

Spatial dimensions of multi-criteria decision analysis

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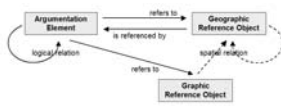
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Research program

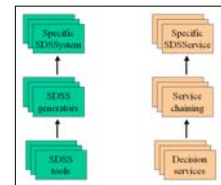
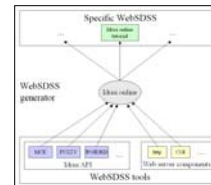
- **Argumentation Maps** to support distributed group decision-making



- (Source: Rinner 1999, ...)

Research program

- **Web-based spatial decision support**



- (Source: Rinner 2003b)

Research program

- **Spatial multi-criteria decision analysis**
 - Focus on decision support by geographic visualization
 - Supported by NSERC discovery grant
 - Main part of this talk ;-)

Research program

- **Location-based decision support**



- (Source: Raubal & Rinner 2004)

GIS and multi-criteria decision analysis

- Janssen and Rietveld 1990; Carver 1991; Church et al. 1992; Banai 1993; Pereira and Duckstein 1993; Jankowski 1995
 - Implementation and/or application of various MCDA methods in GIS context
- Eastman 1997
 - Decision support module in Idrisi GIS
- Malczewski 1999, Thill (ed.) 1999
 - Comprehensive reviews

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GIS and multi-criteria decision analysis

- **Raster-based:** Overlay analysis
 - Criterion maps (Source: Idrisi tutorial)
 - Criteria may result from spatial operations (e.g. *distance to town*)
 - Objectives may include explicit spatial constraints (e.g. *find at least 3 square km of forest area*)

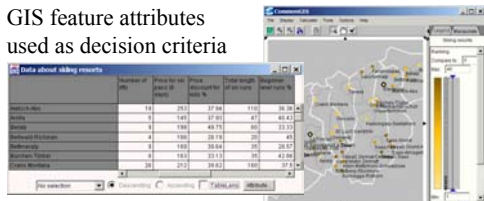
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GIS and multi-criteria decision analysis

- **Vector-based:** Calculations in a data table
 - GIS feature attributes used as decision criteria



– (Source: CommonGIS Wallis application)

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Spatial dimensions of MCDA

- Location plays an increasing role:
 - **MCDA for geographic objects**
 - Calculation in attribute space
 - Mapping of evaluation results
 - **Geographic visualization in conjunction with MCDA ...**
 - **Integration of spatial relations in multi-criteria decision rules ...**

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Geographic visualization in conjunction with MCDA

- Jankowski, Andrienko & Andrienko 2001
 - Map-based setting of aspiration levels
 - Manual classification of decision alternatives
- Andrienko & Andrienko 2001
 - Utility symbols in CommonGIS
- Rinner & Malczewski 2002
 - Ordered Weighted Averaging (OWA) in CommonGIS
 - Interactive modification of decision strategy (in terms of "risk" and trade-off)

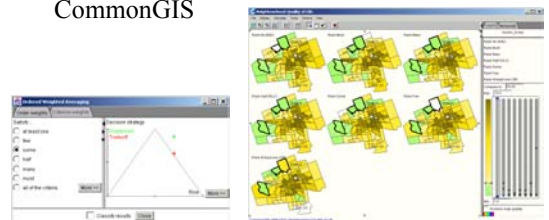
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Geographic visualization in conjunction with MCDA

- Assessment of decision strategies in CommonGIS



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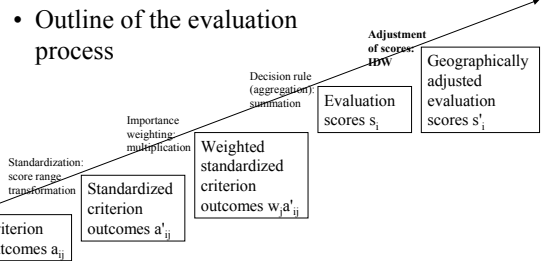
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Integration of spatial relations in multi-criteria decision rules

- Could evaluation scores be influenced by neighbours' scores?
 - E.g. skiing resort A scores low but nearby resort B scores high ... does A become more attractive?
- Two ideas:
 - Interpolate scores** from neighbours' scores using IDW, or
 - Adjust scores** by inverse distance-weighted difference to the scores of neighbouring alternatives

Integration of spatial relations in multi-criteria decision rules

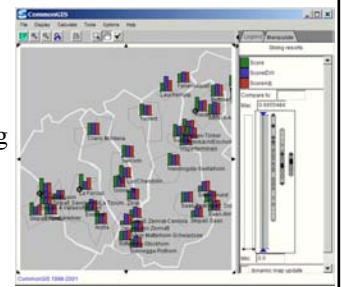


Integration of spatial relations in multi-criteria decision rules

- Inverse distance weighted **interpolation**:
 - Score $s_i' = \sum v_k s_k / \sum v_k$, $k = 1..n$, $k \neq i$, with weights $v_k = 1/d_{ik}^p$
- Inverse distance-based **adjustment**:
 - Score $s_i' = \sum v_k s_k / \sum v_k$, $k = 1..n$ (incl. i), with weights $v_k = 1/(1+d_{ik}^p)$
- Applied to Wallis skiing resorts with equally weighted attributes *number of lifts*, *ski pass price*, and *beginner-level ski runs [%]*

Integration of spatial relations in multi-criteria decision rules

- Score distribution under simple additive weighting vs. cubic IDW vs. cubic adjustment (bar charts)



Integration of spatial relations in multi-criteria decision rules

- Mean and standard deviation of SAW vs. IDW vs. geographically adjusted scores

ID	Score	IDW, p=1	IDW, p=2	IDW, p=3	Adj, p=1	Adj, p=2	Adj, p=3
1	0.40	0.44	0.47	0.49	0.43	0.44	0.44
2	0.52	0.42	0.42	0.41	0.43	0.44	0.44
3	0.42	0.44	0.45	0.46	0.43	0.44	0.45
4	0.49	0.43	0.44	0.44	0.43	0.45	0.45
5	0.43	0.44	0.47	0.48	0.43	0.45	0.46
6	0.52	0.43	0.44	0.45	0.44	0.46	0.47
7	0.47	0.43	0.45	0.47	0.43	0.46	0.47
8	0.52	0.41	0.40	0.37	0.43	0.43	0.43
9	0.31	0.43	0.45	0.47	0.42	0.42	0.42
10	0.34	0.42	0.42	0.41	0.42	0.41	0.40
mean	0.4210	0.4197	0.4234	0.4284	0.4198	0.4205	0.4219
st.dev.	0.1107	0.0130	0.0332	0.0496	0.0085	0.0178	0.0250

Integration of spatial relations in multi-criteria decision rules

- Individual scores under simple additive weighting vs. cubic IDW vs. cubic adjustment (utility bars)



Integration of spatial relations in multi-criteria decision rules

- Final score interpolation (regular IDW) vs. geographical adjustment (IDW-based)
 - Where else does a need for adjustment of values based on spatial relations occur?
 - Explain the behaviour of individual decision alternatives under different scenarios...
 - Allow for geographical weighting of some criteria (and not others) – What are possible application scenarios for this?

Conclusions

- Raise concepts of GIS-based multi-criteria decision analysis to the next level
 - **Use spatial relations in decision rule**, in analogy to spatial interpolation
 - **Combine with interactive mapping for data exploration**
- Demonstrated with skiing resort application in CommonGIS