Spatial Similarity Relations in Multi-scale Map Spaces

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Outline

- **Introduction**
- **Literature Review**
- ***Concepts***
- ***Model Construction***
- ***Model Validation***
- ***Applications***
- Conclusions.

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1 Introduction

- Background
- Significances
- Classification of Objects
- Objectives
- Scope of the Study
- A concept

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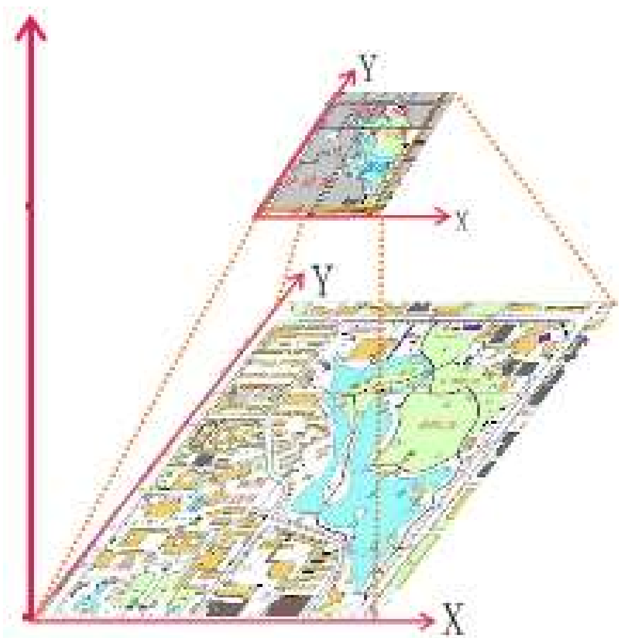
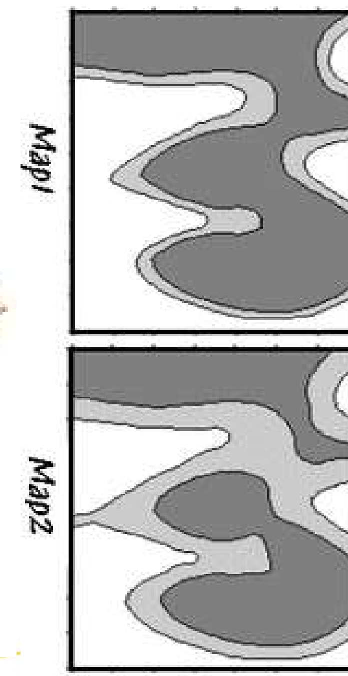
1 Introduction: background

- Why automated map generalization (AMG)?
- Similarity-related problems in AMG
- when to terminate a map generalization procedure?
- how to assess the quality of generalized maps?
- how to calculate threshold values of the algorithms in AMG?



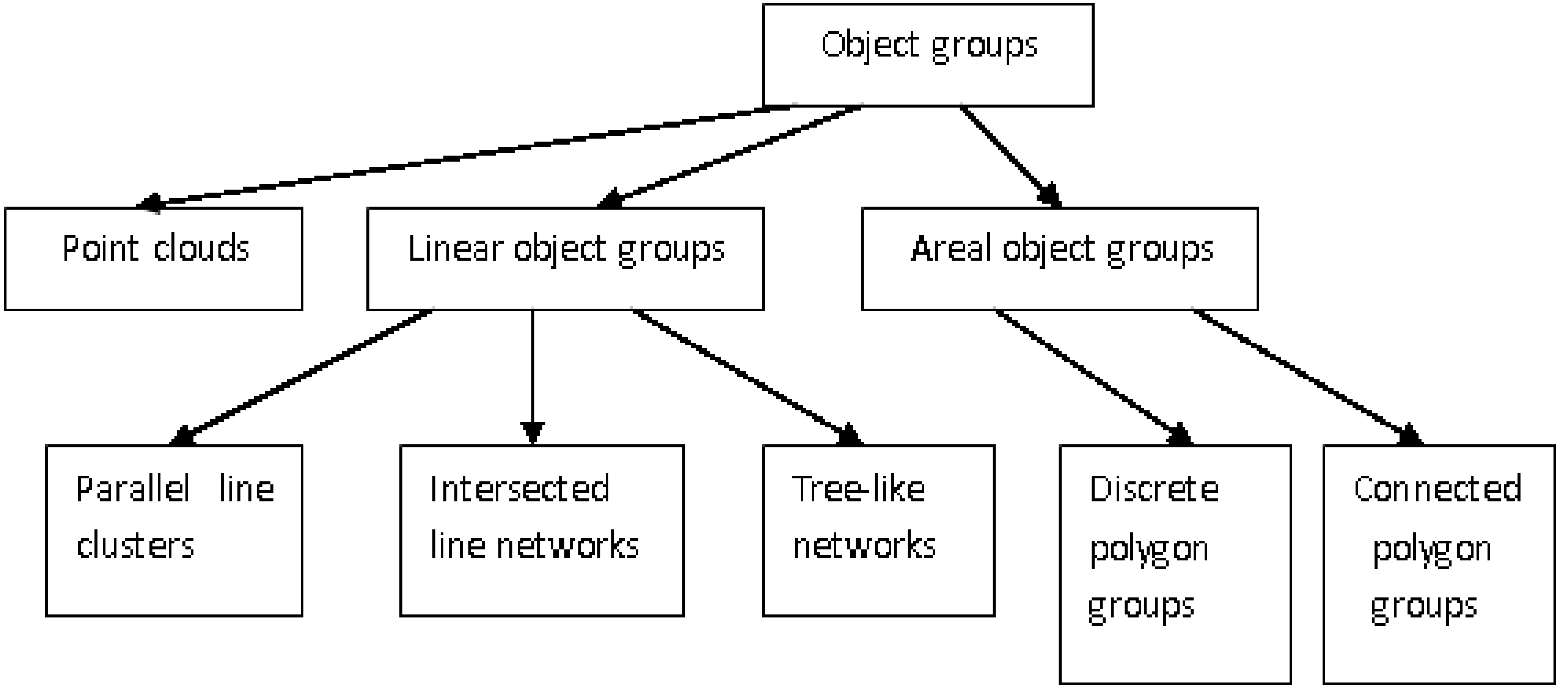


1 Introduction: Significance

- Theory of spatial relations
- Spatial description, reasoning, retrieval…
- Spatial cognition
- Automated map generalization

1 Introduction: classification of objects

- Individual objects: three types
- Object groups: six types
- Maps



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1 Introduction: Research objectives

- **Fundamental issues**: Definitions, features, classification, factors and their weights…
- **Calculation models**: for multi-scale map spaces.
- **Applications** of the theory in automated map generalization.

1 Introduction: scope

- Topographic maps
- 2-dimensional spaces
- Vector data

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1 Introduction: a concept

- An important Definition: There are two maps M0 and M1. Their scales are S0 and S1, respectively. M1 is a generalized map of M0. The ratio S0/S1 is called the **map scale change** from M0 to M1.

2 Literature Review: definitions & features

- **Definitions**: geometry, computer science, engineering, psychology, music, chemistry, geography.
- **Features**: computer science, psychology, geography.

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2 Literature Review: Classification, Calculation models & factors

- **Classification:** a system proposed by Yan (2010).
- **Factors:** geography, cartography & GIS
- **Calculation models of similarity relation**: psychology, computer science, music, and geography (conceptual neighbourhood approach, projection-based approach, combination approach, TDD model, and spatial semantic-oriented model).
- **Applications**: very few.

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3 Concepts: definitions

- **Definitions**: similarity relation/degree → spatial similarity relation → spatial similarity relation in multi-scale map spaces: **set theory**.
- **Idea**: *the spatial similarity degree between two objects is the sum of the similarity degrees of the properties of the two objects*.

$$Sim_{A,B} = w_1 Sim_{A,B}^{P_1} + w_2 Sim_{A,B}^{P_2} \ldots + w_n Sim_{A,B}^{P_n}$$

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3 Concepts: features

- **Features**: 10 features are given and described in mathematical language by logic symbols, including *equality, finiteness, miniality, auto-similarity, symmetry, non-transitivity, weak symmetry, asymmetry, triangle inequality, and scale-dependence*.

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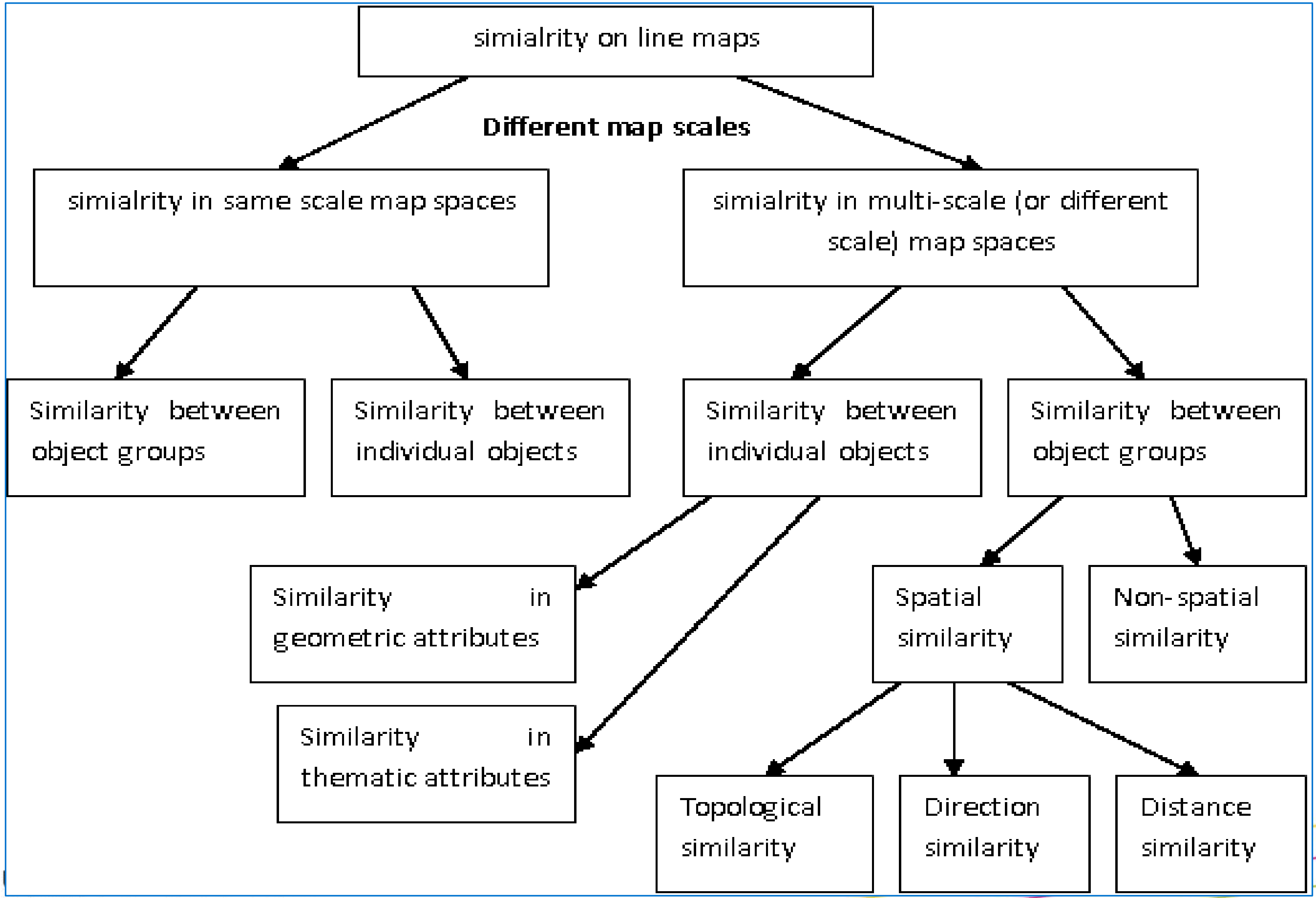
3 Concepts: factors & classification

- **Factors**: for individual objects (geometric and thematic attributes) for object groups (topological, distance, direction, and attributes)
- **Determine the weights** of the factors by psychological experiments
- **Classification** system

A classification system of similarity on line maps



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4 Model Construction

- **Problem description:** given a map at one scale and its generalized counterpart at another scale, calculate the similarity degree of the two maps.
- **10 models**: 3 for individual objects, 6 for object groups, and 1 for maps.
- **Principle**: to find the difference or the similarity of the ***properties*** of the two objects/groups/maps.

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4.1 Model Construction

- **Three types of individual objects**: individual points, lines, or polygons.

$$Sim(A_k, A_m) = w_{thematic} Sim^{thematic}_{A_k, A_m} + w_{geometric} Sim^{geometric}_{A_k, A_m}$$

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4.2 Model Construction

- Individual points

$$Sim(\mathrm{A}_l, \mathrm{A}_m) = 0 \quad or \quad 1$$

- *Individual lines*

$$Sim(\mathrm{A}_k, \mathrm{A}_m) = Sim_{A_k, A_m}^{geometric} = Sim_{A_k, A_m}^{shape} = \frac{l}{L}$$

- *Individual polygons*

$$Sim_{P_k, \mathrm{P}_m}^{shape} = 1 - \frac{Abs\left|A_{P_k} - A_{P_m}\right|}{A_{P_k}}$$

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4.3 Model Construction

- **6+1 models for object groups and maps** (point clouds, parallel lines clusters, intersected line networks, tree-like networks, discrete polygon groups, connected polygon groups, and maps): topology, distance, direction, and attributes are considered.

$$Sim(A_l, A_m) = \sum_{i=1}^{4} w_i Sim_{A_l, A_m}^{P_i}$$

5 Model Validation

- “Are the similarity degrees calculated by the models the same as that of my recognition?” and “Are the calculated similarity degrees acceptable by a majority of people?”.
- We validate the ten new models, aiming at proving that the models are acceptable to majority of people.

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5 Model Validation: general strategies

- The development team
- Users
- Third parties
- Scoring models

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5 Model Validation: strategies

- **Theoretical justifiability**: 10 models for 10 categories of objects; factors proposed by others for individual objects and object groups.
- **Third party involvement**: weights of the factors obtained by psychological experiments.
- **Comparison with existing approaches**
- **Experts' participation**, i.e. psychological experiments

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5 Model Validation: psychological experiments

- **Time**: October 20, 2013.
- **Place**: Lanzhou Jiaotong University, China.
- **Subjects**: 50 students at undergraduate or graduate level, 24 female and 26 male, 17 to 27 years old, majoring in geography, experienced in making maps.
- **Goal**: to know the confidence level of the new models.

5 Model Validation: psychological experiments

- Step 1: Preparation of sample data: three or four samples are selected for each model; the samples for each model are obviously different from each other so that they can be good representations of other objects of corresponding category.
- Step 2: Psychological experiments
- Step 3: Statistics
- Step 4: Analysis

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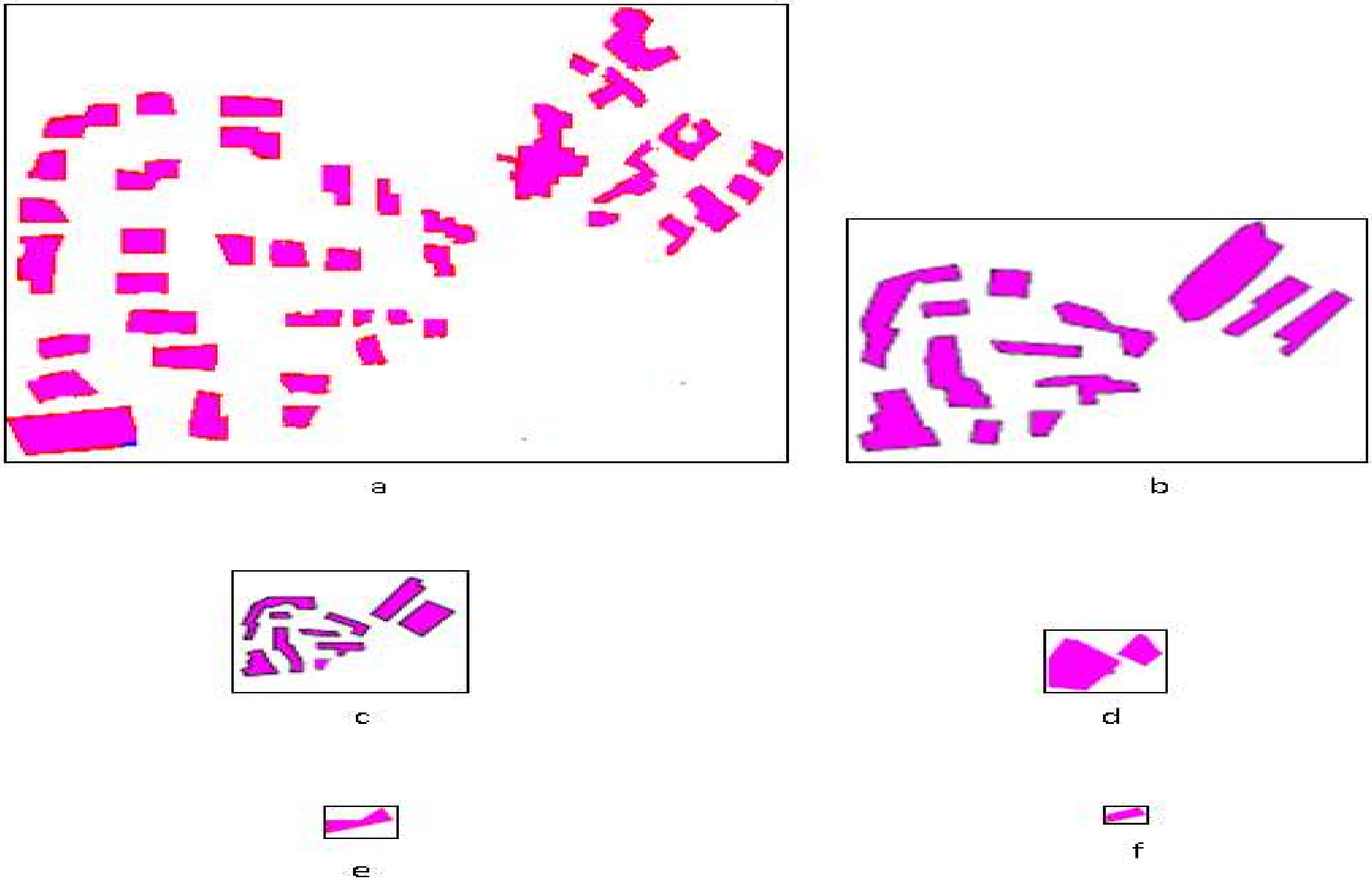
Sample



The above shows a map at four different scales. Below gives two groups of fractions in A and B. Each group comprises five values, representing the five similarity degrees between (a) and each of the other five objects/maps.

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Answer sheet

Similarity degrees

A: $Sim_{a,b}^{Map} = 0.77$, $Sim_{a,c}^{Map} = 0.45$, $Sim_{a,d}^{Map} = 0.32$, $Sim_{a,e}^{Map} = 0.00$, $Sim_{a,f}^{Map} = 0.00$.

B: $Sim_{a,b}^{Map} = 0.89$, $Sim_{a,c}^{Map} = 0.55$, $Sim_{a,d}^{Map} = 0.43$, $Sim_{a,e}^{Map} = 0.00$, $Sim_{a,f}^{Map} = 0.00$.

You are required to complete the following work.

- Tick at appropriate positions to tell if you can accept the similarity degrees in A.

A is acceptable (________) **A is not acceptable (________)** **I have no idea (________)**

- Tick at appropriate positions to tell which result is better between A and B.

A is better than B (________) **B is better than A (________)** **I have no idea (________)**

- Use three values in [0,1] to represent the describe similarity degrees between (a) and the other five maps, respectively.

Value 1: (____________) **Value 2: (_______________)** **Value 3: (_______________)**

Value 4: (   ) **Value5: (   )**

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Results

	$Sim^{V}_{a,f}$	$DScale_{a,d}$		
1	1.00, 1.00, 1.00, 1.00, 1.00	2, 4, 8, 16, 32	50, 0, 0	50, 0, 0
2	1.00, 1.00, 1.00, 1.00, 1.00	2, 4, 8, 16, 32	50, 0, 0	50, 0, 0
3	1.00, 1.00, 1.00, 1.00, 1.00	2, 4, 8, 16, 32	50, 0, 0	50, 0, 0
4	0.87, 0.64, 0.38, 0.38, 0.38	2, 4, 8, 16, 32	50, 0, 0	47, 0, 3
5	0.91, 0.78, 0.52, 0.44, 0.36	2, 4, 8, 16, 32	50, 0, 0	46, 2, 2
6	0.75, 0.55, 0.44, 0.35, 0.26	2, 4, 8, 16, 32	48, 0, 2	48, 2,0
7	1.00, 1.00, 1.00, 1.00, 1.00	2, 4, 8, 16, 32	50, 0, 0	50, 0, 0
8	0.95, 0.88, 0.73, 0.65, 0.55	2.5, 10, 25, 50, 125	50, 0, 0	48, 2, 0
9	0.91, 0.82, 0.66, 0.52, 0.52	2.5, 10, 25, 50, 100	50, 0, 0	50, 0, 0
10	1.00, 0.55, .055, 0.55, 0.55	2.5, 10, 25, 50, 100	50, 0, 0	48, 0, 2
11	1.00, 1.00, 1.00, 1.00, 1.00	2.5, 5, 10, 25, 50	50, 0, 0	50, 0, 0
12	0.76, 0.57, 0.36, 0.21, 0.15	2, 5, 10, 25, 50	50, 0, 0	48, 2,0
13	0.82, 0.62, 0.36, 0.19, 0.12	2, 5, 10, 25, 50	50, 0, 0	50, 0, 0

Back

Important

Formation of coordinate pairs

5 Model Validation: concluding words

- **First, similarity degrees are closely related to map scale change.**
- Second, people are accustomed to describing spatial similarity relations qualitatively and fuzzily; however, quantitative spatial similarity relations do exist and are used in many communities such as cartography and geography.
- Third, each of the percentages of the subjects that **agree with** the similarity degrees calculated by the new models is between 94% and 100%.
- Fourth, 97% of the subjects agree that the ten new models are **better** than the raster-based ones.
- Fifth, **average deviation** between the similarity degrees calculated by the new models and that given by the subjects is 0.045.
- Last, the new models are tested selecting 50 experienced cartographers as subjects, which makes the experiments go easily. On the other hand, it **limits the varieties of the subjects** and therefore decreases the credibility of the experimental results.

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6 Applications

- To find an approach to ***determine the relations between spatial similarity degree and map scale change*** in map generalization;
- to find an approach to ***determine when to terminate a map generalization algorithm***; and
- to find an approaches to ***calculate the threshold values*** of a specific map generalization algorithm.

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6 Applications: curve fitting

- Procedures of curve fitting (10 formulae obtained)

$$Sim_{M_0,M_i} = f(C_i^{scale})$$

- Determine the data points
- Select candidate functions
- Calculate the coefficients of each function
- Compare the functions to determine the most suitable one (goodness of fit).

R-squared is usually used to compare the candidate functions and make decision.

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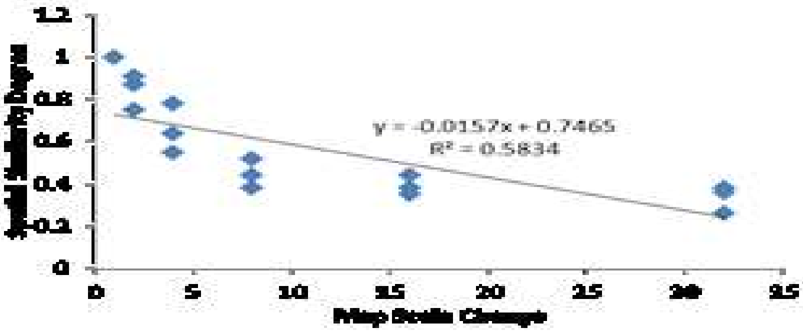
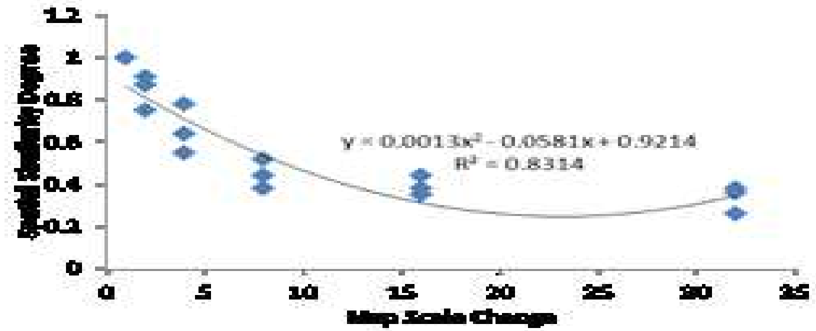
Example

21 points : (1, 1.00) , (2, 0.87), (4, 0.64), (8, 0.38), (16, 0.38), (32, 0.38), (2, 0.91), (4, 0.78), (8, 0.52), (16, 0.44), (32, 0.36), (2, 0.75), (4, 0.55), (8, 0.44), (16, 0.35), (32, 0.26), (2, 1.00), (4, 1.00), (8, 1.00), (16, 1.00), (32, 1.00).



(a)



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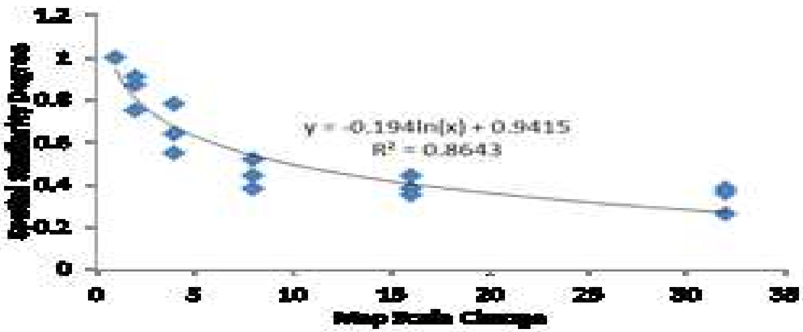
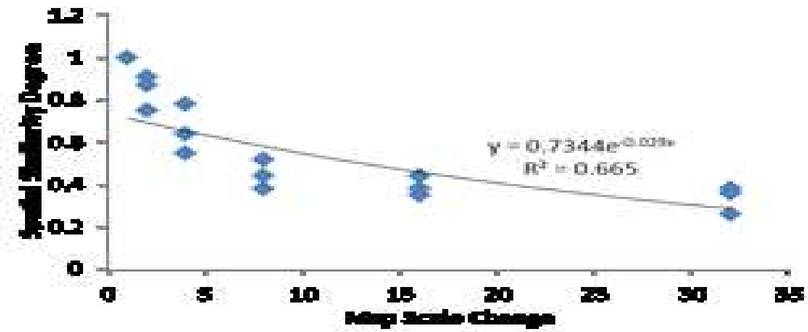


(c)



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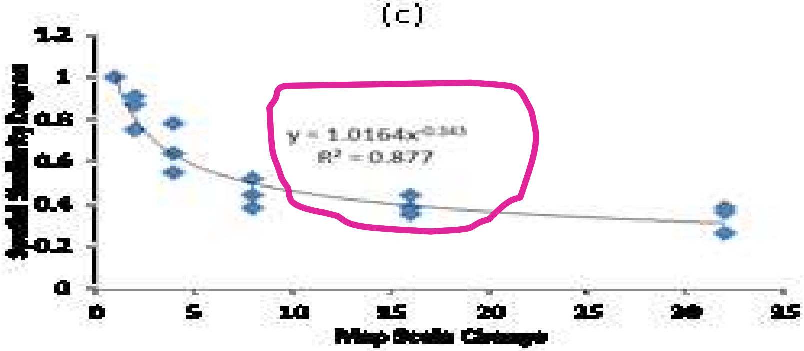
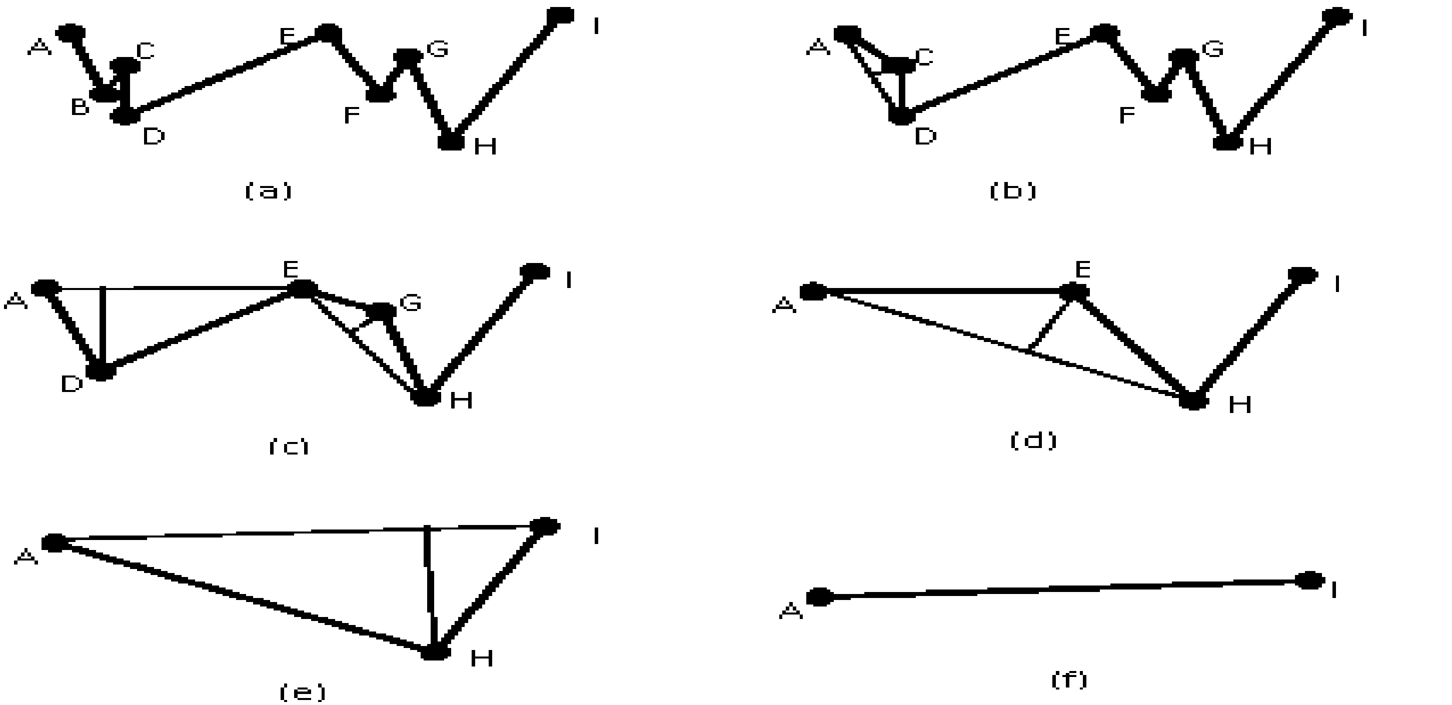


Curve fitting for individual linear features

6 Applications: terminate a procedure

- Step 1: calculate the spatial similarity degree between the original objects and the resulting objects using the corresponding formula.
- Step 2: simplify the objects/map using the algorithm/system, which generates a series of intermediate objects/maps after each round of generalization. Calculate the spatial similarity degree between the original objects and the intermediate objects using the corresponding model.
- Step 3: compare the similarity degree calculated using the formula with that by the new models, and determine if the procedure can be terminated.
- Step 4: take the intermediate objects as the result, and end the procedure.

6 Applications: distance tolerance in DP



A series of digital line maps at one scale are going to be generalized to produce the maps at a given smaller scale using the DP Algorithm. How can the distance tolerance be obtained so that the execution of the DP Algorithm becomes fully automatic?

6 Applications: distance tolerance in DP

- First, a theoretical spatial similarity degree (y1) can be calculated by the formula.
- Second, select a number of sample curves.
- Third, gradually simplify each curve and calculate the similarity degree () at each step. When a y2 is most close to y1, record the distance tolerance of this step.
- Fourth, the average of all distance tolerance is the result.
-

7 Conclusions: Contributions

- **Fundamental theories** of spatial similarity relations are explored: definitions, features, factors and their weights, and a classification system.
- **Models** for calculating spatial similarity degrees for the ten types of objects in multi-scale map spaces are proposed, and their validity has been proved.
- **Applications**: (1) ten formulae are constructed; (2) an approach to terminate a map generalization algorithm; and (3) an approach to calculate the distance tolerance of the DP Algorithm.

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7 Conclusions: Limitations

- First, spatial similarity relations are usually describe using **qualitative** terminologies, and people, including cartographers and geographers, are not accustomed to **quantitative** descriptions of spatial similarity relation; hence, it is difficult for cartographers and geographers to accept and use the mathematical formulae and models proposed in this study in short period of time.
- Second, the proposed formulae and models are based on psychological experiments. As is well known, the more subjects and samples the experiments possess, the more accurate the experiments are, and the better the models and the formulae should be. Nevertheless, **the number of the subjects and samples** in the psychological experiments are limited, which is a negative aspect for the accuracy of the formulae and the models.
- As a final note, spatial similarity relation roots itself in human's spatial cognition. It may be slightly different from people to people due to their difference in age, gender educational background, culture, etc. Thus, the **adaptability** of the models and formulae should be taken into consideration before they are widely used.

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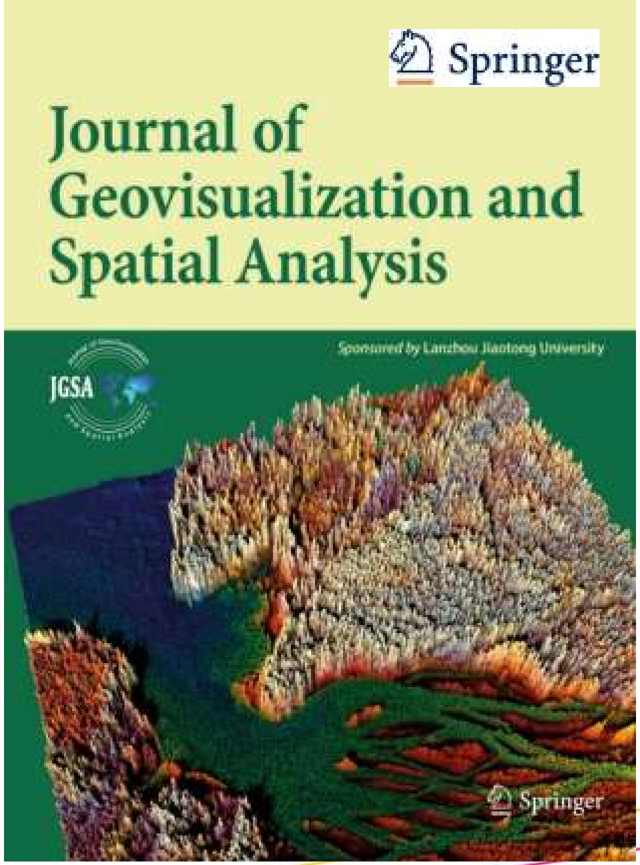

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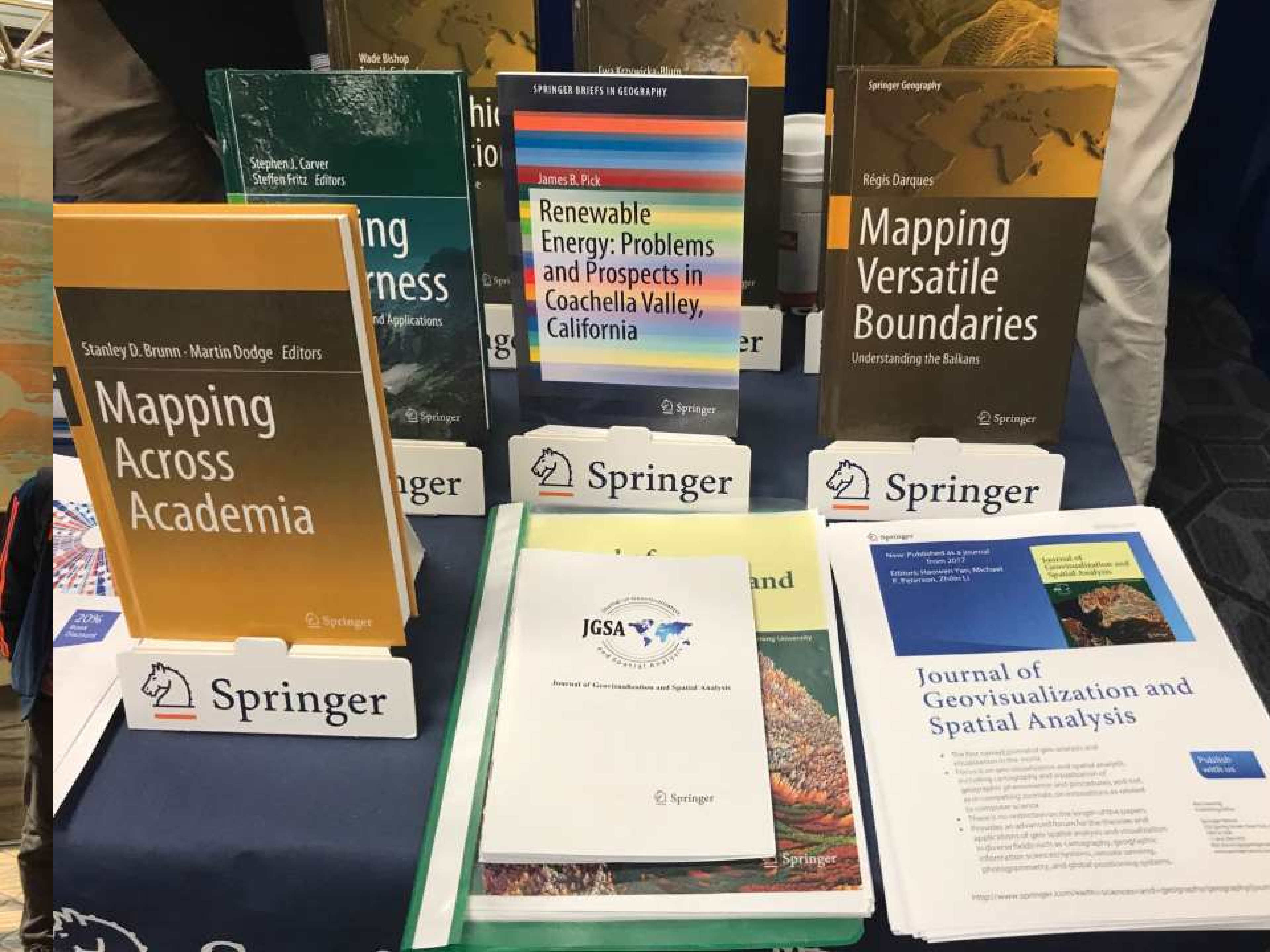
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