METRIC BASED ON MORPHOLOGICAL DILATION FOR THE DETECTION OF SPATIALLY SIGNIFICANT ZONES

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ABSTRACT

The ability to derive spatially significant zones within a cluster of zones has interesting applications in understanding commonly sharing physical mechanisms. Using morphological dilation distance technique, we introduce geometrically-based criteria that serve as indicator of the spatial significance of zones within a cluster of zones. This presentation focuses on the problem of identifying zones that are 'strategic' in the sense that they are the most central or important based on their proximity to other zones. We have applied this technique to a task aiming at detecting spatially significant water body from a cluster of water bodies retrieved from IRS LISS-III multispectral satellite data.

AGENDA

- Introduction
- Methodology
- Experimental Results
- Conclusions

INTRODUCTION

SPATIALLY SIGNIFICANT ZONES

Spatial Entities -

- Spatial Entities can be well identified/ mapped from Digital Elevation Models generated from high resolution remotely sensed data.
  - Spatial Entities – water bodies, zones of influence, geomorphic basins, and urban features of the specific thematic maps.
- Understanding the organization of these spatial entities is an important aspect from the point of ‘**Spatial Reasoning**’.

Spatially Significant Zones

- Spatially Significant Zone (SSZ) can be defined as "**a zone from which it is easy to reach all of its neighbouring zones**".
- SSZ necessarily be at a strategic location, and also possessing relatively larger size.
- Cluster of spatial entities (zones) can be treated as a **'Spatial System'.**
  - **Eg:** Geomorphological basin (cluster of sub-basins) consists of sub-basins (zones), and sub-basins consist of still minor sub-basins, and so on.

Characteristics of SSZ

- SSZ within a cluster of zones possess a geometric characteristics that is greater proximity to other zones.
- Identifying the spatial significance of a zone from geometric point of view based on qualitative spatial reasoning is non-trivial.
- Recognizing SSZ within a spatial system composed of various zones could be accomplished quantitatively.
  - Need to define an appropriate measure of the spatially significance of a zone.

Spatial System - SSZ

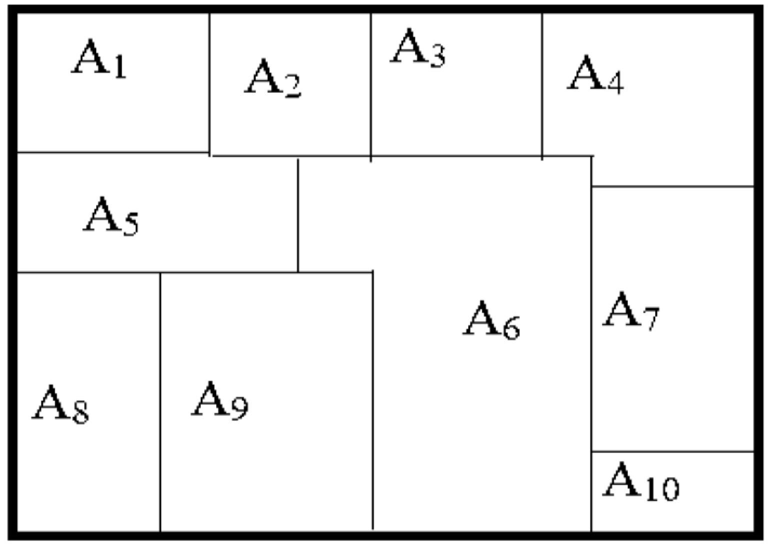


Fig: A 2-D representation of a spatial system with 10 zones.

For a geometric basin (A_i), if A1 is considered as an origin zone, then all the other zones (A_2-A_{10}) are treated as destination zones.

METHODOLOGY

METHODOLOGY

- To provide an equation based on dilation distances among zones in a cluster.
- To automatically compute spatial significance index (SSI) for each zone of a cluster of zones.

- Morphological Dilation
- Spatial System and its Subsystems
- Dilation Distances Between Origin and Destination Zones
- Spatial Significance Index of a Zone

A. Morphological Dilation

- Binary dilation is a fundamental morphological operation, can be performed on any set on 2-D Euclidean space.
- **Dilation**: The Boolean OR transformation of a set A by a set B.

$$A_b = \{a + b : a \in A\}$$

$$B = \{a : -a \in B\}$$

$$A \oplus B = \{a : B_a \cap A \neq \varnothing\} = \bigcup_{b \in B} A_b$$

  - **Multi-scale Dilations** can be performed by varying the size of the structuring element (**nB**). (n$\geq$0)
  - Iterative dilations can also be represented mathematically, as follows:

$$(A \oplus nB) = \left(A \oplus B\right) \oplus B \oplus \cdots \oplus B$$

$$n = 0,\ 1,\ 2, \ldots, N.$$

B. Spatial System and Its Subsystems

- Let **'A'** be a cluster of zones composed of a number of non-empty, compact sets **(zones)**

$$A_1, A_2, A_3, \cdots, A_N$$

$$A = \bigcup_{i=1}^{N} A_i$$

- Any pair of zones **Ai** & **Aj**, from this cluster, that i≠j, the following spatial relations holds true:

I
$$A_i \cap A_j = \varnothing$$

II
$$A_i \cap \left(\bigcup_{\substack{j=1 \\ j \neq i}}^{N} A_j \right) = \varnothing, \forall i, j = 1 - N \quad ,$$

III
$$\left(A_i \oplus B\right) \cap \left(\bigcup_{\substack{j=1 \\ j \neq i}}^{N} A_j \right) = \left(\left(\left(\bigcup_{\substack{j=1 \\ j \neq i}}^{N} A_j \right) \oplus B \right) \cap A_i \right) \neq \varnothing$$

- The relations I & II would be satisfied for the cases of water bodies, nodes, point-specific data.
- Relation III will be satisfied, if all the zones of a cluster are in contiguous form.

C. Computation of Euclidean Distances

- Based on **Euclidean** metric, determining distances between spatial objects is a challenge.
- If the sizes of the zones are **similar**, simple Euclidean distances would suffice to detect the spatially significant centroid of a corresponding zone.
- If the cluster consists of **dissimilar** shapes and sizes, then detecting the spatially significant zone can be done through –
  - **Computation of zone centroids**
    - **Minimal Skeleton Points (MSPs)**
  - **Euclidean distance between centroids of two zones**
    - **Zones Morphological properties cannot be considered**

ITERATIVE DILATION DISTANCE IS A BETTER CHOICE TO COMPUTE DISTANCES BETWEEN ZONES

Iterative Dilation Distances

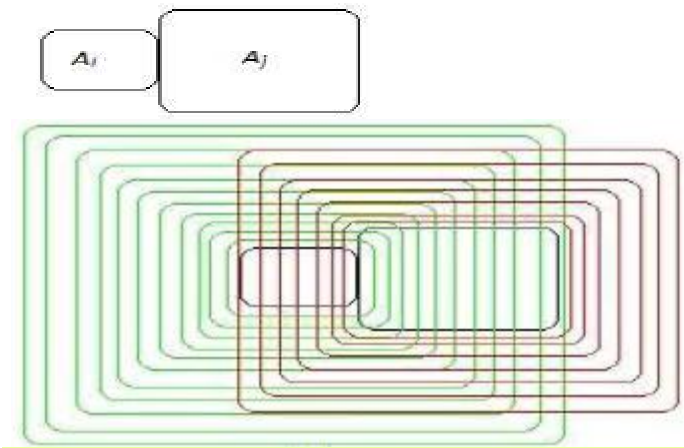
Let non-empty, disjoint compact zones Ai and Aj be the original and destination zones. (**Ai < Aj**)

- The distance from Ai to Aj represented by:

$$d\left(A_{ji}\right) = \min_{i \neq j}\left(n : A_i \subseteq \left(A_j \oplus nB\right)\right)$$

- The distance between Aj and Ai represented by:

$$d\left(A_{ij}\right) = \min_{i \neq j}\left(n : A_j \subseteq \left(A_i \oplus nB\right)\right)$$



dilation distances $d\left(A_{ij}\right) = 11$, and $d\left(A_{ji}\right) = 7$, and $\rho\left(A_{ij}\right) = 7$

The following conditions will be satisfied, iff both '**Ai**' & '**Aj**' possess identical size, shape & orientation.

$$d\left(A_{ij}\right) = d\left(A_{ji}\right)$$

$$d\left(A_{ii}\right) = 0, \quad d\left(A_{ij}\right) \neq d\left(A_{ji}\right)$$

Iterative Dilation Distances

- If the compact zones shape-sizes are dissimilar, then:

$$d\left(A_{ij}\right) \neq d\left(A_{ji}\right)$$

- The **min. of d(A_{ij})** and **d(A_{ji})** is **Hausdorff dilation distance**: $\rho\left(A_{ij}\right) = \min\left(d : d(A_{ij}), d(A_{ji})\right)$
- The max. distance (**d_{max}**) between origin zone (A_i) & destination zone (A_j) is computed as:

$$d_{\max}\left(A_{ij}\right) = \max_{\forall j}\left(\min\left(n : \left(A_j \subseteq \left(A_i \oplus nB\right)\right)\right)\right) = \min\left\{n : \left(\bigcup_{\substack{j=1 \\ j \neq i}}^{N} A_j\right) \subseteq \left(A_i \oplus nB\right)\right\}$$

- **d_{max}** between the destination zones and an origin zone is computed as: $d_{\max}\left(A_{ji}\right) = \max_{\forall j}\left(\min\left(n : \left(A_i \subseteq \left(A_j \oplus nB\right)\right)\right)\right)$

Estimation of the dilation distance between the origin & destination zones is justified as such as a **dilation distance is essential to compute distances between zones**.

Limitation: This distance is essential affected by the object's boundary points that are farthest out with respect to other spatial objects.

D. SSI of a Zone

- A zone (**Ai**) is said to the best zone and termed as **spatially the most important zone**, if it's satisfies the below characteristics:
  - If it is located in a place closer to all **Aj** s, and
  - Reaching Ai from all Aj s required shorter distance.
- Spatial Significance Index of a zone is defined as involving dilation-distances between origin (**Ai**) and destination zones (**Aj**).

$$SSI = \min_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right)$$

- SSI of a zone is a **<u>dimensionless unit</u>.**
- Lower the SSI of a zone (Ai) in a cluster of zones, the <u>higher is its significance</u>.

METHODOLOGY

SSI & NSSI of a Zone

- Normalized Spatial Significance Index (NSSI) that ranges between **0** and **1** takes form of:

$$NSSI = \left(\frac{\min\limits_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right)}{\max\limits_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right)} \right)$$

- If the zones of a cluster are **identical**, then:

$$\min_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right) \qquad \min_{\forall j}\left(d_{\max}\left(A_{ji}\right)\right)$$

- If the zones of a cluster are **dissimilar**, then:

$$\min_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right) \qquad \min_{\forall j}\left(d_{\max}\left(A_{ji}\right)\right)$$

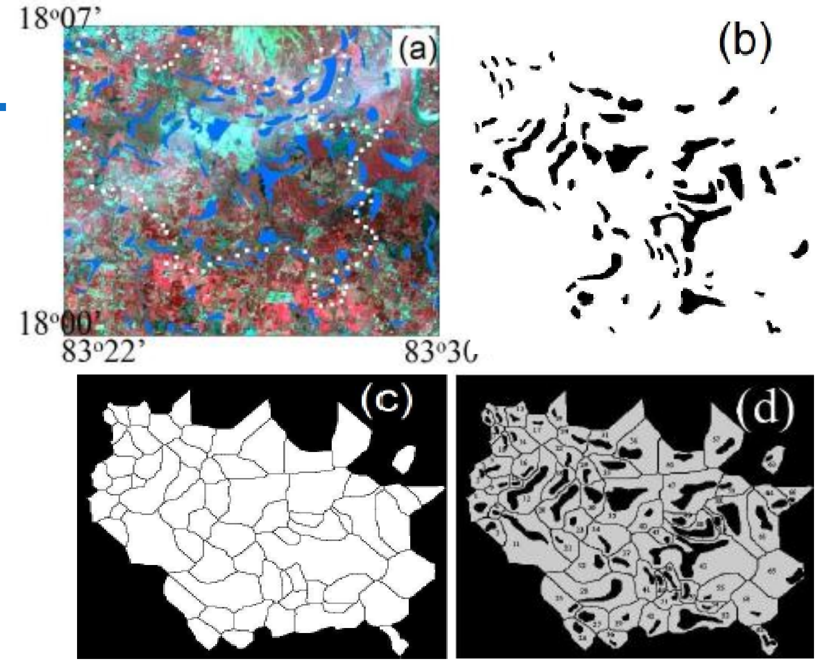
- When all the zones in a cluster are similar both in terms of size & shape, the following relationship holds **good**.

$$\left(\frac{\min\limits_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right)}{\max\limits_{\forall i}\left(d_{\max}\left(A_{ij}\right)\right)} \right) = \left(\frac{\min\limits_{\forall j}\left(d_{\max}\left(A_{ji}\right)\right)}{\max\limits_{\forall j}\left(d_{\max}\left(A_{ji}\right)\right)} \right)$$

EXPERIMENTAL RESULTS

Cluster of Zones of Water Body Influence

- Small water bodies and their zones of influence of varied sizes and shapes arranged heterogeneously.
- Max. dilation distances observed from distances computed between every water body and every other water body belonging to a cluster of 66 water bodies.
- The observed min. distances among 66 max. distances for both water bodies & zones include 53 &52 respectively
- The max. distances among 66 max. distances for both water bodies and zones observed include 109 & 110 respectively.



a. LISS-III input image.

83°22′-83°30′ E.long

18°00′ - 18°07′ N.lat

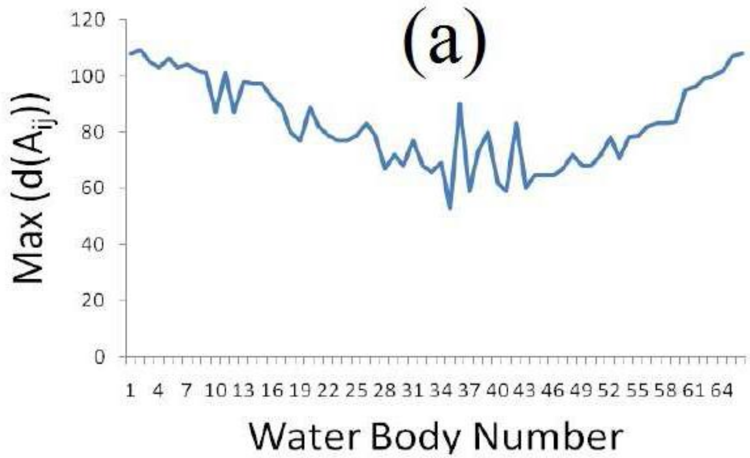
b. Extracted water bodies from RS data. (**60**)

c. Zones of influence, by corresponding water bodies. (**66**)

d. Water bodies and zones with labeling.

EXPERIMENTAL RESULTS

SSI – Water Bodies Zones of Influence



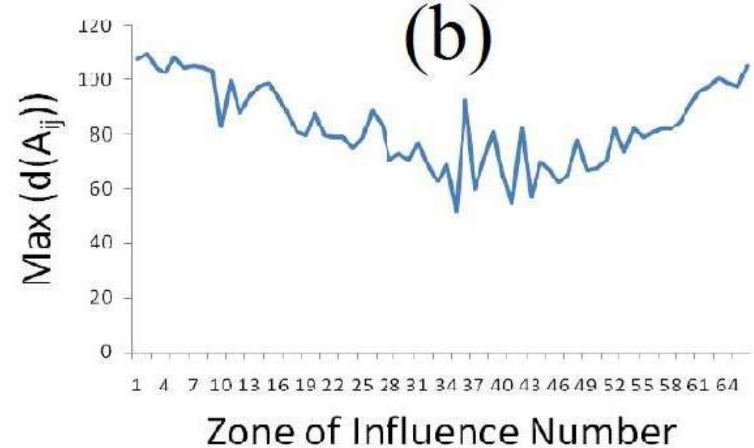
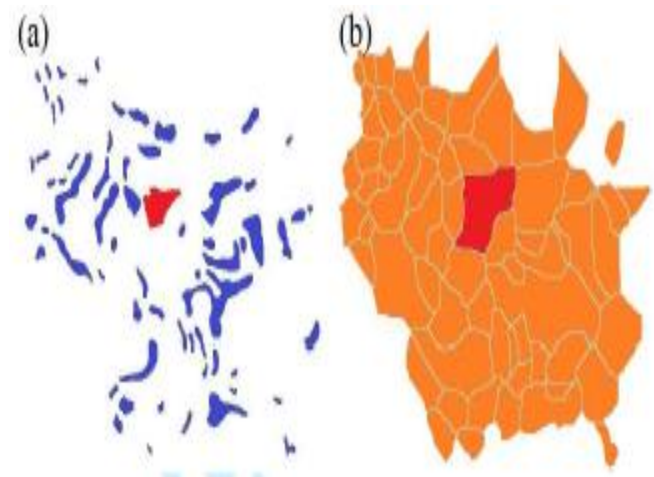


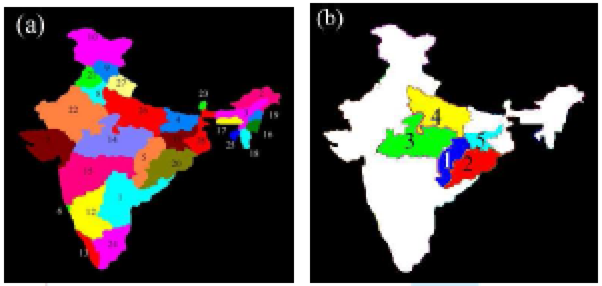
TABLE I. SSI OF TOP FIVE WATER BODIES AND ZONES

RANK	WATER BODY (W) LABEL	D-DIST	ZONE (Z) LABEL	D-DIST	NSSI (W)	NSSI (Z)
1	35	53	35	52	0.48	0.47
2	41	59	41	55	0.54	0.50
3	43	59	43	57	0.54	0.51
4	49	60	37	60	0.55	0.54
5	46	62	46	62	0.56	0.56



B. States of India

- The dilation distances between every state to other state are estimated, and origin-state specific max. distances are computed.
- Max. dilation distances observed from the estimated distances between every state and every other state of a cluster of 28 states of India are considered, and min. of these max. distances are considered to detect spatially significant state.
- Minimum of all these max. distances is **189**, followed by 206, 213, 226,233.
- Maximum of max. distances estimated between each origin-state and all destination-states is **383**.



RANK	STATE LABEL	D-DIST	NSSI
1	5	189	0.49
2	20	206	0.53
3	14	213	0.55
4	26	226	0.59
5	11	233	0.60

The computational complexity increases with increasing:

1. No. of spatial objects
2. Spatial resolution

Note: The no. of dilation distances required to be computed increases with no. of spatial objects, their sizes of the individual spatial objects.

CONCLUSIONS

Conclusions

- This iterative dilation distances technique can be extended:
  - To a wide class of metric spaces and to other representations (objects bounded by 2-D vectors), and
  - To 3-D case by replacing dilation distance with gray-scale geodesic distances.
- This technique useful insights in:

i. Clustering-classification frameworks,

ii. Detecting the spatially significant segmented zones obtained via various segmentation approaches,

iii. Automatically deriving a central node from a large no. of nodes,

iv. Determining the influence of a node in a vector-based network setting,

v. Deciding on nodal centre(s) to establish an administrative facility, from a cluster of cadastral zones from mapped from remotely sensed satellite data.

Thank You