

Cartographic Adaptations of the GAIA Visualization Method for Spatial Decision Support

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Context

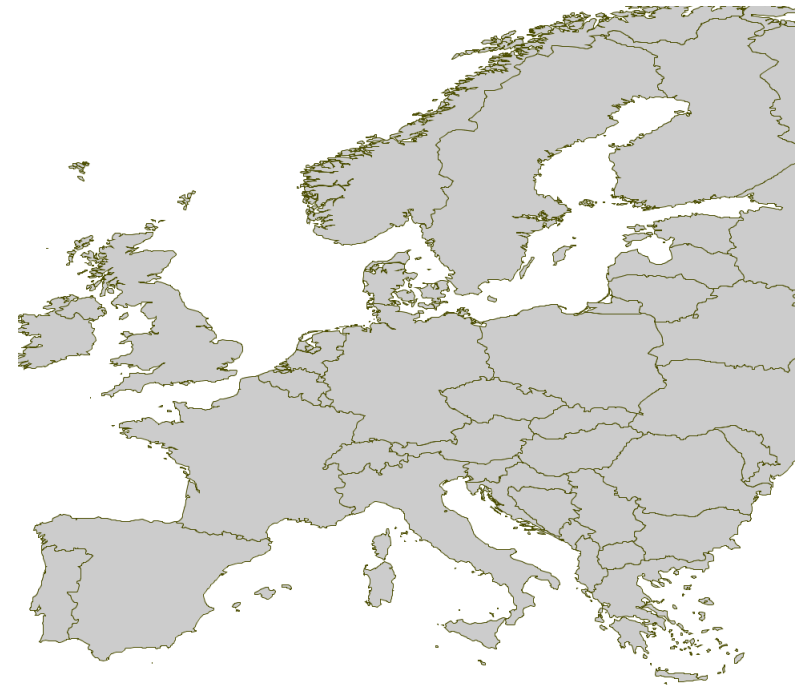
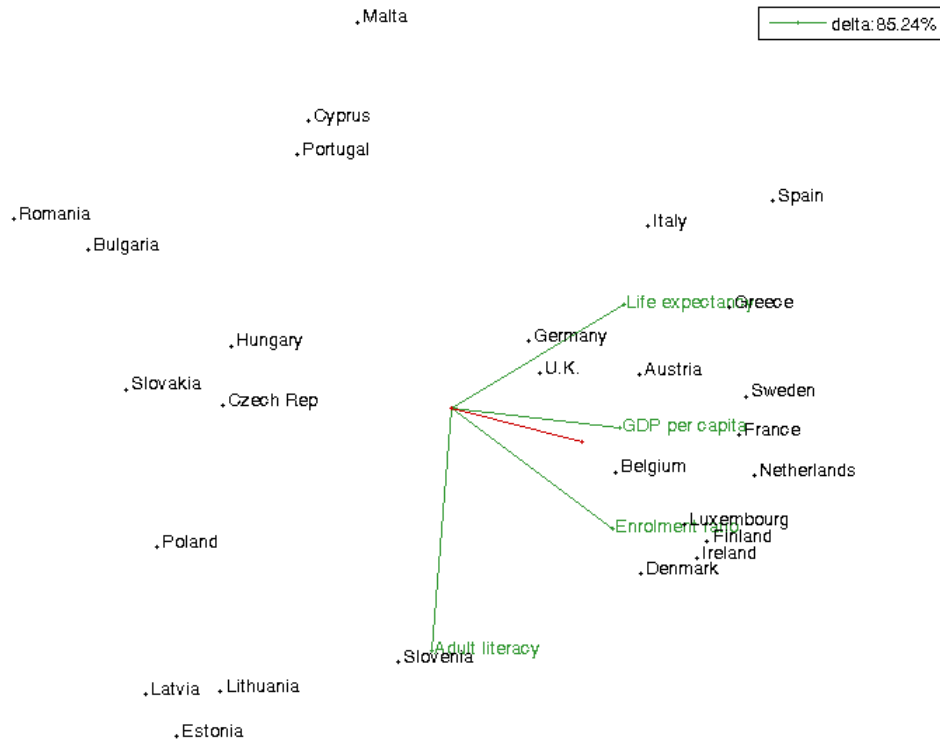
- Spatial decision problems are multi-criteria problems
 - Tackle existing situations
 - Several stakeholders
- Need to take several aspects into account:
 - Multiple criteria
 - Multiple viewpoints
- PhD thesis presented recently on the integration of MCDA in GIS
- In this work we focus on spatially referenced problems and their visualization

Data exploration

- Get an understanding of our problem
 - ➔ Visualization will be a key factor
- GAIA visualization method
 - ➔ Other uses than those proposed in the GAIA plane?
 - Positions of the alternatives
 - Positions of the criteria
 - ...

Examples of spatially referenced problems

- Human Development Index (HDI)
- Environmental Performance Index (EPI)
- ...



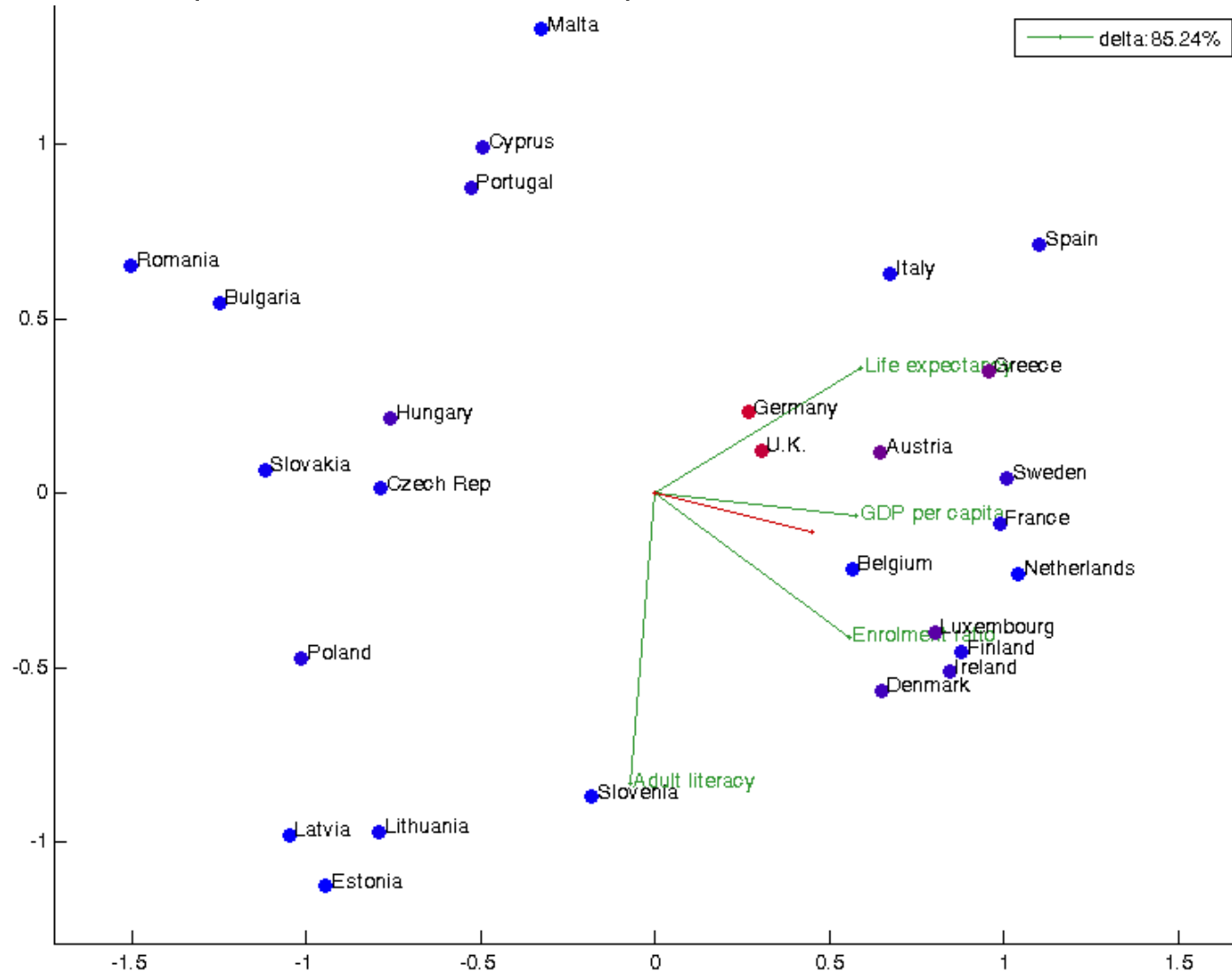
Illustrative case 1

Human Development Index in European countries

- Life expectancy at birth (in years)
- Adult literacy rate (in %)
- Combined gross enrolment ratio in education (in %)
- GDP per capita (in purchasing power parity US\$)

Illustrative case 1

- Human Development Index in European countries (GAIA: $\delta = 85\%$)



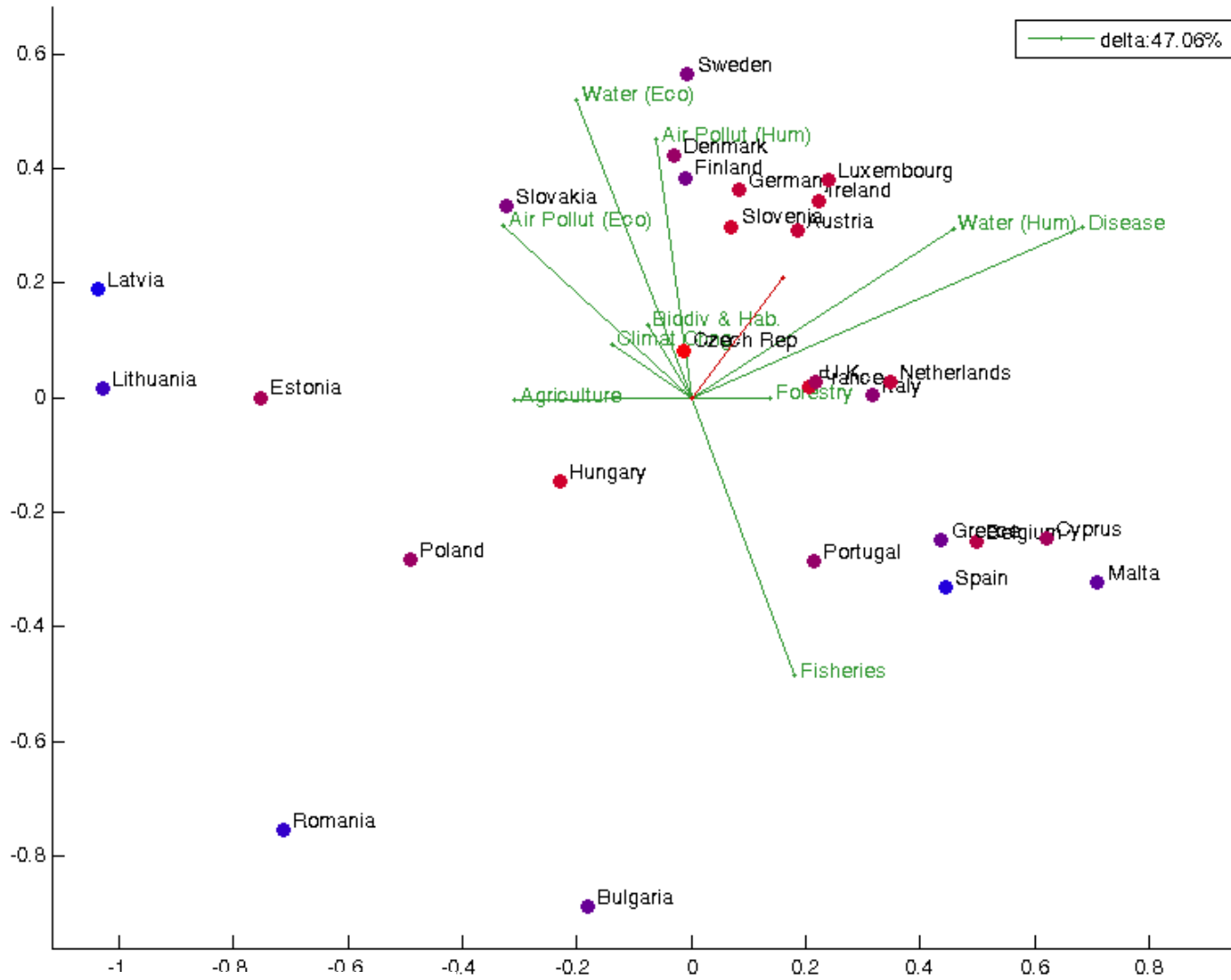
Illustrative case 2

Environmental Performance Index in European countries

- Environmental Burden of Disease
- Air Pollution (Effects on Humans)
- Water (Effects on Humans)
- Air Pollution (Effects on Ecosystem)
- Water (Effects on Ecosystem)
- Biodiversity and Habitat
- Forestry
- Fisheries
- Agriculture
- Climate Change

Illustrative cases

- Environmental Performance Index in Euro. countries (GAIA: $\delta = 47\%$)



Evaluation of the loss of data

- Evaluation of the amount of information preserved for each alternative:
 - Delta of the GAIA plane:

$$\delta = \frac{\lambda_1 + \lambda_2}{\sum_{j=1}^k \lambda_j}$$

or

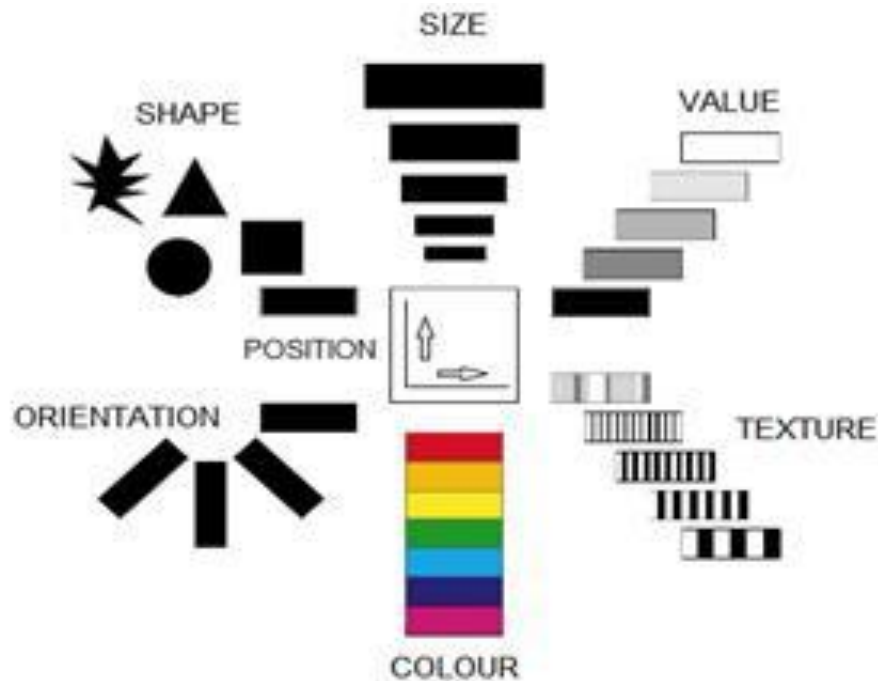
$$\delta = \frac{\sum_{i=1}^n u_i^2 + \sum_{i=1}^n v_i^2}{\sum_{i=1}^n \sum_{j=1}^q \varphi_j(a_i)^2} = \frac{\sum_{i=1}^n (u_i^2 + v_i^2)}{\sum_{i=1}^n \sum_{j=1}^q \varphi_j(a_i)^2} = \sum_{i=1}^n \delta_{a_i}$$

- Single alternative:

$$\delta_{a_i} = \frac{u_i^2 + v_i^2}{\sum_{j=1}^q \varphi_j(a_i)^2}$$

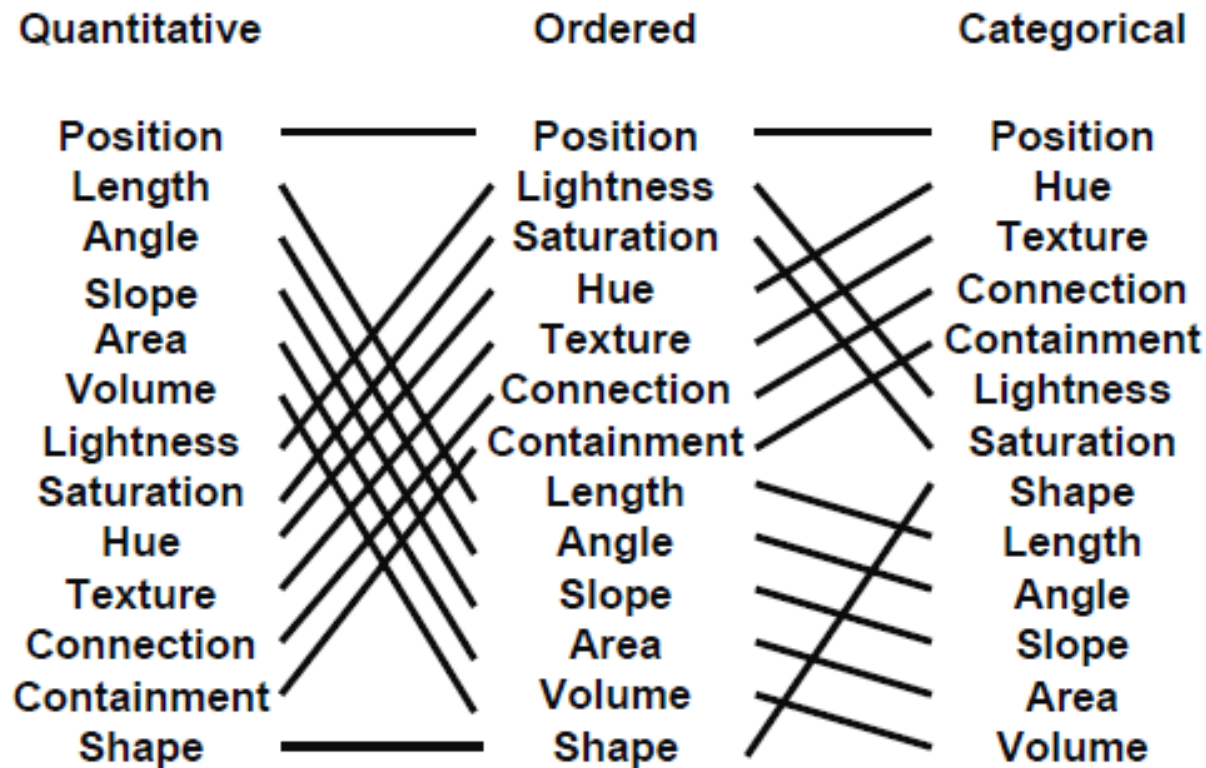
Analysis of graphical devices

- Bertin (1983)
 - Properties of graphical representations on maps (size, shape, orientation, colour...)



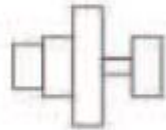
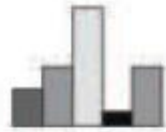
Basics of information visualization

- Mackinlay's ranking of graphical devices (1986):



Construction of glyphs

- Glyph:
 - Marker or symbol used to visually represent a piece of data



Variations on Profile glyphs



Stars and Anderson/metroglyphs



Sticks and Trees



Autoglyph and box glyph



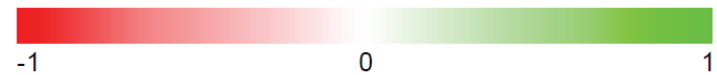
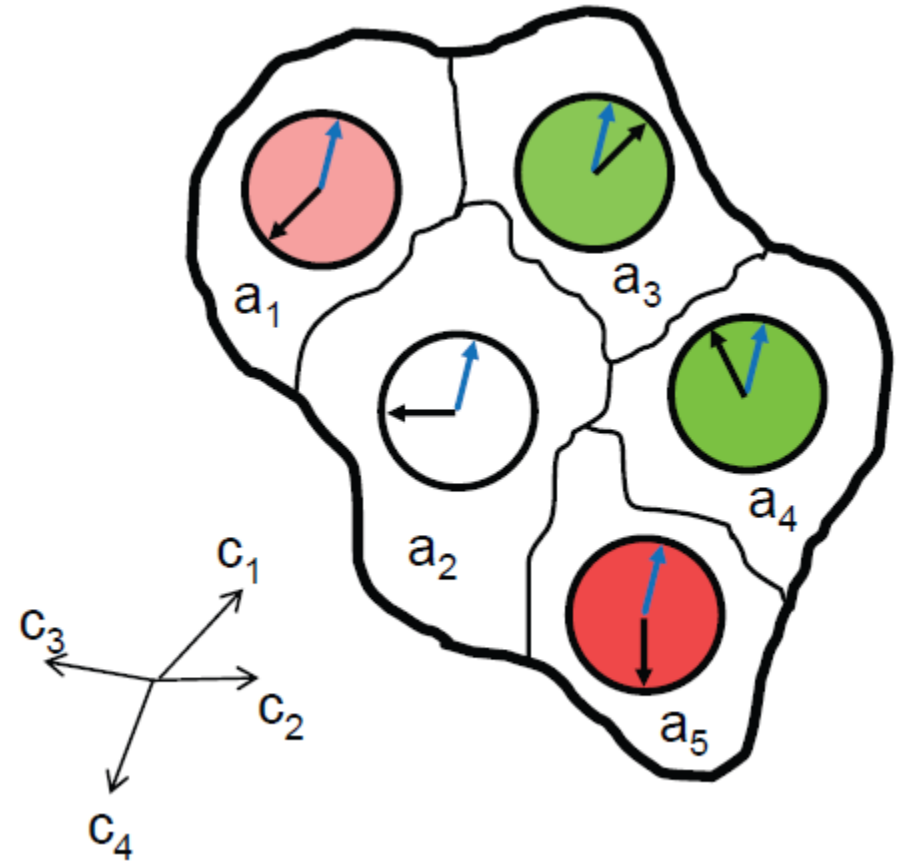
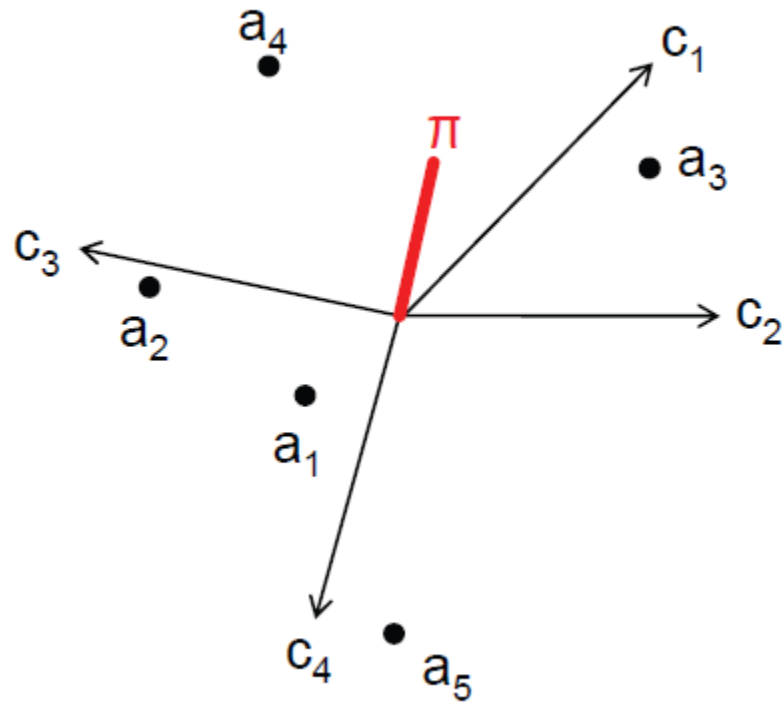
Face glyphs



Arrows and Weathervanes

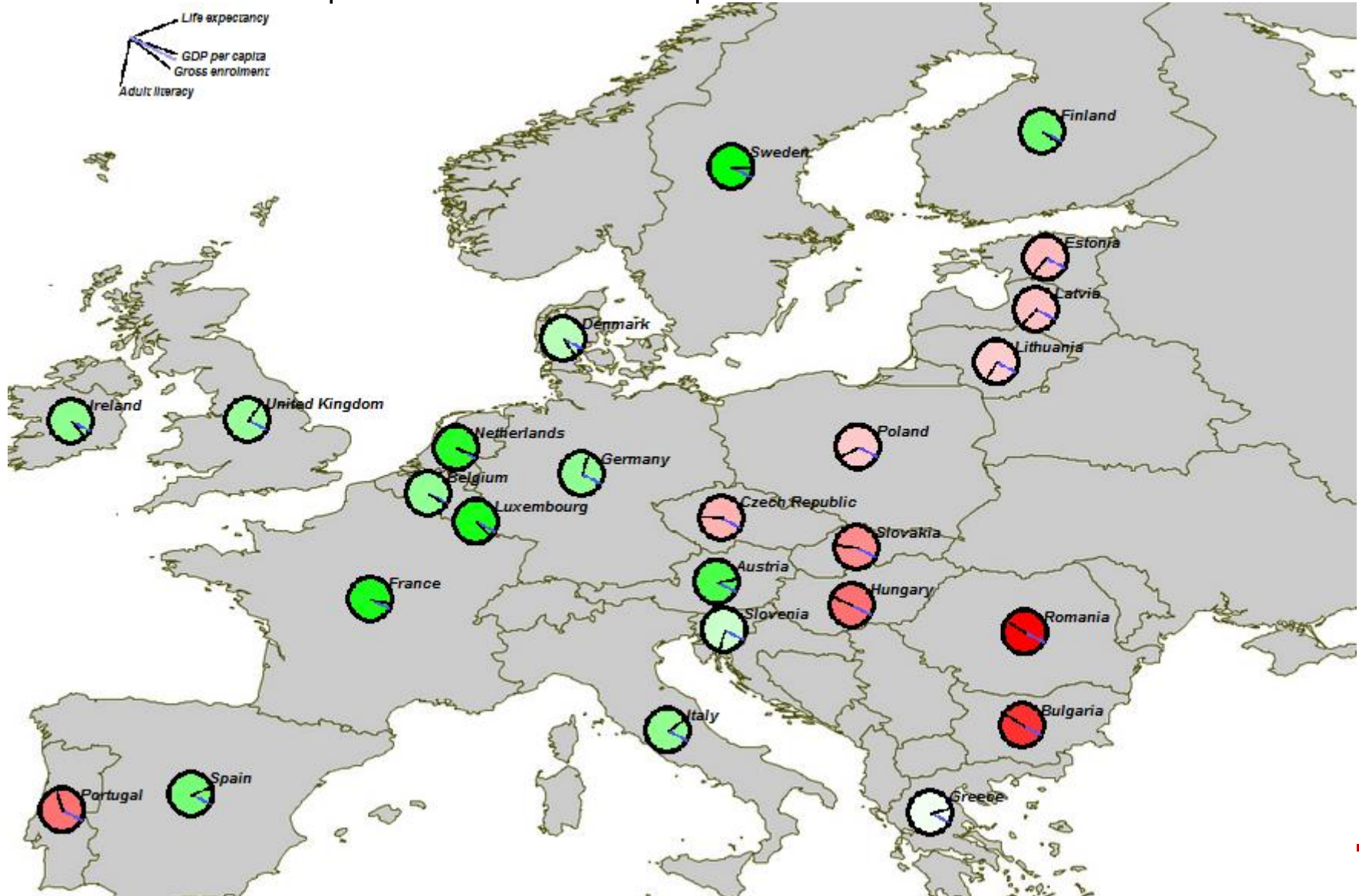
First tool: Decision clocks

- Construction of the glyphs using the GAIA plane:



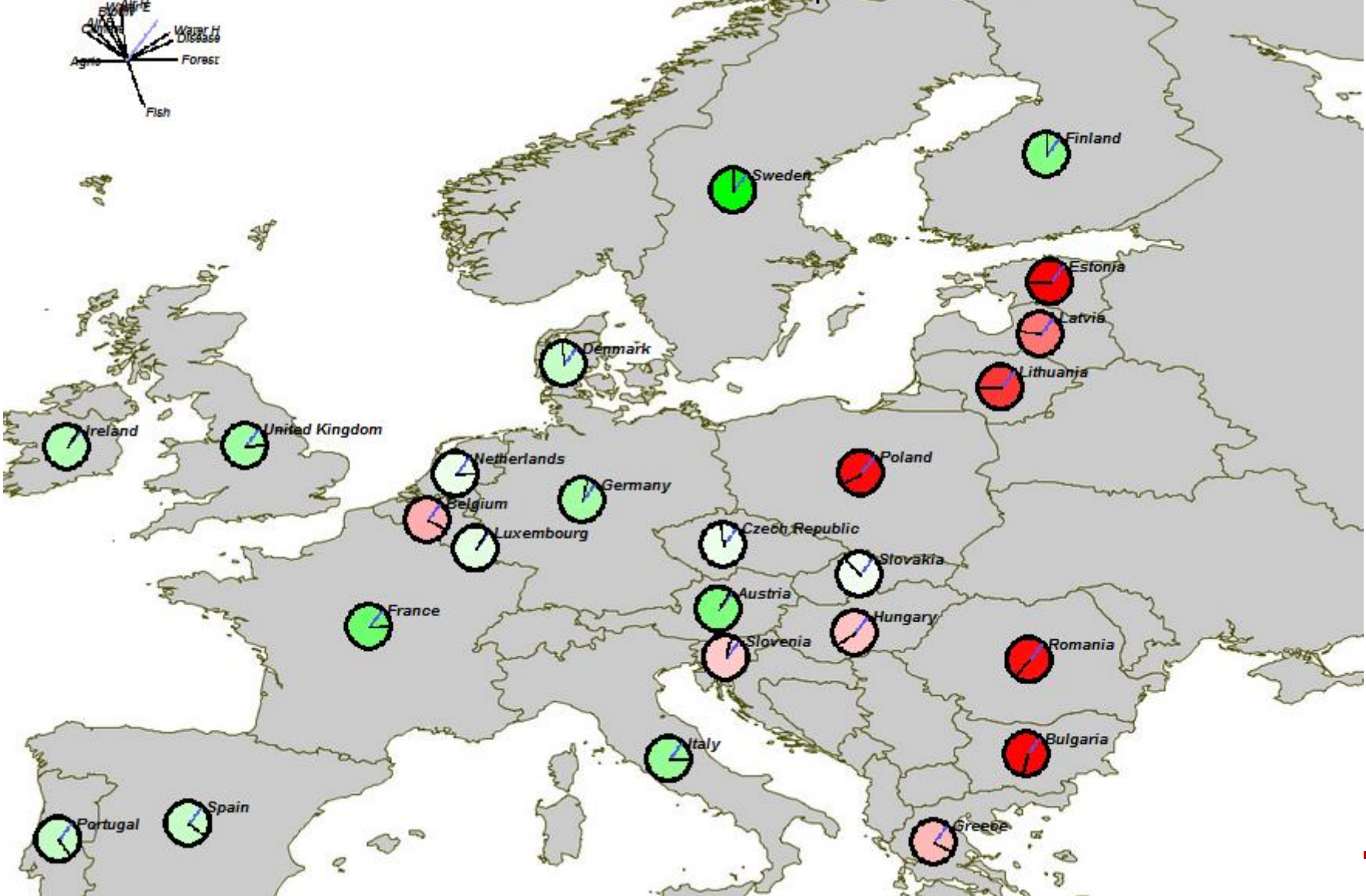
First tool: Decision clocks

- Human Development Index in European countries



First tool: Decision clocks

- Environmental Performance Index in European countries

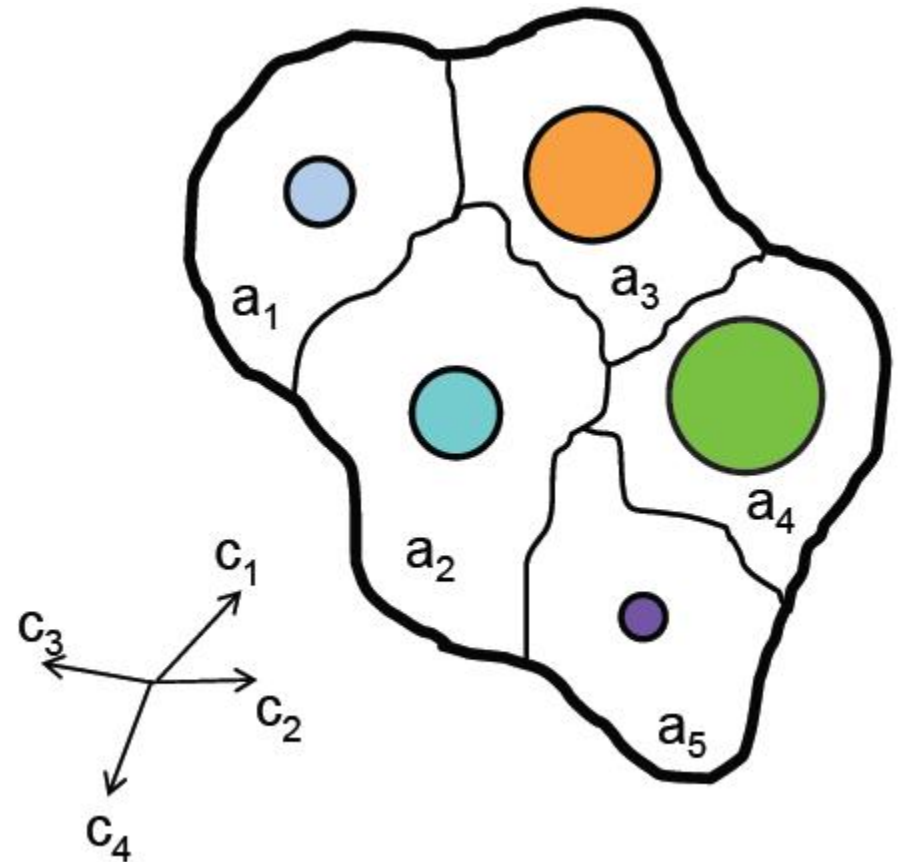
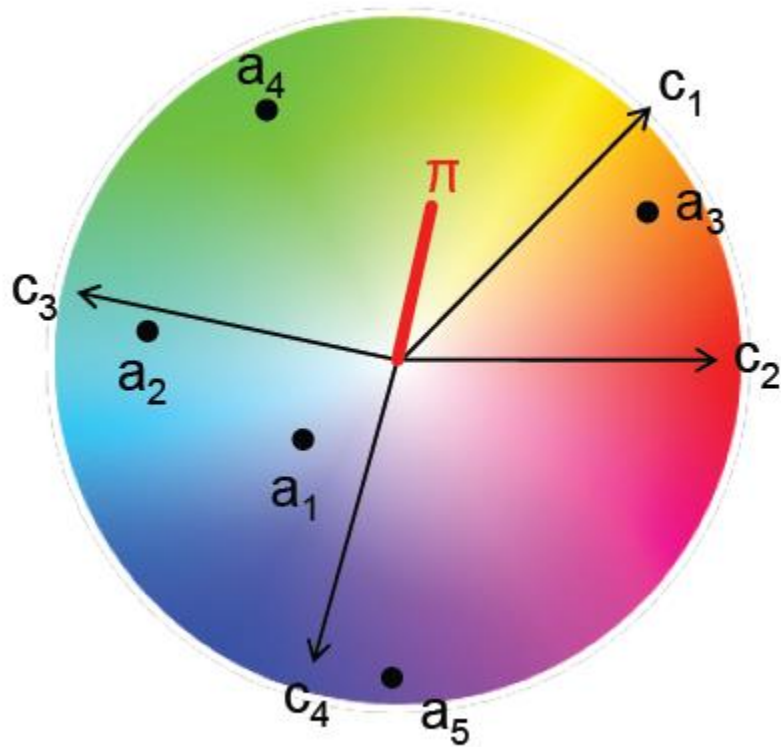


Quality of the results

- Decision clocks:
 - Intuition regarding proximity to the objective
 - Quick way to identify sets of alternatives based on net flows
 - Bad for comparing alternatives
 - Less precise than GAIA projection
- Lidouh, K., De Smet, Y. and Zimanyi, E. (2009) "GAIA Map : A Tool for Visual Ranking Analysis in Spatial Multicriteria Problems", In Proc. of 13th International Conference on Information Visualisation, IV 2009, pp.393-402, Barcelona, Spain. IEEE Computer Society Press.

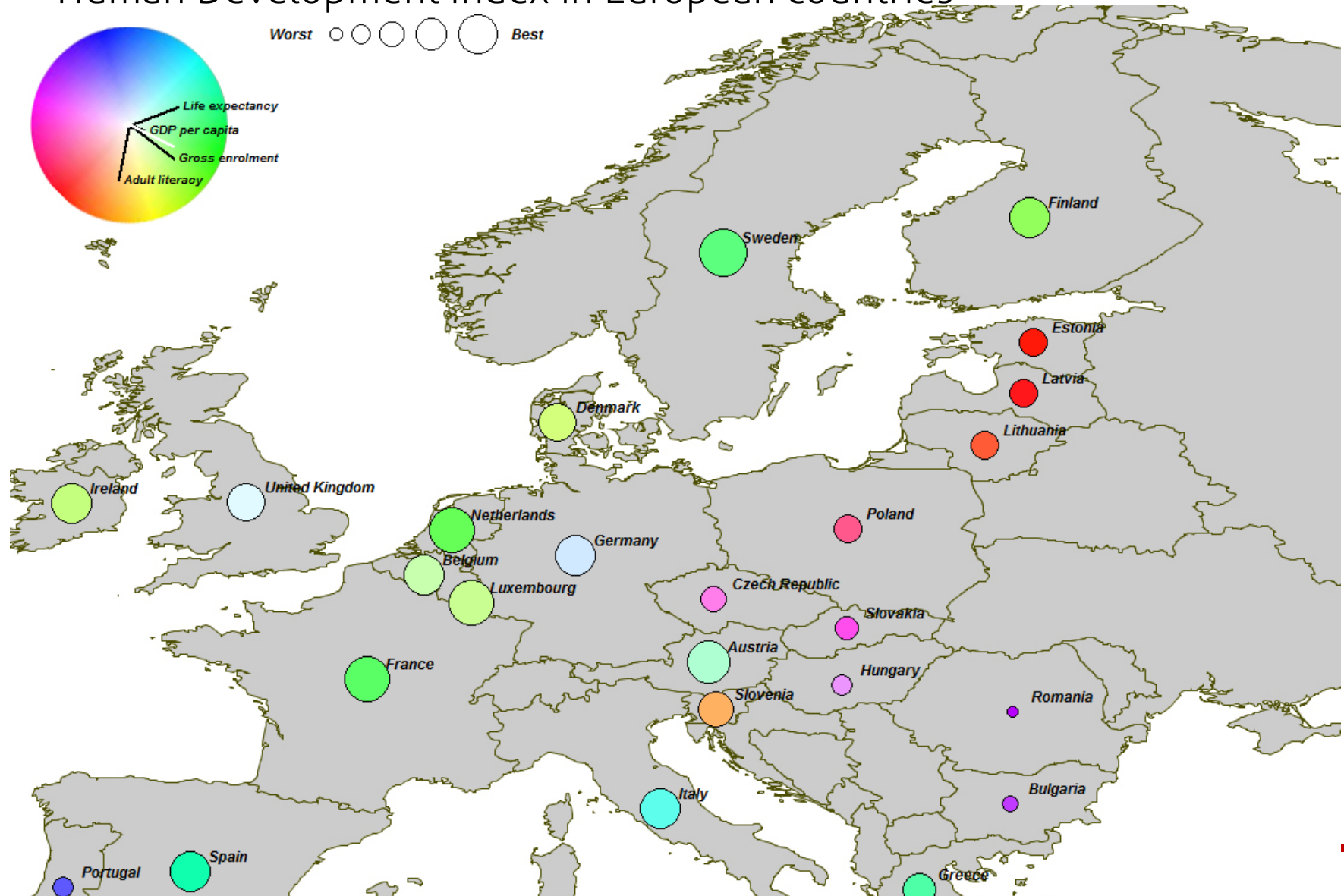
Second tool: Colored circles

- Construction of the glyphs using the GAIA plane:



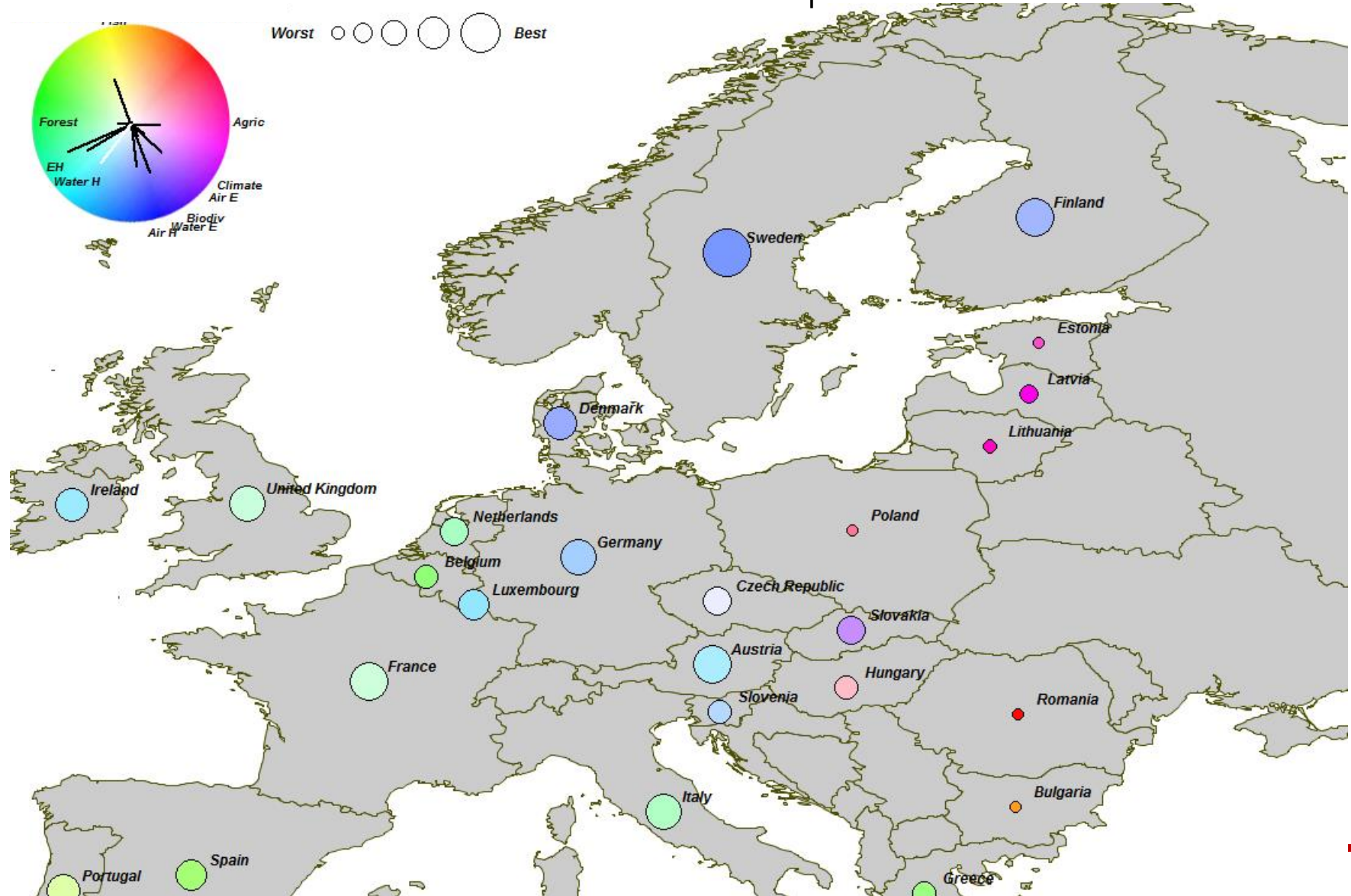
Second tool: Colored circles

- Human Development Index in European countries



Second tool: Colored circles

- Environmental Performance Index in European countries



Quality of the results

- Colored circles:
 - More precise conclusions drawn
 - Identification of profiles
 - Clusters of similar countries
 - Link between spatial proximity and profile similarity

Implementation

- Demo application with the illustrative cases
 - Interactive interface in Javascript
 - Pre-computed results
 - Available online: <http://mcda-gis.ulb.ac.be>
 - Used to illustrate the results of the associated paper:
Lidouh, K., De Smet, Y., and Zimanyi, E. (2011) “An Adaptation of the GAIA Visualization Method for Cartography : Using the HSV color system for the representation and comparison of multicriteria profiles”, In Proc. of Symposium Series in Computational Intelligence (SSCI 2011). IEEE Computer Society Press.

Visualization outside of spatial context

- The GAIA plane is a very rich representation
 - Positions of alternatives
 - Positions of criteria
 - Loss of information
- A few ideas of how other representations can be improved...

Representation of a dataset

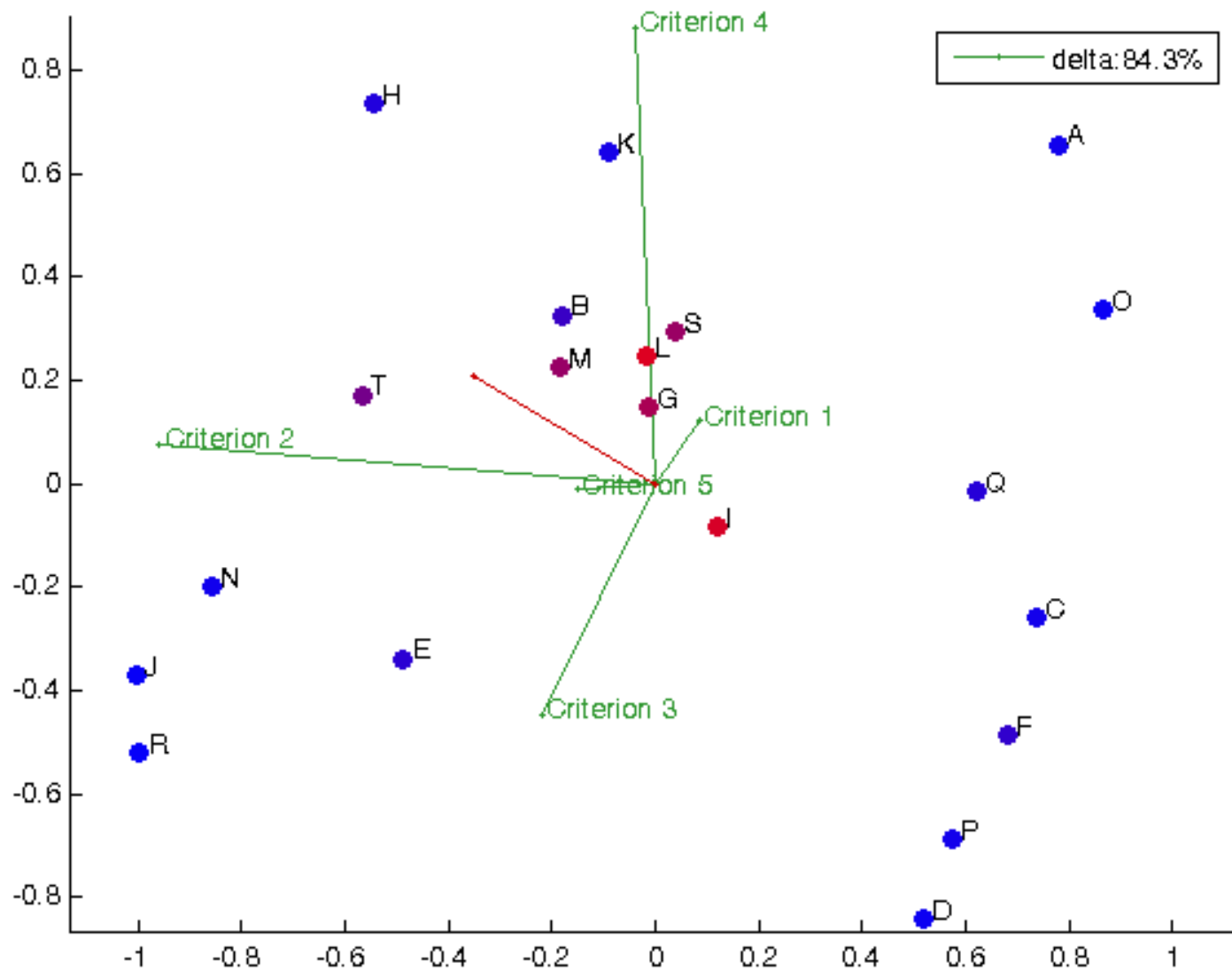
	Crit 1	Crit 2	Crit 3	Crit 4	Crit 5
A	7	0	2	9	3
B	6	5	5	7	8
C	7	0	5	3	5
D	3	1	9	0	4
E	2	7	5	2	4
F	1	1	3	1	0
G	2	4	5	6	3
H	7	7	5	10	10
I	1	3	7	5	4
J	0	10	9	3	10
K	3	5	0	8	7
L	10	5	2	5	1
M	0	5	3	6	10
N	5	9	9	4	7
O	7	0	0	6	1
P	6	1	6	0	9
Q	3	1	2	4	9
R	4	10	10	2	10
S	0	4	1	6	5
T	4	8	0	4	6
q	4	0	1	2	5
p	8	3	10	5	10
w	0,1	0,3	0,2	0,3	0,1

Representation of a dataset

	Crit 1	Crit 2	Crit 3	Crit 4	Crit 5
A	7	0	2	9	3
B	6	5	5	7	8
C	7	0	5	3	5
D	3	1	9	0	4
E	2	7	5	2	4
F	1	1	3	1	0
G	2	4	5	6	3
H	7	7	5	10	10
I	1	3	7	5	4
J	0	10	9	3	10
K	3	5	0	8	7
L	10	5	2	5	1
M	0	5	3	6	10
N	5	9	9	4	7
O	7	0	0	6	1
P	6	1	6	0	9
Q	3	1	2	4	9
R	4	10	10	2	10
S	0	4	1	6	5
T	4	8	0	4	6
q	4	0	1	2	5
p	8	3	10	5	10
w	0,1	0,3	0,2	0,3	0,1

	Crit 1	Crit 2	Crit 3	Crit 4	Crit 5	Net flows
A	0,197	-0,754	-0,228	0,667	-0,105	-0,0627
B	0,105	0,158	0,053	0,368	0,074	0,1863
C	0,197	-0,754	0,053	-0,228	0	-0,2645
D	-0,04	-0,614	0,45	-0,667	-0,042	-0,3023
E	-0,105	0,509	0,053	-0,386	-0,042	0,0326
F	-0,184	-0,614	-0,14	-0,544	-0,379	-0,4318
G	-0,105	0	0,053	0,211	-0,105	0,0526
H	0,197	0,509	0,053	0,79	0,211	0,4408
I	-0,184	-0,193	0,24	0,07	-0,042	-0,0115
J	-0,276	0,895	0,45	-0,228	0,211	0,2835
K	-0,04	0,158	-0,415	0,509	0,042	0,1172
L	0,553	0,158	-0,228	0,07	-0,274	0,0507
M	-0,276	0,158	-0,14	0,211	0,211	0,0759
N	0,026	0,79	0,45	-0,07	0,042	0,3127
O	0,197	-0,754	-0,415	0,211	-0,274	-0,2538
P	0,105	-0,614	0,135	-0,667	0,126	-0,3342
Q	-0,04	-0,614	-0,228	-0,07	0,126	-0,2422
R	-0,026	0,895	0,544	-0,386	0,211	0,2798
S	-0,276	0	-0,322	0,211	0	-0,0288
T	-0,026	0,684	-0,415	-0,07	0,011	0,0996

GAI A plane



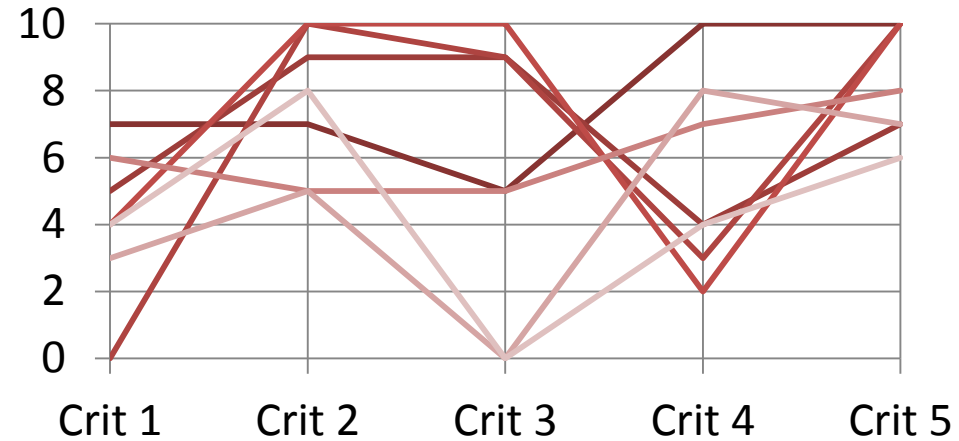
Reordering of criteria and alternatives

	Crit 3	Crit 5	Crit 2	Crit 4	Crit 1
H	5	10	7	10	7
N	9	7	9	4	5
J	9	10	10	3	0
R	10	10	10	2	4
B	5	8	5	7	6
K	0	7	5	8	3
T	0	6	8	4	4
M	3	10	5	6	0
G	5	3	4	6	2
L	2	1	5	5	10
E	5	4	7	2	2
I	7	4	3	5	1
S	1	5	4	6	0
A	2	3	0	9	7
Q	2	9	1	4	3
O	0	1	0	6	7
C	5	5	0	3	7
D	9	4	1	0	3
P	6	9	1	0	6
F	3	0	1	1	1

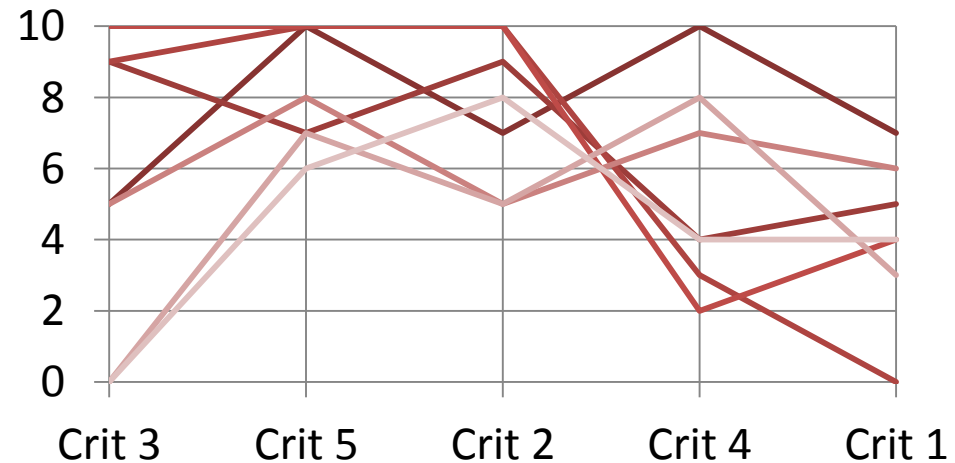
	Crit 3	Crit 5	Crit 2	Crit 4	Crit 1	Net flows
H	0,053	0,211	0,509	0,79	0,197	0,4408
N	0,45	0,042	0,79	-0,07	0,026	0,3127
J	0,45	0,211	0,895	-0,228	-0,276	0,2835
R	0,544	0,211	0,895	-0,386	-0,026	0,2798
B	0,053	0,074	0,158	0,368	0,105	0,1863
K	-0,415	0,042	0,158	0,509	-0,04	0,1172
T	-0,415	0,011	0,684	-0,07	-0,026	0,0996
M	-0,14	0,211	0,158	0,211	-0,276	0,0759
G	0,053	-0,105	0	0,211	-0,105	0,0526
L	-0,228	-0,274	0,158	0,07	0,553	0,0507
E	0,053	-0,042	0,509	-0,386	-0,105	0,0326
I	0,24	-0,042	-0,193	0,07	-0,184	-0,0115
S	-0,322	0	0	0,211	-0,276	-0,0288
A	-0,228	-0,105	-0,754	0,667	0,197	-0,0627
Q	-0,228	0,126	-0,614	-0,07	-0,04	-0,2422
O	-0,415	-0,274	-0,754	0,211	0,197	-0,2538
C	0,053	0	-0,754	-0,228	0,197	-0,2645
D	0,45	-0,042	-0,614	-0,667	-0,04	-0,3023
P	0,135	0,126	-0,614	-0,667	0,105	-0,3342
F	-0,14	-0,379	-0,614	-0,544	-0,184	-0,4318

Effect on parallel coordinates

- 7 best alternatives:

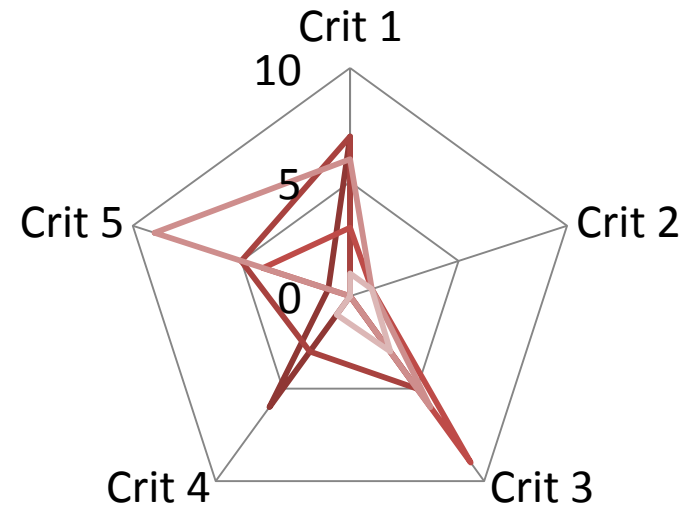


- 7 best alternatives (reordered criteria):

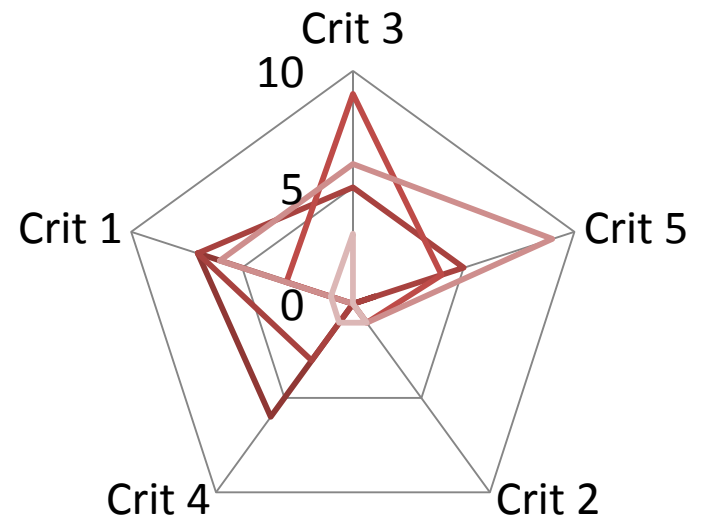


Effect on spider/radar charts

- 5 worst alternatives:



- 5 worst alternatives (reordered criteria):



Conclusion

- Focus on spatial representations using glyphs
 - Results
 - Multi-criteria profiles
- Many other possibilities:
 - New glyphs
 - Other graphs
- Information visualization techniques and studies can help

Thank you.