Cartography M.Sc.

Heuristic Reasoning about Geospatial Data under Uncertainty

M.Sc. Thesis

Lorenzo Libertini, 8th intake

September 28th, 2020

Rational choice vs. Heuristics and biases

Problem ————————————◯———————————→ Decision

Mathematical probabilities

Problem ————————————◯———————————→ Biased decision

Heuristics

Motivation:
Heuristics, biases & reasoning

People use intuitive logical shortcuts to reason under uncertainty; these are helpful but potentially inaccurate

Under-researched issue despite its relevance in the geospatial field

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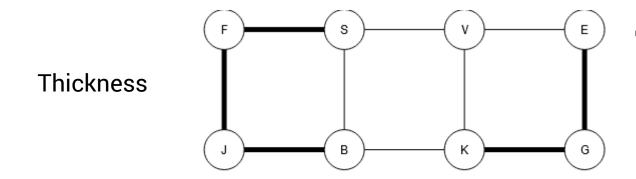
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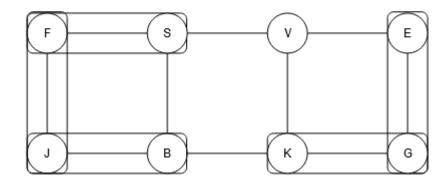Under-researched issue despite its relevance in the geospatial field

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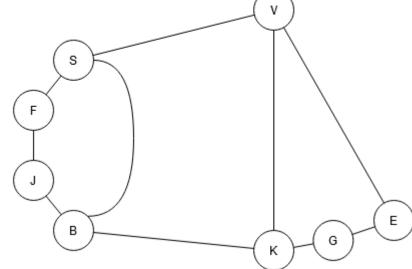
Thickness

Containment

Distance

Redrawn from Tversky et al. (2012)

Objectives

Explore how visual variables influence heuristics-driven reasoning on uncertain geospatial data, with a specific focus on the issue of "borderization";

Adapt visualization techniques to represent "borderization" and investigate users' cognitive biases when reasoning under geospatial uncertainty;

Build and conduct a user test to interpret how visual variables for uncertainty visualization affect users' map perception.

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Tversky & Kahneman's heuristics

Representativeness: rating the likelihood of an event based on its perceived degree of similarity to a standard;

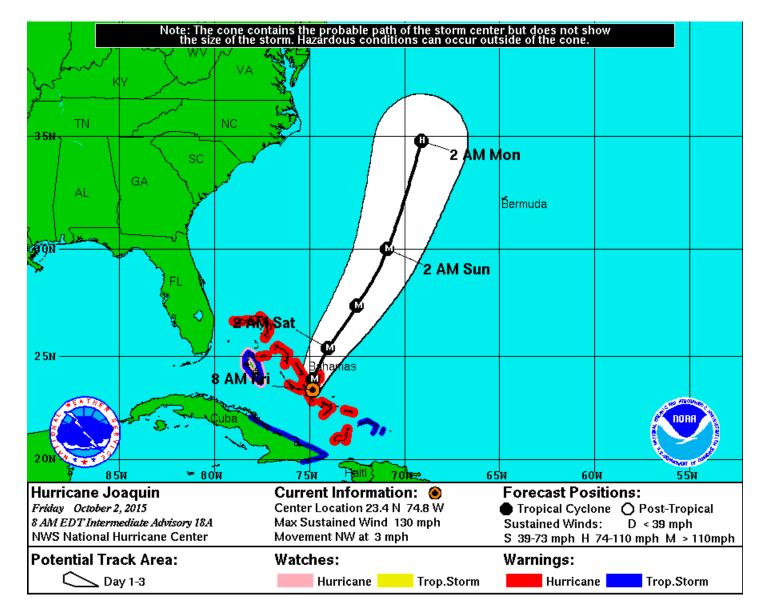Availability: judging an event, fact or topic basing on the examples that come most easily to mind;

Anchoring: relying on the first piece of information to make decisions;

Further heuristics introduced later on (e.g., affective association)

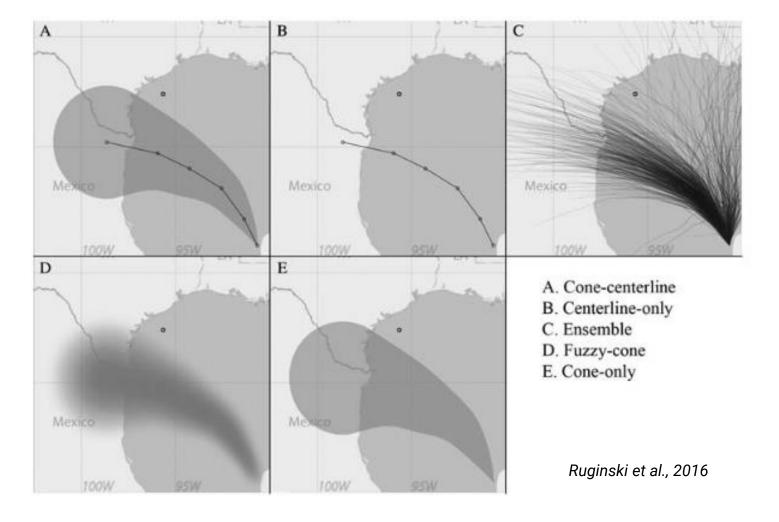# «Borderization» & the biases of distance and containment

NOAA, 2015

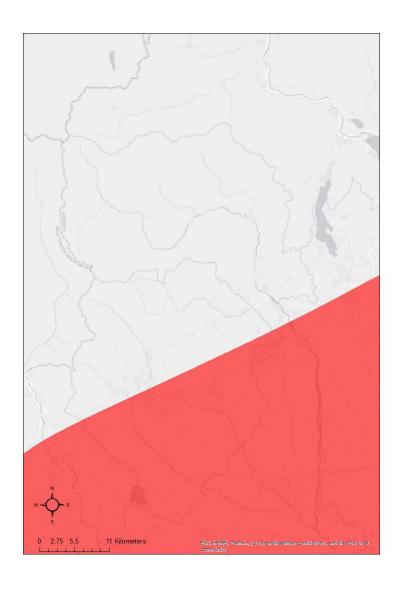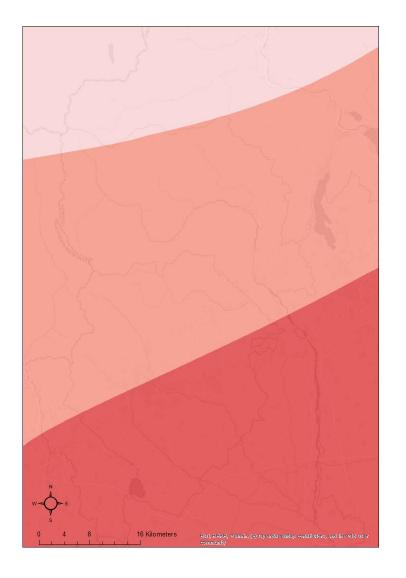# «Borderization» & the biases of distance and containment

A. Cone-centerline
B. Centerline-only
C. Ensemble
D. Fuzzy-cone
E. Cone-only

Ruginski et al., 2016

Case studies

Case studies: «fuzzy borders»

Case studies: PM10 maps

Average PM10 concentration (EEA, 2017)
- High
- Moderate
- Housing location

Average PM10 concentration (EEA, 2017)
- High
- Moderate
- Uncertain data
- Housing location

Case studies: «fuzzy borders»

Case studies: «hard borders»

Questionnaire

Average PM10 concentration (EEA, 2017)
- High
- Moderate
- Low
- ✕ Housing location

1. How desirable would be a house in each location?

Location A
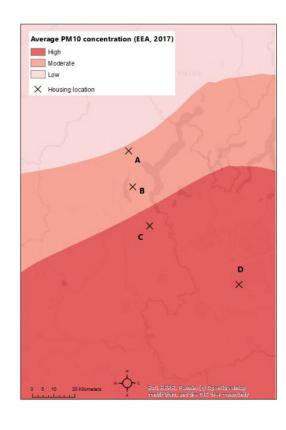
Not desirable at all ○ ○ ○ ○ ○ ○ ○ ○ ◉ ○ Highly desirable

Location B

Not desirable at all ○ ○ ○ ○ ○ ○ ◉ ○ ○ ○ Highly desirable

Location C

Not desirable at all ○ ○ ○ ◉ ○ ○ ○ ○ ○ ○ Highly desirable

Location D

Not desirable at all ○ ○ ◉ ○ ○ ○ ○ ○ ○ ○ Highly desirable

2. Please briefly explain the main reason(s) for your ratings to all the points in two or three sentences.

Moderate isn't really desirable, but being limited to only 4 choices I would definitely choose A. My choices got progressively worse and worse the deeper in the danger zone we get. Even though C and D present the same risk level, proximity to the border between high and moderate can mean I can hope for better days if the wind blows from the right direction.

3. How confident do you feel overall in giving such ratings?

Not confident at all ○ ○ ○ ○ ○ ○ ○ ○ ◉ ○ Highly confident

19

22. Which image, in your opinion, best conveys an intuitive idea of "risk"?

Image A (left)   Image B (right)
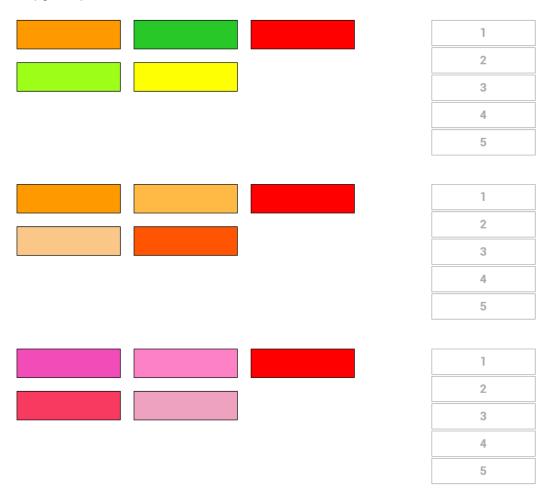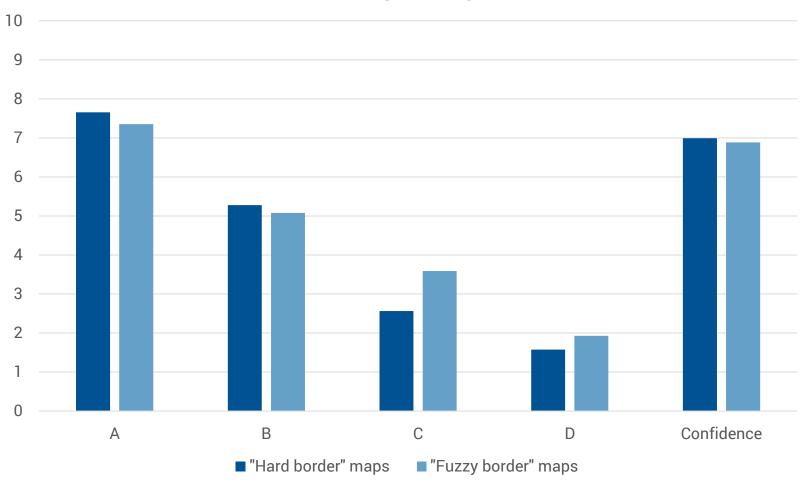
Questionnaire
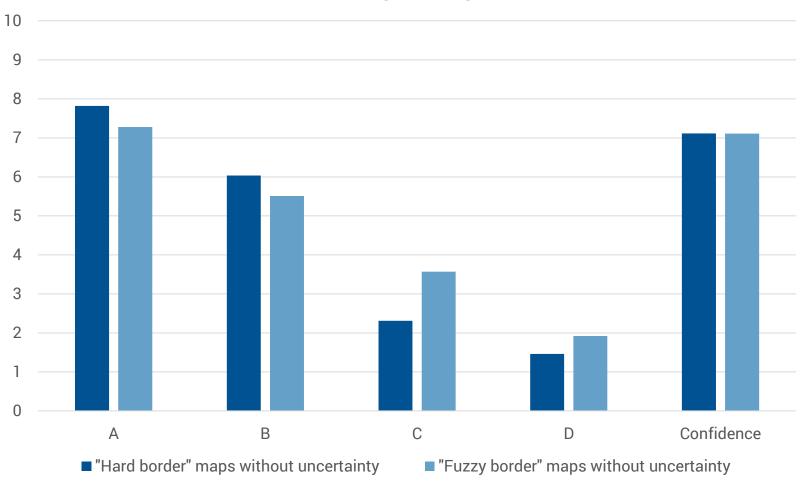
1. If you had to intuitively associate a colour shade with the idea of "risk", how would you rank the following shades from 1 (lowest risk) to 5 (highest risk)?

Results: «hard» vs. «fuzzy» borders

Average ratings

Legend: ■ "Hard border" maps ■ "Fuzzy border" maps

Results: «hard» vs. «fuzzy» borders

Average ratings

Legend:
- ■ "Hard border" maps without uncertainty
- ■ "Fuzzy border" maps without uncertainty

Results: «hard» vs. «fuzzy» borders

Average ratings

Results: «hard» vs. «fuzzy» borders

Average ratings

Legend: Single Hard Border, Limited Fuzzy Border, Layered Hard Border, Total Fuzzy Border

Categories: A, B, C, D, Confidence

Results: uncertainty

Point A

Point B

Point C

Point D

Results: uncertainty & confidence
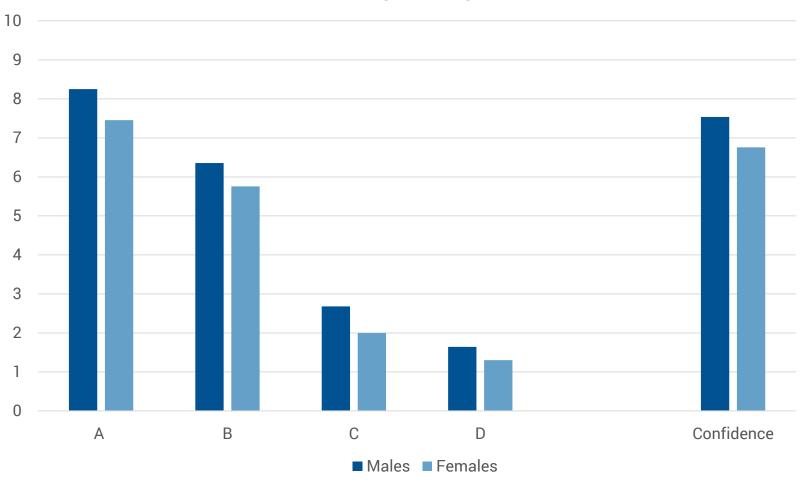
Average confidence

Results: breakdown by gender

Average ratings
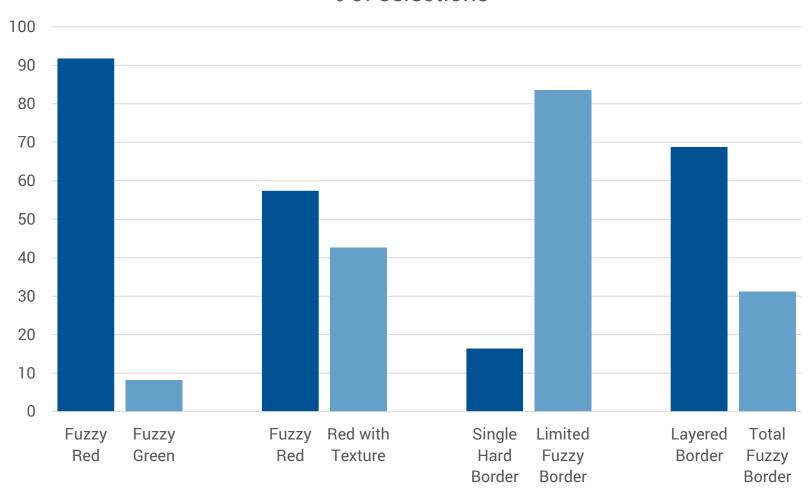
Results: pairwise comparisons

% of selections
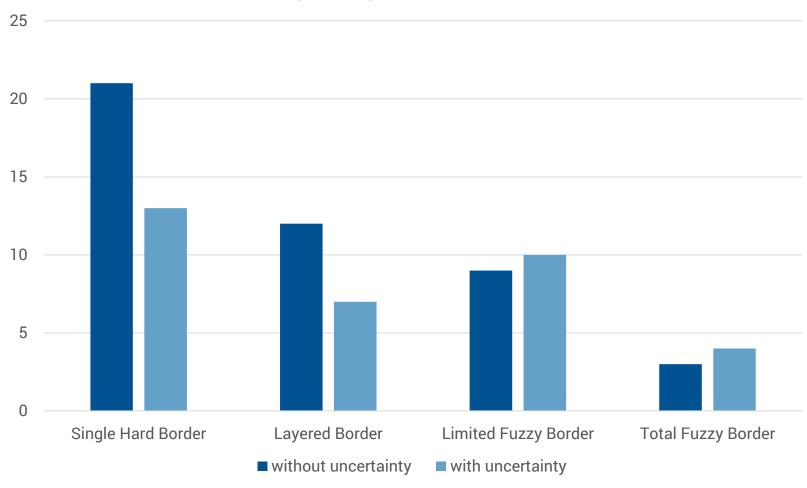
Results: kewyord use

Frequency of keyword use (nr. of users)

Legend: ■ without uncertainty ■ with uncertainty

Categories: Single Hard Border, Layered Border, Limited Fuzzy Border, Total Fuzzy Border
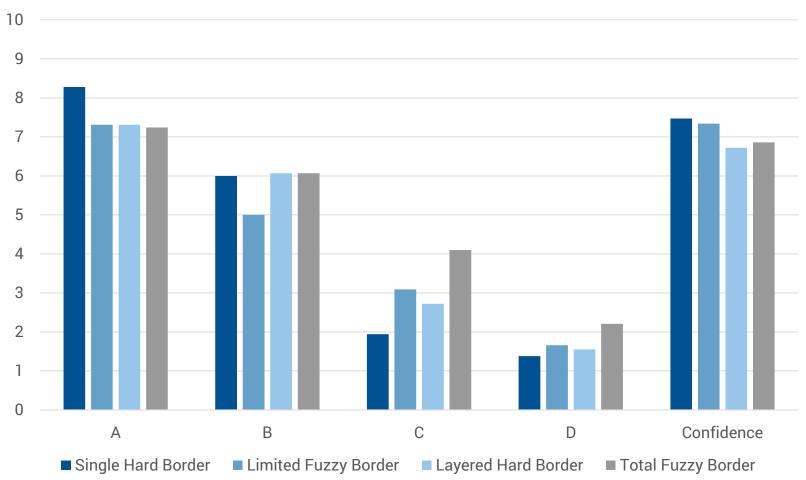
Conclusions & outlook

Abrupt borders trigger containment- and distance-based heuristics, while gradual borders produce more nuanced, mainly colour-based judgements;

Extrinsic uncertainty complicates the use of heuristics by introducing new boundaries and also by changing the overall risk perception;

Some border types and colour shades are viewed as significantly more representative than others to visualize natural hazards.

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Altering borderizations can reduce the use of heuristics, but it doesn't necessarily result in an improved map experience and an easier decision-making process;

Taking heuristics into account is crucial to deliver natural hazard maps and border visualizations that feel both helpful and easy to understand for map readers;

Further work would benefit from different tool choices (e.g., eye tracking or brain imaging) and/or closer collaborations with other cognitive science domains to identify more objective criteria for heuristic use.

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UNIVERSITY OF TWENTE.
ITC

TECHNISCHE
UNIVERSITÄT
DRESDEN

Thank you!

Technical
University
of Munich
TUM

TU
WIEN
TECHNISCHE
UNIVERSITÄT
WIEN
Vienna University of Technology

Users

Gender	M	F		
	28	33		

Age	<25	25-30	31-35	>35
	11	25	15	10

Education	Secondary	Non-university tertiary	University	
	5	4	52	

Level of expertise (5 = very high)	With maps	With natural hazard datasets		
	3,71	2,31		

Assumption for heuristic use

Heuristic	Assumption(s)
Distance Containment	• Significant difference in perception between two locations in the same thematical category but differing in their distance from a thematical border • Significant impact of borderization change on differences in perceptions between two map locations • Significant perceptive alterations after the introduction of extrinsic uncertainty
Availability	• Reported difference in perception between maps depicting different case studies due to lived experience
Adjustment to anchor	• Repeated perception patterns and user behaviours across successive maps
Representativeness	• Significant preference for certain colours to indicate high risk levels • Significant preference for certain borderizations to represent a specific natural hazard