QUANTITATIVE SPATIAL REASONING

Spatial Reasoning

Strategically important set(s)

Directional spatial relationship

Spatial Significance Index of zones

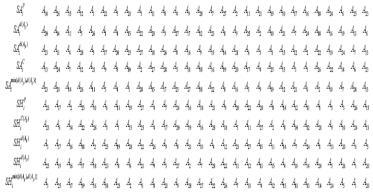
III.II.I. Strategically significant state(s)

$$\begin{split} H/P(A_{ij}) &= -\sum_{\substack{\forall j \\ i \neq i}} \Pr\left[P(A_{ij})\log\Pr\left[P(A_{ij})\right]\right] \\ H/C(A_{ij}) &= -\sum_{\substack{\forall j \\ i \neq j}} \Pr\left[C(A_{ij})\log\Pr\left[C(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall j \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall j \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ i \neq j}} \Pr\left[d(A_{ij})\log\Pr\left[d(A_{ij})\right]\right] \\ H/d(A_{ij}) &= -\sum_{\substack{\forall i \\ \forall i \neq j}} \left\{H/P(A_{ij})\right\} \left(SA_{i}^{P}\right) &= \max_{\substack{\forall i \\ \forall i \neq j}} \left\{\sum_{i} NP(A_{ij})\right\} \\ SH_{i}^{C}) &= \min_{\substack{\forall i \\ \forall i \neq j}} \left\{H/P(A_{ij})\right\} \\ SH_{i}^{C}) &= \min_{\substack{\forall i \\ \forall i \neq j}} \left\{\min\left[\sum_{i} Nd(A_{ij}), \sum_{j} Nd(A_{ji})\right]\right\} \\ SA_{i}^{C}) &= \max_{\substack{\forall i \\ \forall i \neq j}} \left\{\sum_{i} C(A_{ij})\right\} \\ SA_{i}^{C}) &= \max_{\substack{\forall i \\ \forall i \neq j}} \left\{\sum_{i} C(A_{ij})\right\} \\ \end{array}$$

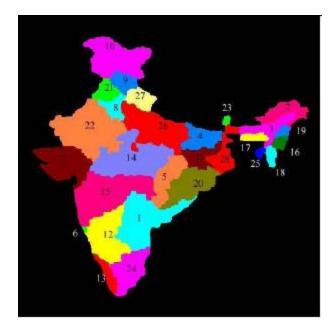
Matrices and Parameters

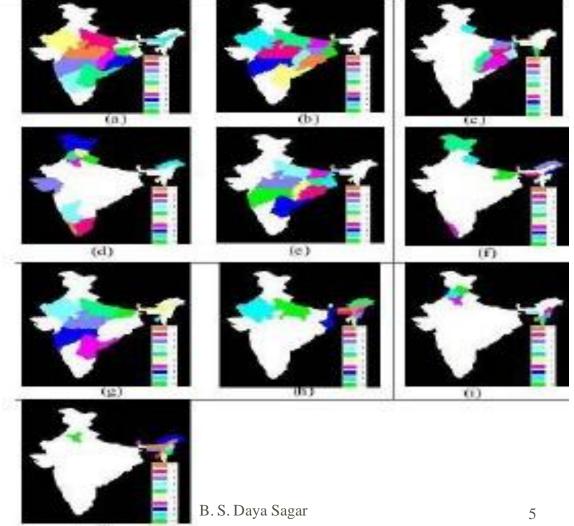
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-		228	208	110	133	250	119	36	0	29	124		293	_	160	259	205	247		153	29	50		280	230	42	30	1
	248	270	249	158	185	303	173	89	53	0	175	266	346	145	215	301	251	288	384	206	67	99	220	336	273	95	80	1
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	145	38	15	103		-	309	-	236		104		269	-	209	0	29	20		108		254	-	219	34		209	
	115	30	9	72	127	287	278	228	106	186	74	218	238	150	179	50	0	39	53	78	233	219	62	188	25	124	179	
	129	64	30	84	140	299	289	239	219	200	85	232	249	160	190	27	42	8	44	89	249	230	74	284	20	135	198	
	149	19	12	104	160	322	313	262	240	220	108	254	273	183	213	- 14	34	33	0	112	272	253	95	223	39	158	208	
-	45	154	129	93	50	-	199	150	178		61	142			100	174	130		183	0	164	140	134		157	86	154	
-	1000	255	235	140	-	-	105	25	30	-	140	200		-	148	285	235	-	-	140	0	32	209	-	264	45	55	1
-	-	330	305	209	164	204	75	79	94	127	208	167	248	67	115	354	305		-	174	91	0	308		338	114	123	2
-	129	52	26	24	69		217	165	145	-	39	169		88	120	78	29	65	80	79	174	157	-	208	52	60	117	
-	-	265	236	231	-	-	172			343	199	51		184	-		244	-	-	139	-	211	273	0	233		294	1
-	110	52	17	65	120	-	273		200		68	1	233	144	173	26	29	15	34		232	213	55		0	225	168	
-	152	215	190	94	89	287	155	184	91	118	93	170	249	49	119	240	185	229	244	109	113	93	163	-	214	8	69	1
-	168	205	180	85	104	222	101	49	32	52	98 27	184	264 213	64	134	226	182 55	-	235 109	124	58	46	149	253	204	20	0	1
	116	80	59	39	79	240	228	179	159	152				103	132			93		67	190	173	78	194	78	78	132	



Strategically significant state(s) w.r.t 10 parameters





24 March 2013

(0)

Directional Spatial Relationship

http://www.isibang.ac.in/~bsdsagar/AnimationOfDirectionalSpatialRelationship.wmv

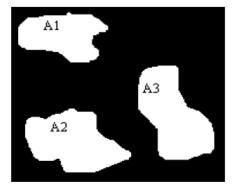
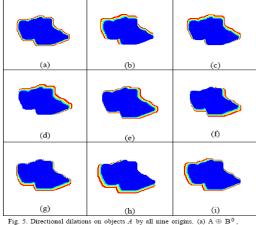


Fig. 1. (A_1, A_2, A_3) three disjoint objects possessing different directional spatial relationship.



⁽b) $A \oplus B^1$, (c) $A \oplus B^2$, (d) $A \oplus B^3$, (e) $A \oplus B^4$, (f) $A \oplus B^5$, (g) $A \oplus B^6$, (h) $A \oplus B^7$, (i) $A \oplus B^8$.

1	1	1	(1)	1	1	1	(1)	1
1	(1)	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
	(B^0)			(B^1)			(B^2)	
1	1	(1)	1	1	1	1	1	1
1	1	1	1	1	(1)	1	1	1
1	1	1	1	1	1	1	1	(1)
	(B^3)			(B^4)			(B^5)	
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	(1)	1	1
1	(1)	1	(1)	1	1	1	1	1
	(B^6)			(B^7)			(B^8)	

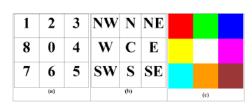


Fig. 4 Shows (a) origins of structuring element, and their corresponding directions in (b) and color codes in (c).

Fig. 3. Structuring element is shown with different possible origins. Except the first structuring element for which the origin is shown at the center, all other eight structuring elements are with other eight possible positions as origins. Those eight other structuring elements are asymmetric structuring elements as their transposes are not equivalents of their non-transposed versions.

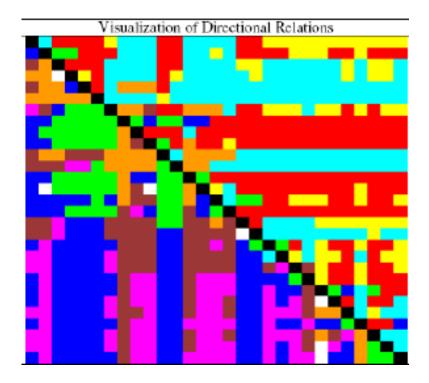
 $A_i \oplus nB^i$ $\Delta(A$ $i \min\{n : A_i \subseteq$

TABLE 1. DISTANCES, UNIQUE ORIGINS AND DIRECTIONS

М	inimun Dista	n Dilat unces	ion	τ	inique	Origi	15	D	irection	al Rela	tio n s			zation (al Relat	
	A_1	A_1	A_3		A_1	A_{2}	A_{j}		A_1	A_1	A_5		A_1	A_2	A_{i}
A_1	0	53	50	$A_{\rm j}$	0	2	1	\mathcal{A}_1	С	N	NW	$A_{\rm l}$			
A_2	46	0	36	A_{2}	6	0	7	A_2	S	С	SW	A_2			
A_{g}	52	49	0	A_3	5	3	0	A3	SE	NE	С	A_{3}			

Directional Spatial Relationship





DETECTION OF SPATIALLY SIGNIFICANT ZONES

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.











INTRODUCTION

SPATIALLY SIGNIFICANT ZONES



- 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 Zone (SSZ) can be defined as "<u>a zone</u> 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.



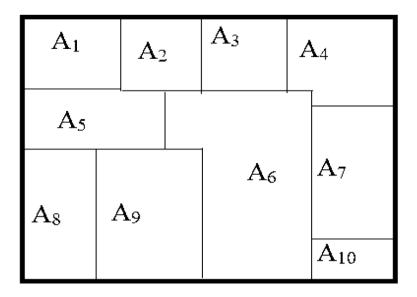


Fig: A 2-D representation of a spatial system with 10 zones.

For a geometric basin (A_i) , if A_1 is considered as an origin zone, then all the other zones (A_2-A_{10}) are treated as destination zones.

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. $\Delta_{-} = \begin{cases} a+b : a \in A \\ a = k \end{cases}$

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

$$A_b = \left\{ a + b : a \in A \right\}$$
$$B = \left\{ a : -a \in B \right\}$$

- Multiscale Dilations can be performed by varying the size of the structuring element (nB). (n≥0)
- Iterative dilations can also be represented mathematically, as follows:

$$(A \oplus nB) = (A \oplus B) \oplus B \oplus \dots \oplus B$$

$$n = 0, 1, 2, \dots, N$$

B. Spatial System and Its Subsystems

So Let **'A'** be a cluster of zones composed of a number of non-empty, compact sets **(zones)** $A_1, A_2, A_3, \dots, A_N$ $A = \bigcup_{i=1}^N A_i$

So Any pair of zones A_i & A_j, from this cluster, that i≠j, the following spatial relations holds true:

$$A_{i} \cap A_{j} = \emptyset$$

$$A_{i} \cap \begin{pmatrix} N \\ \bigcup & A_{j} \\ j=1 \\ j \neq i \end{pmatrix} = \emptyset, \forall i, j = 1 - N'$$

$$(A_{i} \oplus B) \cap \begin{pmatrix} N \\ \bigcup & A_{j} \\ \end{bmatrix} = \begin{pmatrix} N \\ \bigcup & A_{j} \\ \end{bmatrix} \oplus B \cap A_{i} \neq \emptyset$$

j=1

- The relations I & II would be satisfied for the cases of water bodies, nodes, pointspecific 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

Distances

Let non-empty, disjoint compact zones A_i and A_i

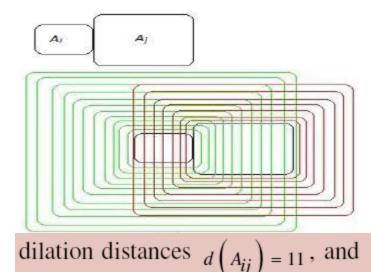
be the original and destination zones. $(A_i < A_j)$

• The distance from A_i to A_j 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 A_j and A_i represented by:

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



 $d(A_{ji}) = 7, \text{ and } \rho(A_{ij}) = 7$ The following conditions will be satisfied, iff both 'Ai' & 'Aj' possess <u>identical size</u>, <u>shape</u> & <u>orientation</u>. $d(A_{ij}) = d(A_{ji})$ $d(A_{ij}) = 0, \quad d(A_{ij}) \neq d(A_{ji})$

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: $\rho(A_{ij}) = \min(d : d(A_{ij}), d(A_{ji}))$
- The max. distance (\mathbf{d}_{\max}) between origin zone (A_i) & destination zone (A_j) is computed as: $d_{\max}(A_{ij}) = \max_{\forall j} \left(\min \left(n : \left(A_j \subseteq (A_i \oplus nB) \right) \right) \right)^{=} \min \left\{ \begin{array}{c} n : \left[\bigcup_{\substack{j = 1 \ j \neq i}}^{\vee} A_j \right] \subseteq (A_i \oplus nB) \right\} \right\}$
- **d**max between the destination zones and an origin zone is computed as: $d_{\max}(A_{ji}) = \max_{\forall j} \left(\min \left(n : \left(A_i \subseteq \left(A_j \oplus nB \right) \right) \right) \right)$

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.



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

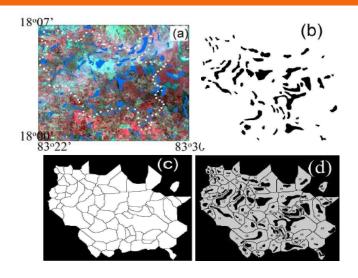
$$SSI = \min_{\forall i} \left(d_{\max} \left(A_{ij} \right) \right)$$

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

	SSI & NSSI of a Zone
b	normalized Spatial Significance Index (NSSI) that
\square	ranges between 0 and 1 takes form of:
OL	$NSSI = \begin{pmatrix} \min(d_{\max}(A_{ij})) \\ \frac{\forall i}{\max(d_{\max}(A_{ij}))} \end{pmatrix}$
	If the zones of a cluster are <u>identical</u> , then:
DO	$\min_{\forall i} \left(d_{\max} \left(A_{ii} \right) \right) \qquad \min_{\forall j} \left(\overline{d_{\max} \left(A_{ji} \right)} \right)$
	If the zones of a cluster are <u>dissimilar</u> , then:
	$\min_{\forall i} \left(d_{\max} \left(A_{ii} \right) \right) \qquad \min_{\forall j} \left(d_{\max} \left(A_{ji} \right) \right)$
	$\lim_{i \to i} \forall i \left(a_{\max} \left(A_{ij} \right) \right) = \prod_{i \to i} \forall j \left(a_{\max} \left(A_{ij} \right) \right)$
	90 When all the zones in a cluster are similar both in
iu -	terms of size & shape, the following relationship
Σ	holds <u>good</u> . $\left(\frac{\min(d_{\max}(A_{ij}))}{\forall i}\right) = \left(\frac{\min(d_{\max}(A_{ji}))}{\forall j}\right)$
	$\left(\begin{array}{c} \max \left(d_{\max} \left(A_{ij} \right) \right) \\ \forall i \end{array} \right) = \left(\begin{array}{c} \max \left(d_{\max} \left(A_{ji} \right) \right) \\ \forall j \end{array} \right)$

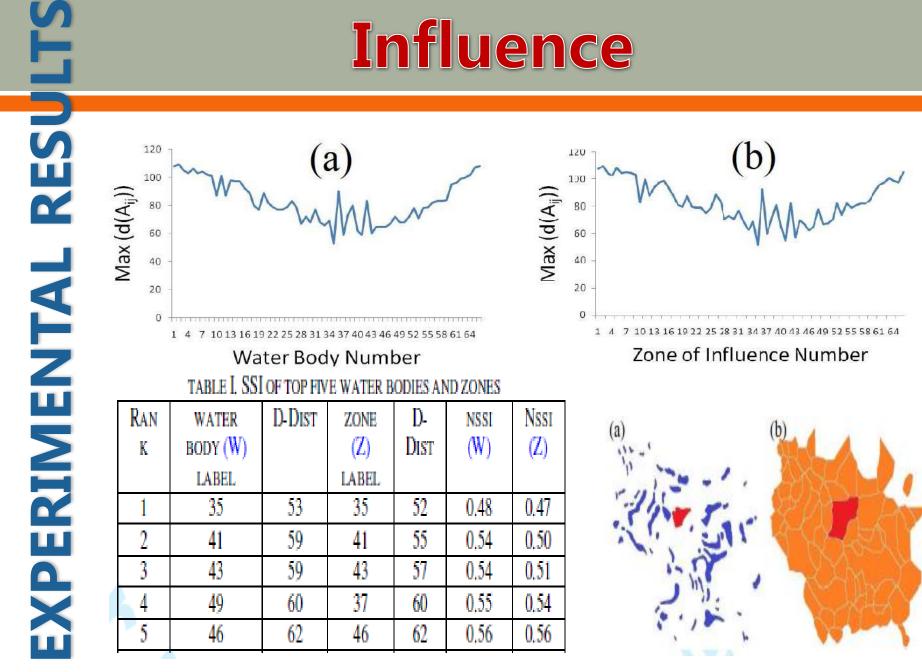
Cluster of Zones of Water Body Influence

- 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.

Water Bodies Zones of Influence



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.

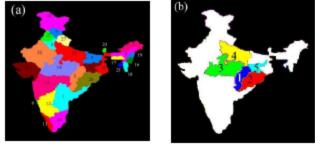
RESULTS

EXPERIMENTAL

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.



	RANK	STATE LABEL	D-DIST	NSSI
1	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



- 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.

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Thank You

Q & A

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