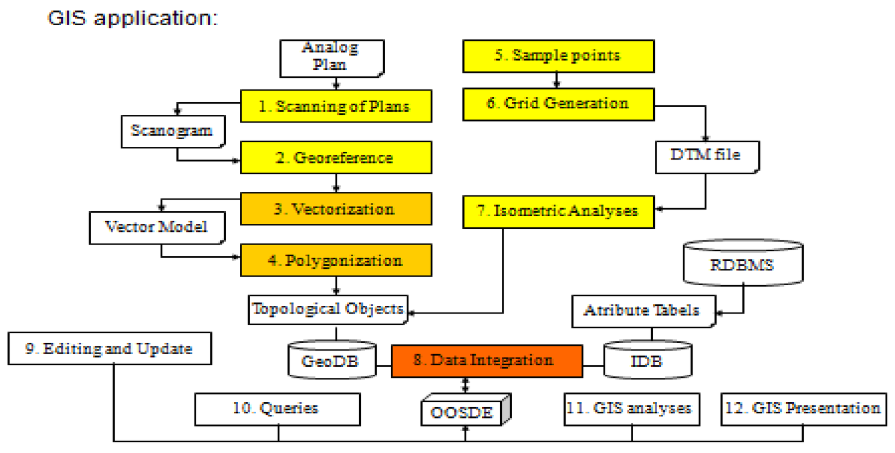
Alternatives – syntesis models (environmental, functional, neutral...)

Adjusting criterial weights – simulation model variants – searching optimal solution

Possibility of GA application in multicriterial optimization process...

Multicriterial Land Valorisation of Tuzla Canton

GIS application:



Criterial Factors and Categories Used for Land Use Valorization

Criterial factors:

- Land accessibility (related to the center of settlement)
- Slope of terrain
- Relative height
- Aspect of terrain
- Land usable value for agriculture (soil classification)
- Environmental value of vegetation coverage (basic topographic classification)

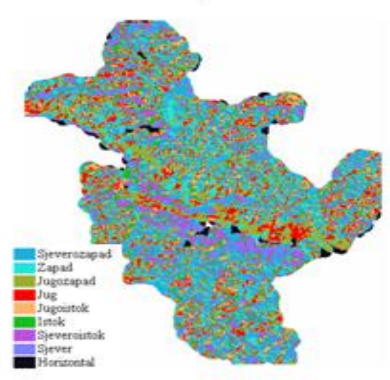
Categories of land use:

- Extraordinary suitable: reconstruction area, collective and individual dwellings with central functions
- Very suitable: intensive urbanization area, collective and individual dwelling units, industrial and recreation zones
- Suitable: extensive urbanization area, individual dwelling units, rural agricultural production and small business
- Unsuitable: area reserved for agricultural production

Preparing of Criterial Values in GIS

3D Model of Tuzla Canton

Classification of Aspects



Scoring of Land Units: Slope of Terrain

Terrain Slope Classes	Values %	Scores (1 to 5)
flat	0 - 2	5
small inclination	2 - 4	4
inclined	4 - 10	3
steep	10 - 20	2
very steep	20 - 30	1

Scoring of Land Units: Aspects of Terrain

Aspects Classes	Values in Degrees	Scores (1 to 5)
Horizontal	0° - 360°	5
South	135° - 225°	4
East	45° - 135°	3
West	225° - 315°	3
North	315° - 45°	1

Scoring of Land Units: Relative Heights

Relative heights classes	Values in meters	Scores (1 to 5)
Plain Land	0 - 300 m	5
Hill Land	300 - 700 m	3
Mountain Land	above 700 m	1

Scoring of Land Units: Land Usable Value

Land Usable Classes	Land Bonity Categories	Scores (1 to 5)
1st agrozone	I - IVa	5
2nd agrozone	IVb - VI	3
3rd agrozone	VII - VIII	1

Scoring of Land Units: Environmental Land Value

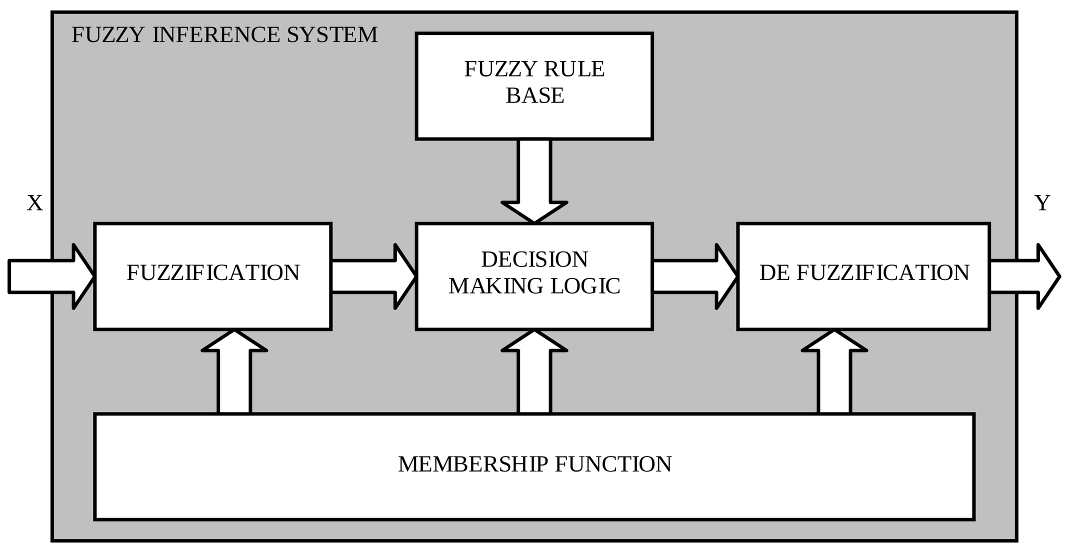
Environment of Land Classes	CORINE Classification	Scores (1 to 5)
Very low values	[illegible]	5
Low values	[illegible]	2
Middle Values	[illegible]	3
High values	[illegible]	4
Very high values	[illegible]	5

Scoring of Land Units: Land Accessibility

Land Accessibility Classes	Time in minutes	Scores (1 to 5)
Very near	0 - 5 min.	5
Near	5 - 10 min.	4
Accessible far	10 - 15 min.	3
Far	15 - 20 min.	2
Very far	20 - 30 min.	1

LIMITATIONS OF CURRENT GIS:

- This procedure is very demanding in time and it was unsuitable for decision making in real time. It produced useful results but it also emphasis some of limitations.
- Current GIS are predominantly based on Boolean logic.
- The representation of geographic data based on the classical set theory affects on reasoning and analysis procedures, adding in all problems of an "early and precisely classification".
- Final decision is made after steps which drastically reduce the intermediate results. Any constraint is accompanied with an absolute threshold value and no exception is allowed.
- Finally, another effect of classical set theory is that the selection result is flat, in the sense that there is no overall ordering of the valid entities as regard to the degree they fulfill the set of constraints.

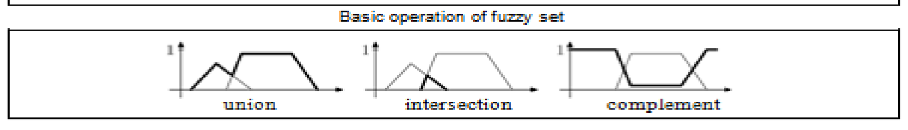


IF X = {x} THEN A = {x, $\mu_A(x)$}, $\forall x \in X$

Definition of fuzzy set A

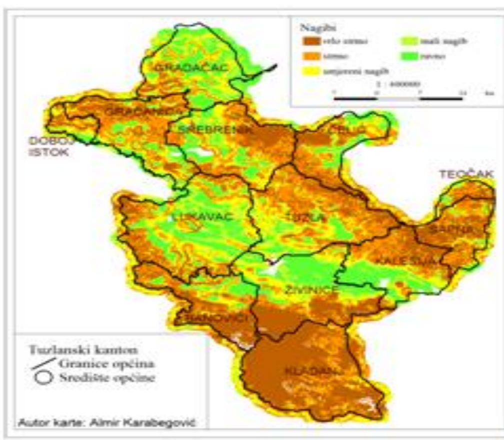
Union:	$\mu_{A\cup B}(x)=\max\{\mu_A(x), \mu_B(x)\}$,	$\forall x \in X$
Intersection:	$\mu_{A\cap B}(x)=\min\{\mu_A(x), \mu_B(x)\}$,	$\forall x \in X$
Complement:	$\mu_{\bar{A}}(x)=1-\mu_A(x)$,	$\forall x \in X$

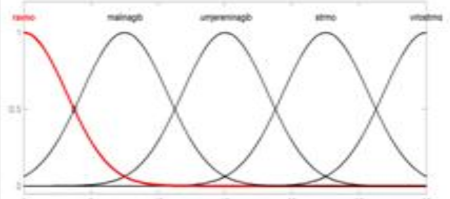
Basic operation of fuzzy set



Level ground and dry land:	$\min\{\mu_{level}(l), \mu_{dry}(l)\}$,	(min {0,8;0,4}=0,4)
Level ground or dry land:	$\max\{\mu_{level}(l), \mu_{dry}(l)\}$,	(max {0,8;0,4}=0,8)
Non-level ground:	$1-\mu_{level}(l)$,	(1-0,8=0,2)

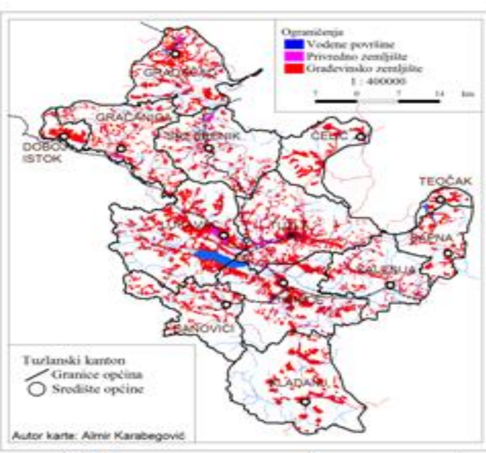
Fuzzy logic

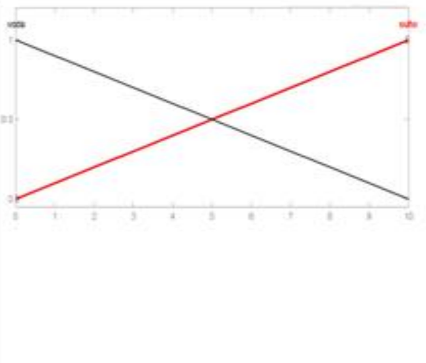




Classes	Klase	from	to
flat (level)	ravno	0	2
small inclination (gentle)	mali nagib	2	4
inclined (moderate)	umjereni nagib	4	10
steep	strmo	10	20
very steep	vrlo strmo	20	30

Classes of slopes





Classes	Klase	Categories
dry	suho	not under water
wet	vodena površina	under water

Classes of constraint: wet areas

IF x IS A THEN y IS B

Fuzzy If-Then Rule

$\mu(x, y) = \Phi m\,[\mu_A(x), \mu_B(y)] \equiv \mu_A(x) \wedge \mu_B(y)$

Membership function with Mamdani Min implication

min(ravno, jug, "veoma blizu", ravnicarska, agrozona3, vegetacija)

IF (slope IS flat) AND (aspect IS south) AND (accessibility IS close) AND (altitudes IS low) AND (usability IS agrozona3) AND (bio_value IS SmallBioVal) AND (wet IS NOT water) THEN area IS suitable (1)

Example of implication relation

```
SELECT ID, Municipality
FROM TK
WHERE Slope Is Not Null AND South Is Not Null AND Close Is Not Null AND Low
Is Not Null AND [Agrozona 3] Is Not Null AND [Vegetation 1] IS NOT NULL AND
Water IS NULL;
```

SQL statement

Rule Base Creation

$\mu_E(x)= \sum_{i=1}^{n} [\mu_{A_i}(x)]^2$ $\mu_{level\text{-}dry}(l)= [\mu_{level}(l)]^2+[\mu_{dry}(l)]^2$

Exponential function

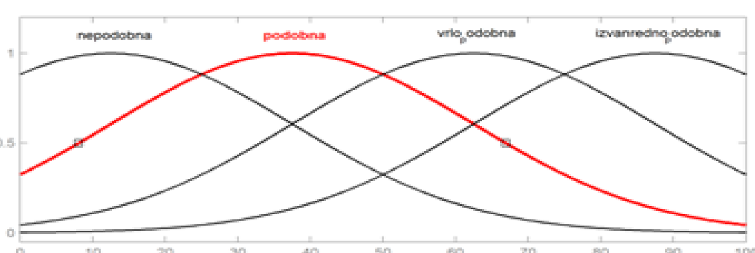
L_1: $\mu_{level}(l)=0{,}8$ i $\mu_{dry}(l)]=0{,}4$ $L_1=0{,}80$

L_2: $\mu_{level}(l)=0{,}6$ i $\mu_{dry}(l)]=0{,}4$ $L_2=0{,}56$

$\mu(x)= [\mu_{level}(x)]^2+[\mu_{south}(x)]^2+[\mu_{close}(x)]^2+[\mu_{low}(x)]^2+[\mu_{agrozone3}(x)]^2+[\mu_{vegetation}(x)]^2$

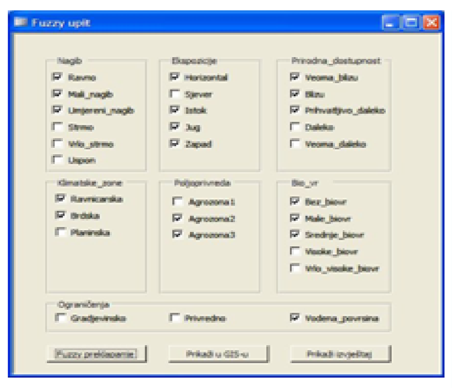
```
SELECT
ID, Municipality, ([Flat]^2 + [South]^2 + [Close]^2 + [Low]^2 + [Agrozone 3]^2 +
[vegetation]^2) AS Result
FROM
TK
WHERE
Flat Is Not Null AND South Is Not Null AND Close Is Not Null AND Low Is Not Null
AND [Agrozone 3] Is Not Null AND [Vegetation] Is Not Null;
```

SQL statement with exponential function



Category classes	Klase kategorizacije	from	to
extraordinarily suitable	izvanredno podobna	75	100
very suitable	vrlo podobna	50	75
suitable	podobna	25	50
unsuitable	nepodobna	0	25

Output: Category Classes




```
SELECT
ID, Municipality,
[flat]+[small_inclination]+[inclined] AS Slope,
[east]+[south]+[west] AS Aspect,
[close]+[near]+[moderate_far] AS Accessibility,
[lawland]+[hill] AS Altitude,
[agrozon2]+[agrozone3] AS Usability,
[nobioval]+[smallbioval]+[medbioval] AS BioValue,
([slope]^2+[aspect]^2+[accessibility]^2+
[altitude]^2+[usability]^2+
[biological_value]^2)/6 AS Result
FROM
TK
WHERE
Slope>0 AND Aspect>0 AND
Accessibility>0 AND Altitude>0 AND
Usability>0 AND BioValue>0 AND
ALL CONSTRAINTS=0;
```

Land Valorization for Municipality Tuzla

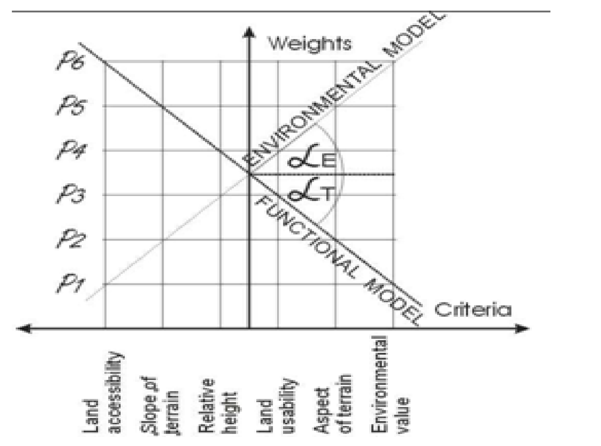
Syntheses Models and Criterial Weights

Synthesis model:

$p1= -2{,}5\ tg_\alpha + 3{,}5$
$p2= -1{,}5\ tg_\alpha + 3{,}5$
$p3= -0{,}5\ tg_\alpha + 3{,}5$
$p4= 0{,}5\ tg_\alpha + 3{,}5$
$p5= 1{,}5\ tg_\alpha + 3{,}5$
$p6= 2{,}5\ tg_\alpha + 3{,}5$ (1)

p1,...., p6 – criterial weights

α – angle of model gravitation



Optimization of Model

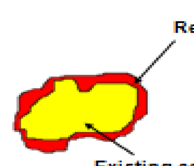
$-1 < \mathrm{tg}\,\alpha_i < 1, \quad -\pi/4 < \alpha_i < \pi/4$

$P=F(x, y, z, \alpha)$

$P_E=F(x, y, z, \alpha_E=\pi/4)$

$P_T=F(x, y, z, \alpha_T=-\pi/4)$

$F_c=(P_r-P_o)^2$ (2)



Pr – searched area intended for reconstruction

Po – existing construction area

Condition for model optimization:

It is searched P_r under condition $F_c=(P_r-P_o)^2$ is minimum.

Substitution of discrete values P_r by polynom $\psi_r(\alpha)$

$$\Phi = [\psi_r(\alpha) - P_O]^2 = \min \qquad (3)$$

$$\psi_r(\alpha) = A_0 + A_1\alpha + A_2\alpha^2 + A_3\alpha^3 + \ldots + A_n\alpha^n$$

Fitness Function (M-fajl)

$$F_f = \sum_{k=1}^{n} \Phi_k = \sum_{k=1}^{n} [\psi_{rk}(\alpha) - P_{Ok}]^2 \qquad (4)$$

Defined by:
- polinomial coeficients for each of municipality
- existing construction areas

f (x) = (348,8377463013 - 21,75263395 41*x(1) + 0,4016226489*x(1)^2 - 0,0016873166*x(1)^3 – 0,0000108673*x(1)^4 + 0,0000000310*x(1)^5 - 165)^2+(186,7937372788 - 10,2743806782*x(2) + 0,2202515320*x(2)^2 -0,0019426141*x(2)^3 + 0,0000002979*x(2)^4 + 0,0000000656*x(2)^5 - 341)^2 + (170,9177048445 - 12,6321305648*x(3) + 0,2665822578*x(3)^2 - 0,0009419160*x(3)^3 –0,0000183937*x(3)^4 + 0,0000001039*x(3)^5 - 383)^2 +(176,4802522369 - 23,2490405188*x(4) + 1,2144378125*x(4)^2 - 0,0175181323*x(4)^3 – 0,0000601802*x(4)^4 + 0,0000017210*x(4)^5 - 124)^2 +(191,7727052208 - 12,4839870027*x(5) + 0,3668836951*x(5)^2 -0,0052456386*x(5)^3 + 0,0000278122*x(5)^4 + ,0000000070*x(5)^5 - 422)^2 +(1580,3244698400 - 64,3594452645*x(6) + 1,0005467834*x(6)^2 - 0,0066359425*x(6)^3 – 0,0000230383*x(6)^4 + 0,0000004928*x(6)^5 - 770)^2 +(1,5022293782 - 0,7271246909*x(7) + 0,0487477510*x(7)^2 -0,0009883981*x(7)^3 + 0,0000052441*x(7)^4 + 0,0000000132*x(7)^5 - 578)^2 + (2328,9583226224 - 68,9768518537*x(8) + 0,4255085854*x(8)^2 -0,0006255124*x(8)^3 + 0,0000409347*x(8)^4 - 0,0000002266*x(8)^5 - 1485)^2 +(357,7610807068 - 23,3160386303*x(9) + 0,5938160152*x(9)^2 -0,0062482157*x(9)^3 + 0,0000079759*x(9)^4 + 0,0000001847*x(9)^5 - 155)^2 + (17,7526193465 - 0,4416848983*x(10) - 0,0042796456*x(10)^2 -0,0009401805*x(10)^3 + 0,0000348514*x(10)^4 - 0,0000002824*x(10)^5 - 280)^2 +(6,6147176627 - 0,6945435717*x(11) + 0,0243475471*x(11)^2 -0,0006222335*x(11)^3 + 0,0000109142*x(11)^4 - 0,0000000741*x(11)^5 - 402)^2 + (629,5265368655 - 27,2595075232*x(12) + 0,5058104623*x(12)^2 -0,0063799621*x(12)^3 + 0,0000482742*x(12)^4 - 0,0000001054*x(12)^5 - 508)^2 +(3030,5668662700 - 2,0346727101*x(13)+1,4679300571*x(13)^2 -0,0049535627*x(13)^3 – 0,0001125021*x(13)^4 + 0,0000011737*x(13)^5 - 127)^2

CONCLUSION FIRST PART:

- Limitations of multi criteria analyses in standard GIS are necessity to define all steps in advance and inability to simple change criteria or thresholds later.
- Getting results with such procedures is only matter of database and GIS is now just a tool for making spatial presentation of results.
- Every change of input data, now, requires only checking its influents to information (classic UPDATE statement in database).

Representation of Chromosome

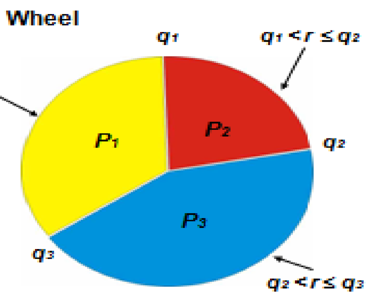
- binary string λ
- variable presents real values of gravitation angle in radians
- domain of searching is defined by precision of 0,01 rad (00000000 to 11111111)
- solutions are presented by 104 bits strings consisting 13 genes
- each gene (8 bits) represents model (angle of gravitation) of specfic municipality

Selection – Roulette Wheel

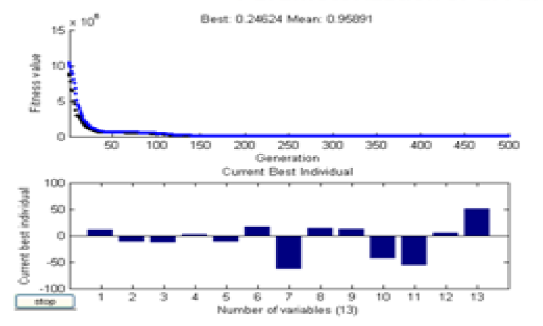
$P = \{a_1, a_2, a_3, \ldots, a_n\}$ $\quad a_i \in P$

$$P_s(a_j) = \frac{fitness(a_j)}{\sum_{k=1}^{n} fitness(a_k)}$$

ANGLE OF SECTOR WHEEL $= 2\pi P_s(a_j)$



Parameterization of GA and Results



n. test

No. of variables: 13
Selection: Roulette Wheel
Population size: 100 chromosomes
Reproduction:
-elite count 2,
-crossover fraction 0.8
Mutation: Gaussian
-scale: 1.0
-shrink: 1.0
Crossover: single point
Stopping criterion: 500 generation

gen k	1	2	3	4	5	6	7	8	9	10	11	12	13
x(k) *100	10,3	-11,8	-13,1	2,6	-12,7	16,2	63,9	13,3	11,8	-43.7	-57,1	4,9	50,7

CONCLUSION SECOND PART:

- Methodology for optimization of validation model consists:
  - definition of syntheses models (alternatives),
  - definition criteria and criterial values,
  - design of multicriterial database in GIS,
  - application of GA in multicriterial optimization and
  - presentation of land use plan in GIS.
- By the applied methodology and description of DSS it is enabled:
  - interactive searching the alternatives of spatial organization
  - finding the optimum alternative for various given parameters (objectives)
  - development of a DSS for spatial multicriterial analysis by GA aproach which is capable to handle with descrete values