DISTANCE-BASED SPATIAL VERIFICATION (PUTTING THE SPATIAL VERIFICATION METHODS TO THE TEST)

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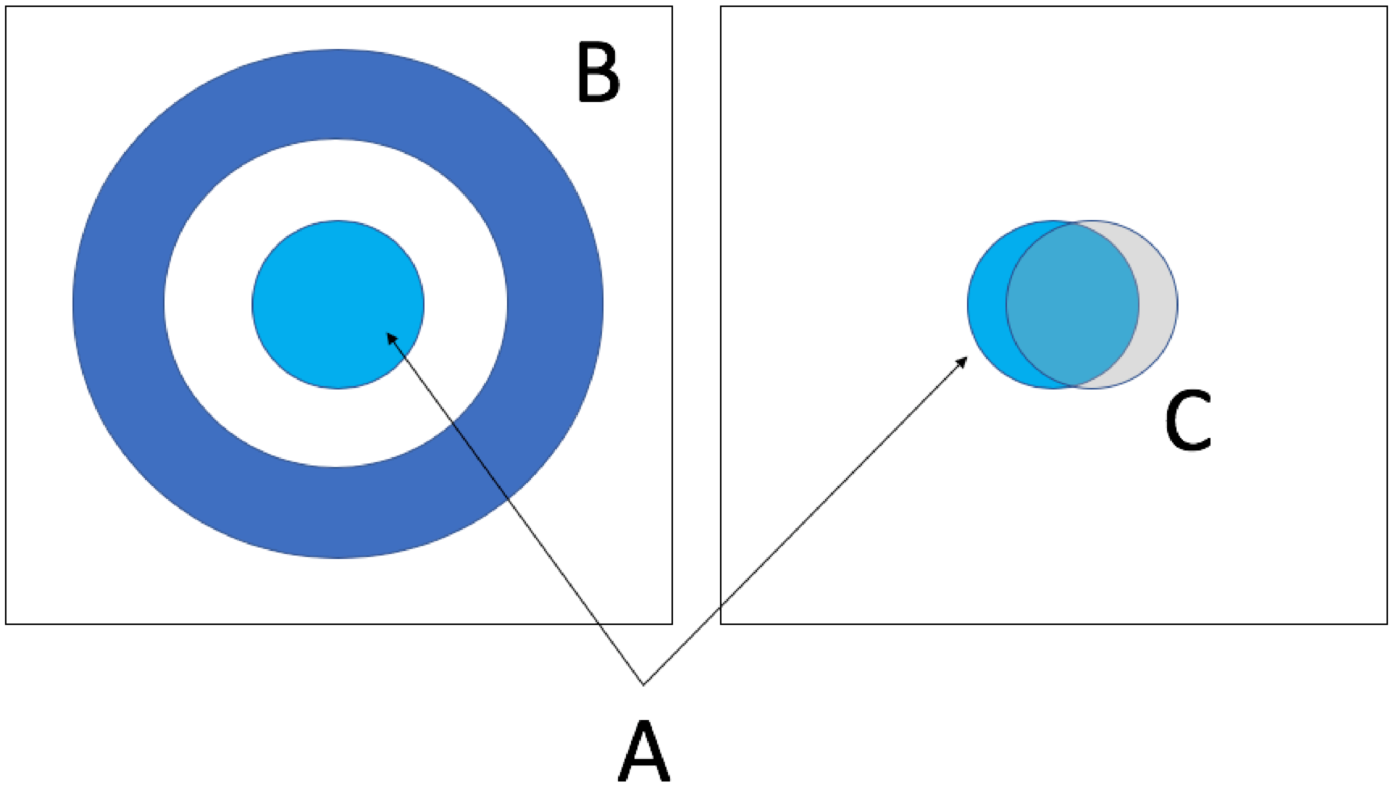
WHAT ARE DESIRABLE PROPERTIES FOR A SUMMARY MEASURE OF LOCATION ERRORS ?

A mathematical metric, $m(A, B) \geq 0$, that measures the "closeness" between two event sets (non-zero grid point values in a binary field, for example) requires that the following three properties be met:

- identity: $m(A, B) = 0$ if and only if $A = B$
- symmetry: $m(A, B) = m(B, A)$
- triangle inequality: $m(A, B) \leq m(A, C) + m(B, C)$

WHAT ARE DESIRABLE PROPERTIES FOR A SUMMARY MEASURE OF LOCATION ERRORS



SOME DISTANCE MEASURES OF INTEREST

Centroid distance

Distance map measures

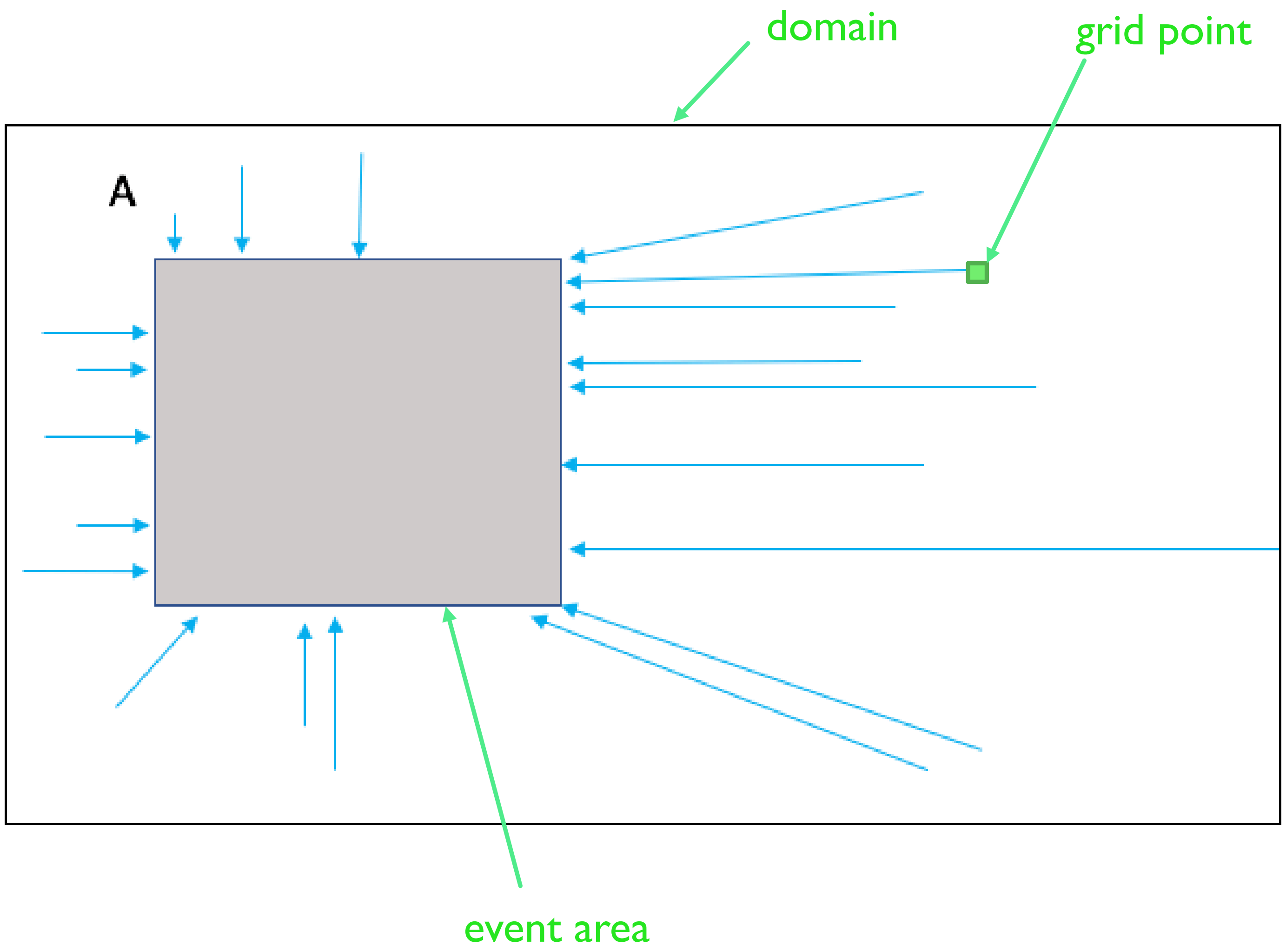
- Baddeley's Δ
- Hausdorff distance
- Mean-error distance (MED)
- others (not shown here)

Fractions Skill Score

- distance FSS (dFSS)

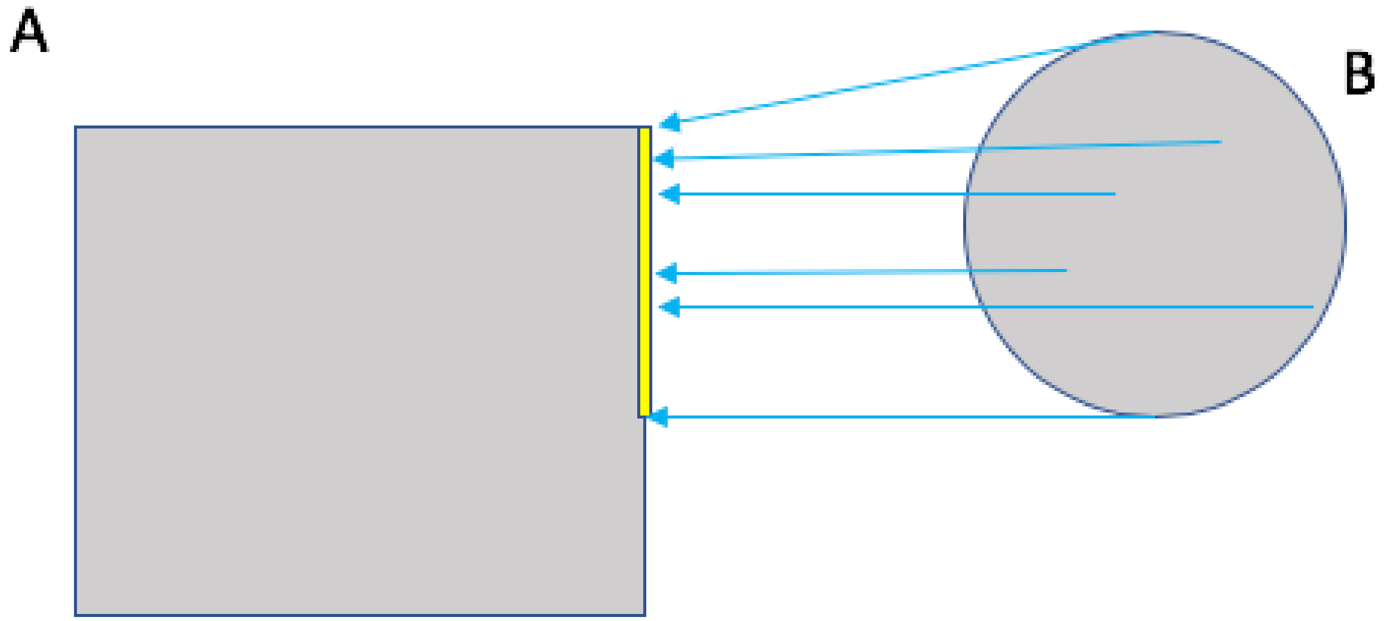
DISTANCE MAPS

- Transform the original fields of interest into binary fields (e.g., by setting values below a threshold to zero, and above the threshold to one)
- Create a new field of grid point values of the same dimension as the original binary field where the value at each grid point is the shortest distance from that grid point to the nearest one-valued grid point. Call this new field the distance map.
- Fast algorithms exist for computing these maps.

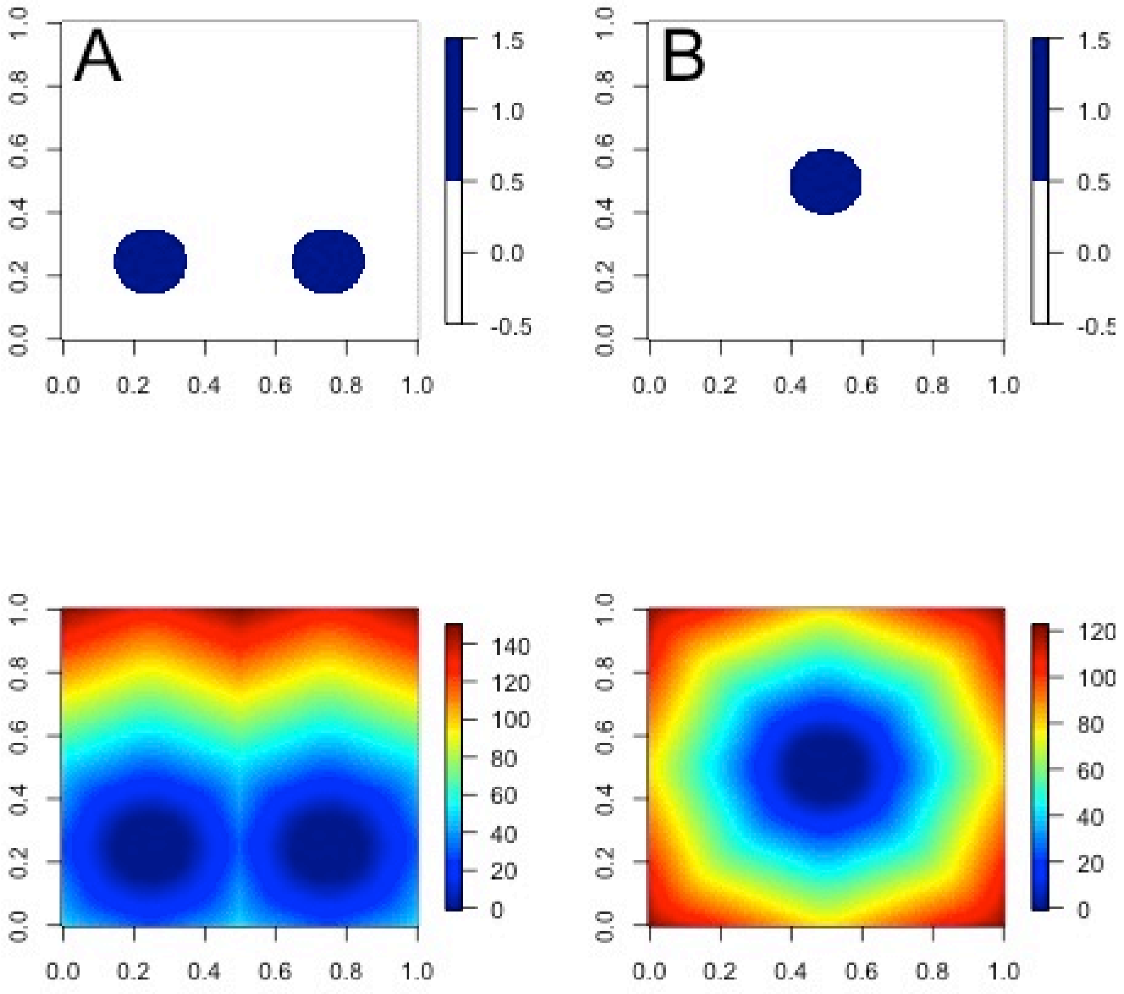


DISTANCE MAPS

- Distances from within an event set B to the nearest point in A. Note that they all fall along the yellow line.

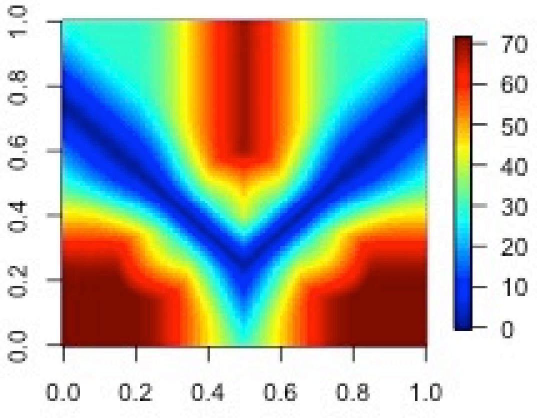


Domain size: 200 x 200 gridpoints

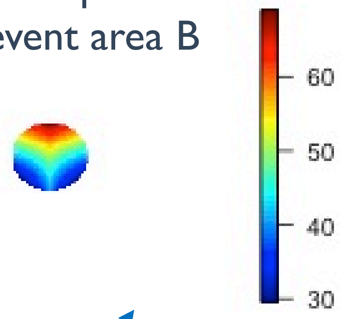


DISTANCE MAPS

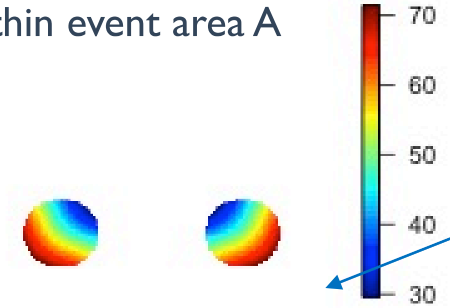
DISTANCE MAPS



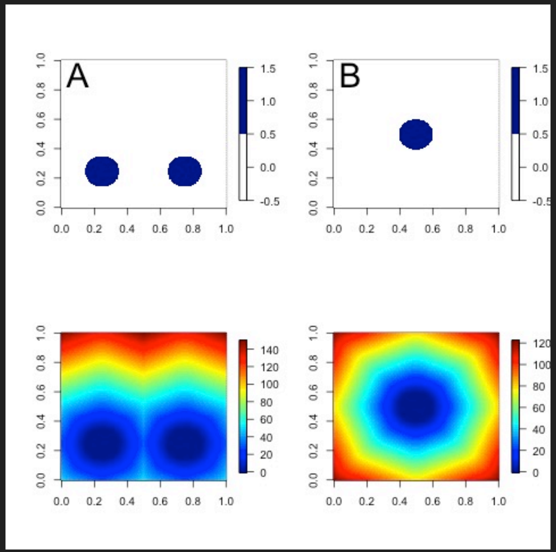
Distance map for A within event area B



Distance map for B within event area A



Note the lack of axes to emphasize that it is only the distances within these event areas that are of interest (for certain measures).



BADDELEY'S DELTA

$d(\mathbf{s}, A)$ is the distance map for A.

$d(\mathbf{s}, B)$ is the distance map for B.

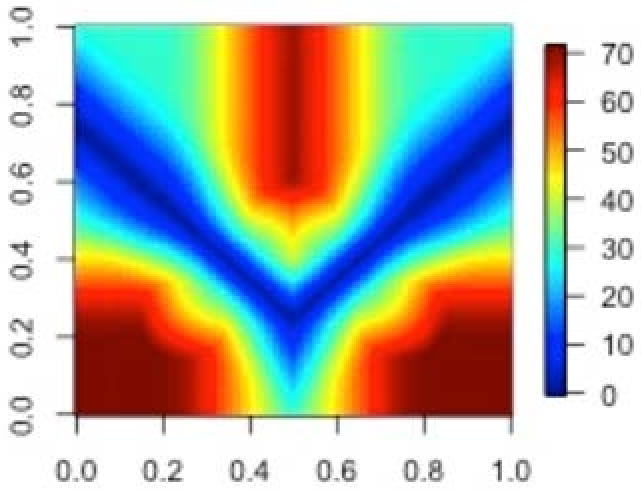
$$\Delta(A, B) = \left[\frac{1}{N} \sum_{\mathbf{s} \in \mathcal{D}} \left| w\big(d(\mathbf{s}, A)\big) - w\big(d(\mathbf{s}, B)\big) \right|^p \right]^{1/p}$$

N is the size of $\mathcal{D}$.

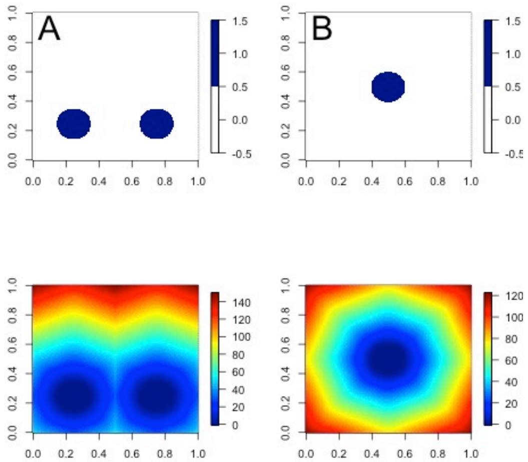
$\mathbf{s} = (x, y)$ are the spatial locations (grid points) and the sum is over the entire domain $\mathcal{D}$.

$w(\cdot)$ is a concave function that is strictly increasing at zero. That is, $w(s + t) \leq w(s) + w(t)$ and $w(t) = 0$ if and only if $t = 0$. Usually, $w(t) = \min\{t, c\}$, where c is a user-defined constant. This transform is called the cutoff transform.

BADDELEY'S DELTA METRIC



Hausdorff distance is the maximum of this field. Can also first apply the cutoff-transform, in which case it likely will be c.



Baddeley's Δ is the Lp norm of the field, possibly after setting distances larger than a constant c to c (i.e., applying the cutoff transform).

MEAN-ERROR DISTANCE

distance map for A.

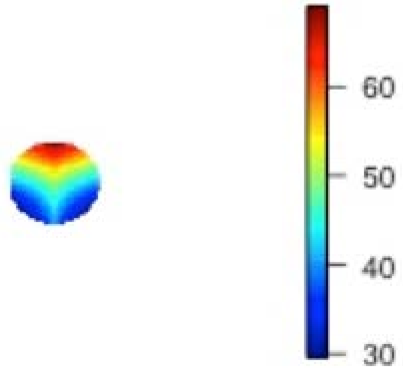
$$\mathrm{MED}(A, B) = \frac{1}{n_B} \sum_{\boldsymbol{s} \in B} d(\boldsymbol{s}, A)$$

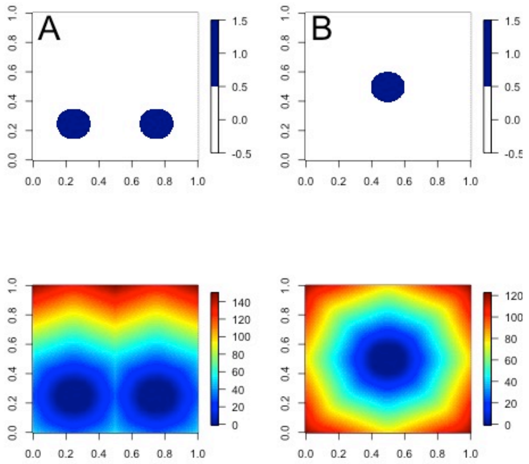
n_B is the number of grid points in B.

Summation is only over the grid points in the set B.

MEAN-ERROR DISTANCE

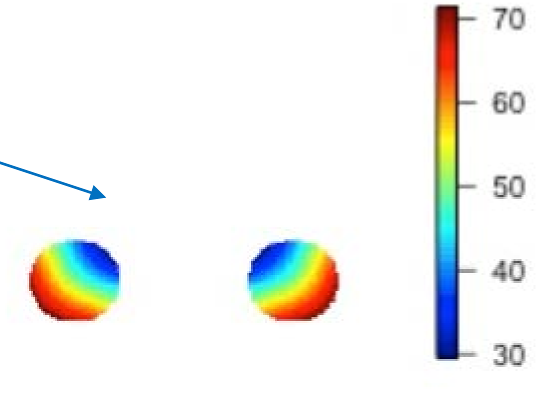
$\mathrm{MED}(A, B)$ is the average over these distances.

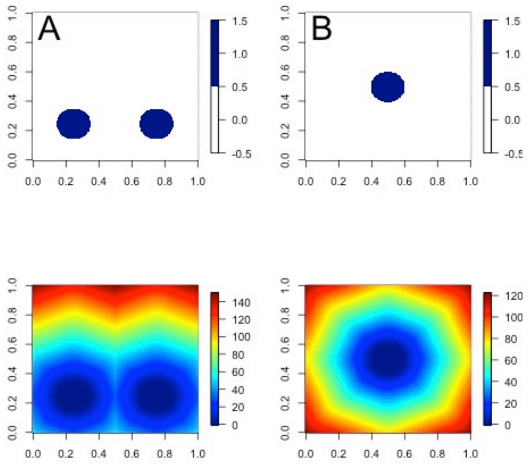




MEAN-ERROR DISTANCE

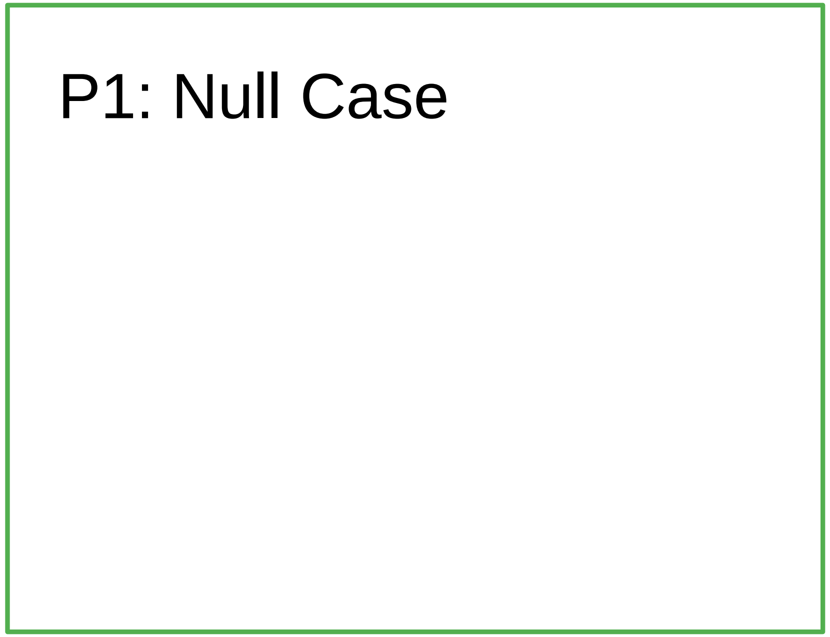
$\mathrm{MED}(B, A)$ is the average over these distances.

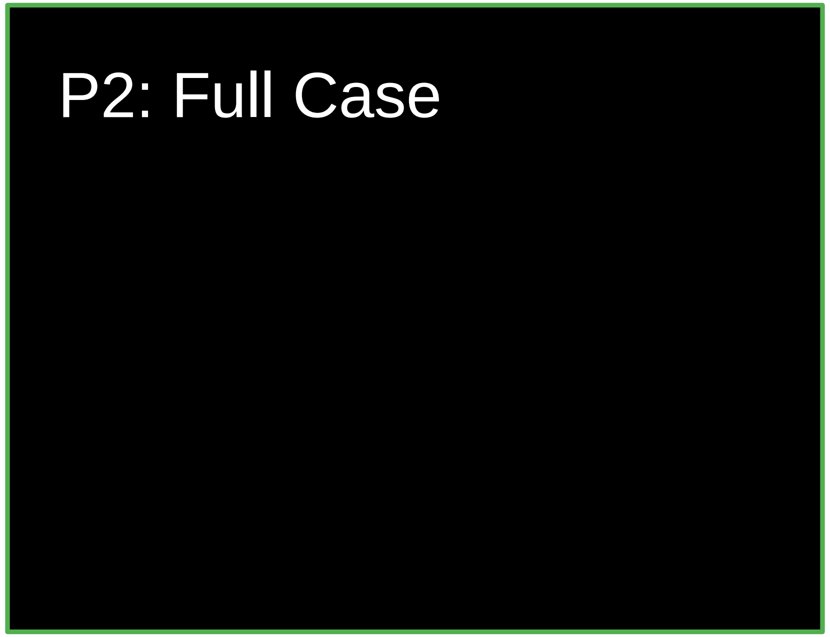




NEW GEOMETRIC CASES

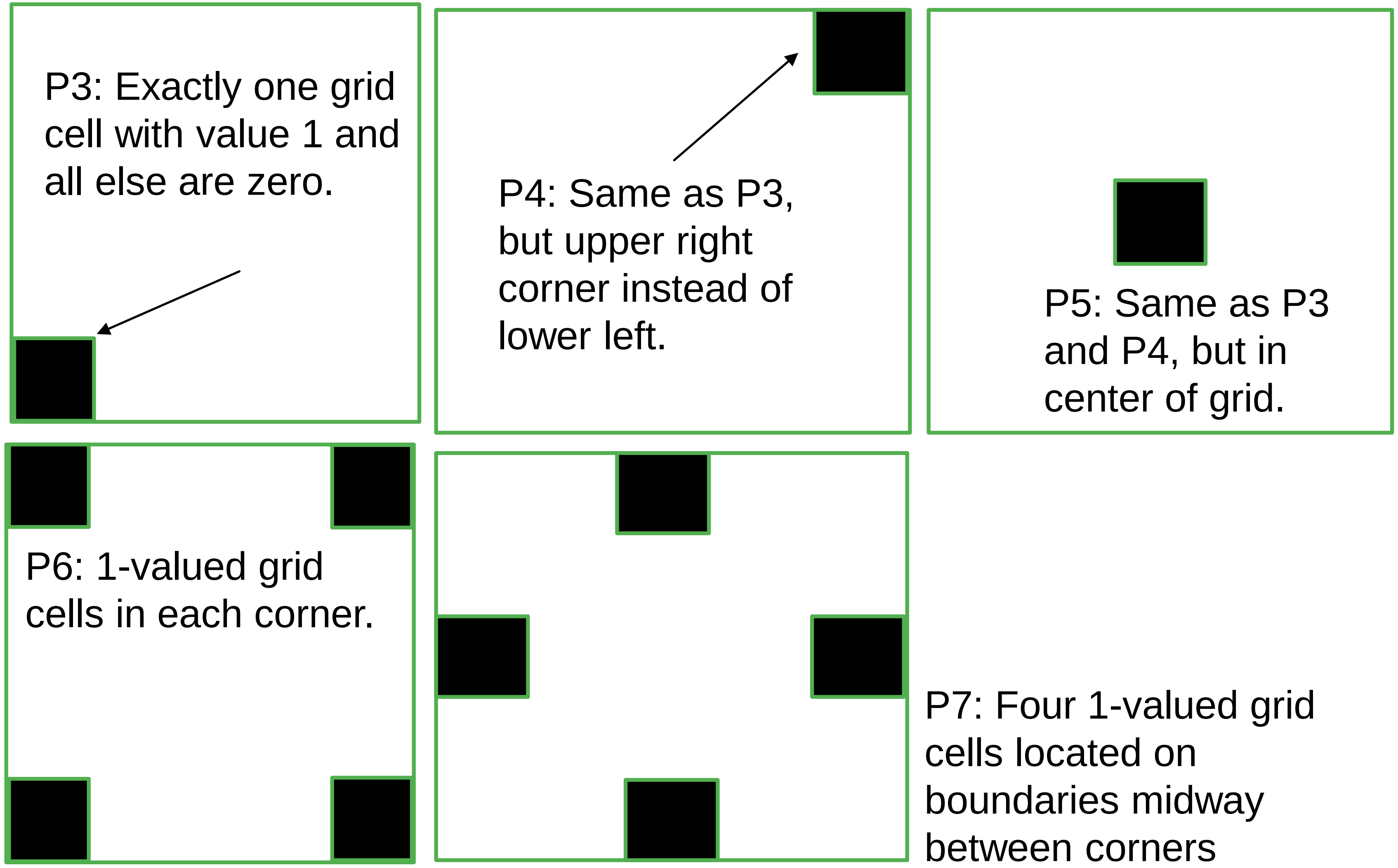
Pathological Cases





NEW GEOMETRIC CASES

Pathological Cases



NEW GEOMETRIC CASES

P1P3: Exactly one grid cell with error = -1 and all else are zero.

Measures are not defined

rP1P3: Exactly one grid cell with error = 1 and all else are zero.

Measures are not defined

P1P4: Same as P1P3, but different placement of the error.

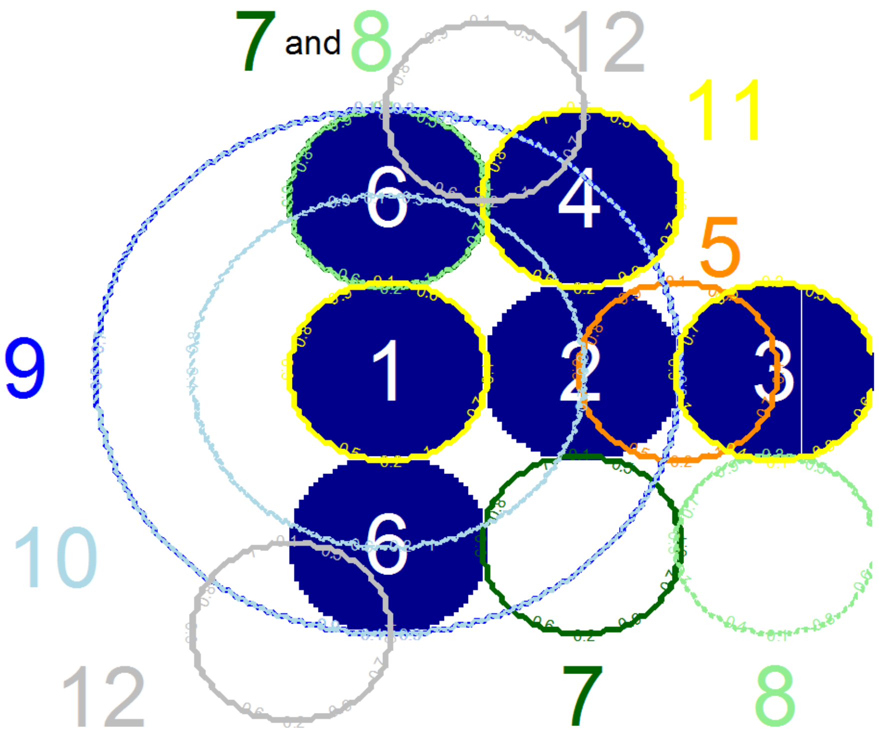
Measures are not defined

P1P5: Same as P1P3 and P1P4, but different placement of the error.

Measures are not defined

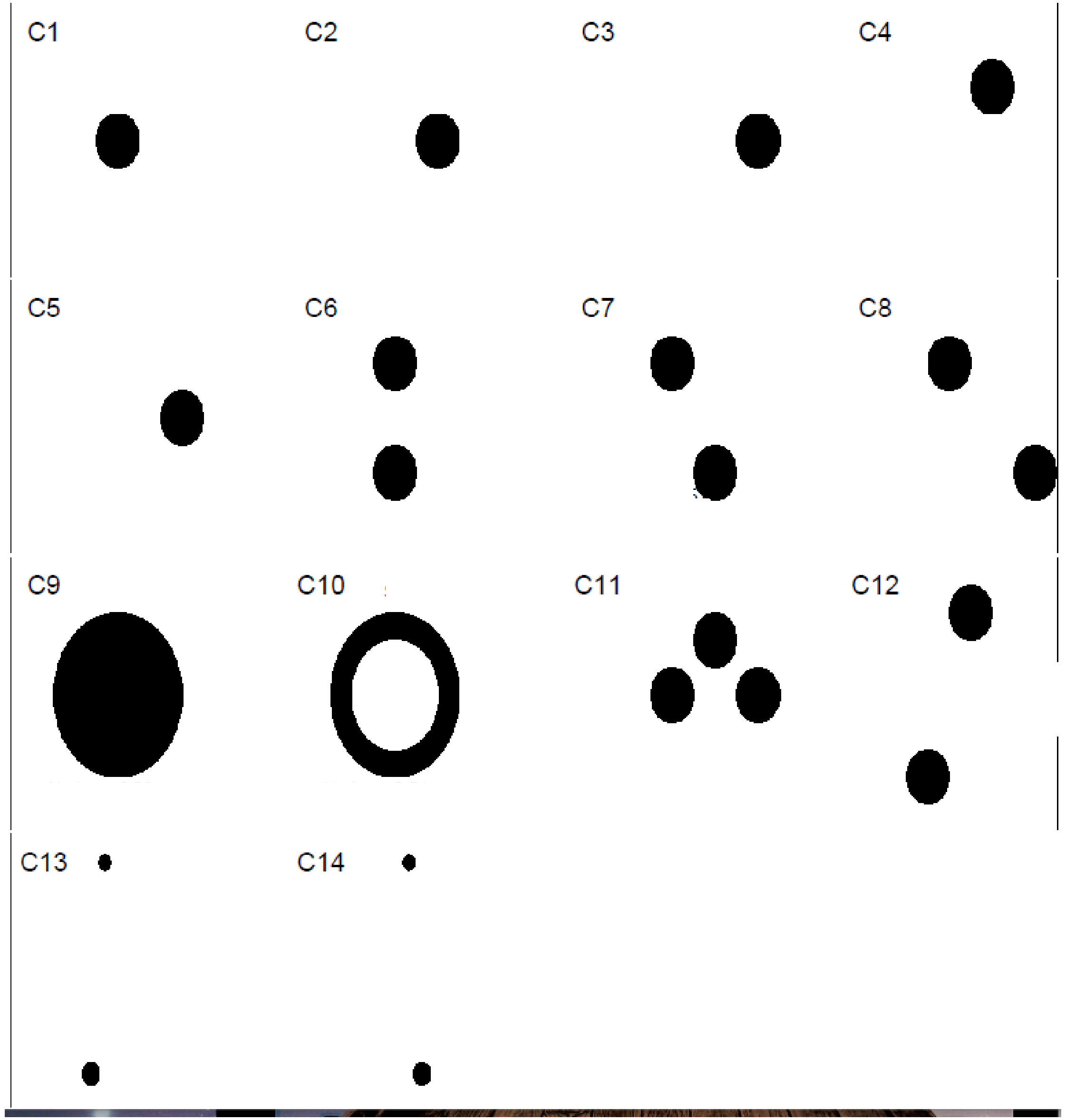
P2P5: Same as P1P5 but the one grid square is the only non-error.

Δ = 86.21, H = 142..13
CD = 0.71, MED(P2, P5) = 0.00, MED(P5, P2) = 80.88



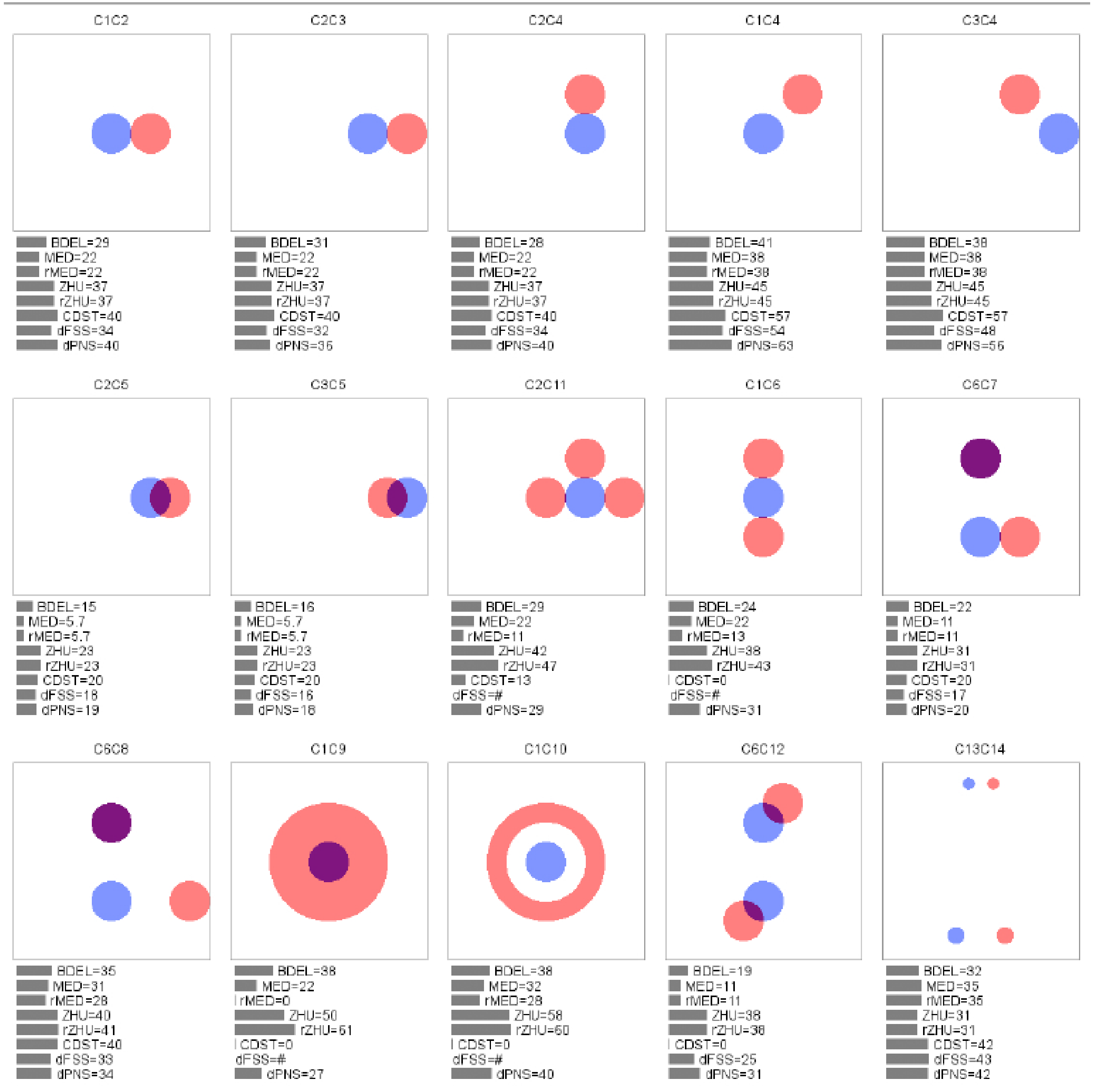
NEW GEOMETRIC CASES

CIRCLE CASES



NEW GEOMETRIC CASES

CIRCLE CASES

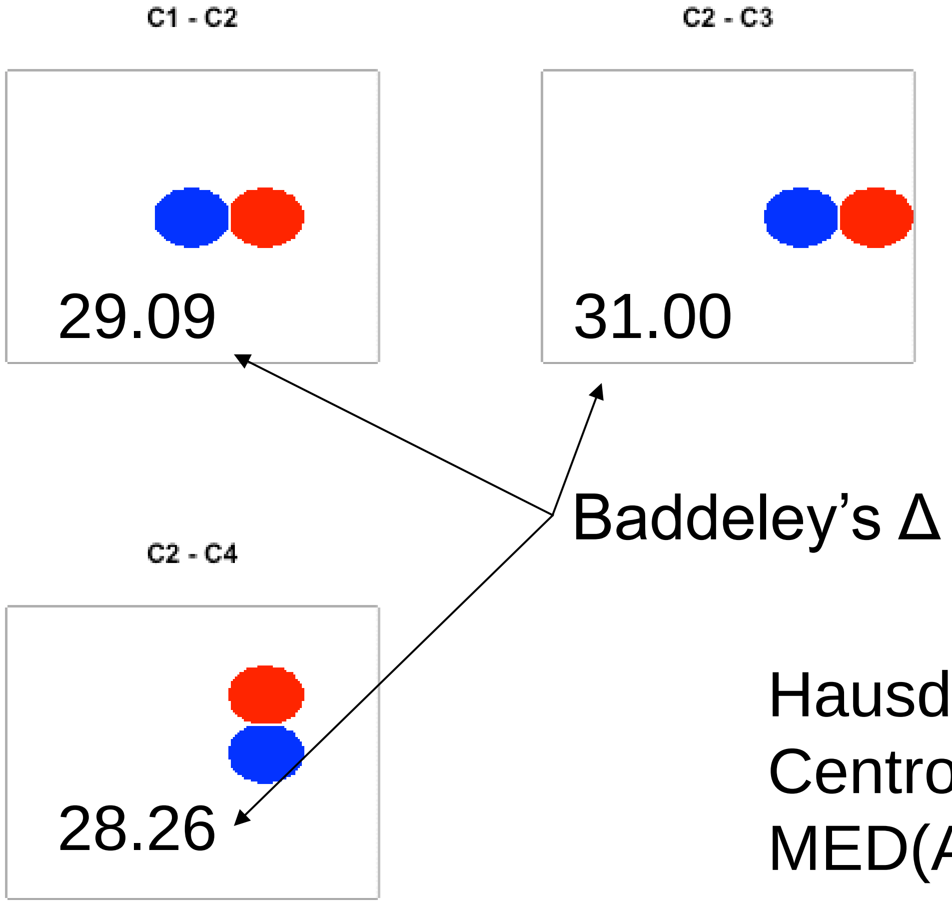


NEW GEOMETRIC CASES

CIRCLE CASES:

PROPOSED COMPARISONS

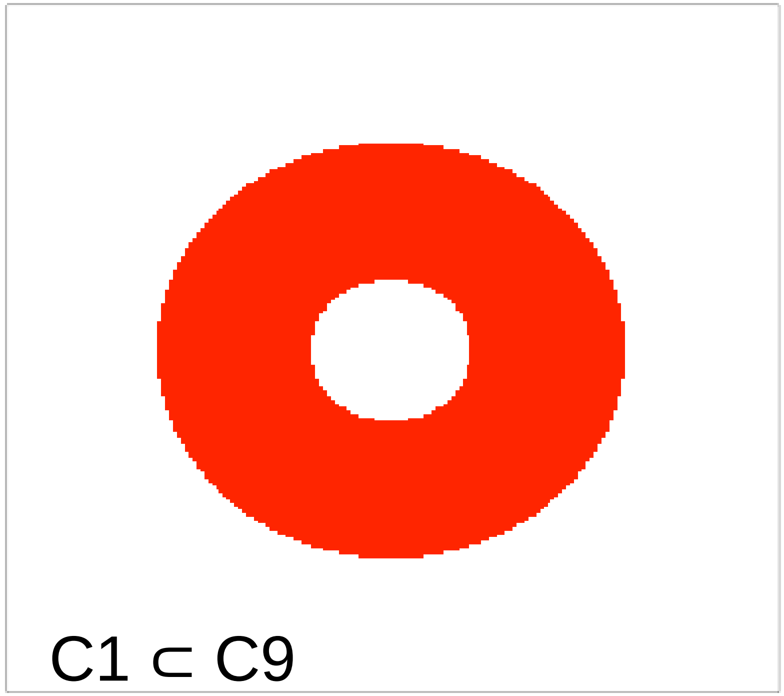
NEW GEOMETRIC CASES



Hausdorff = 40.20
Centroid distance = 40.00
MED(A,B) = MED(B,A) = 21.92

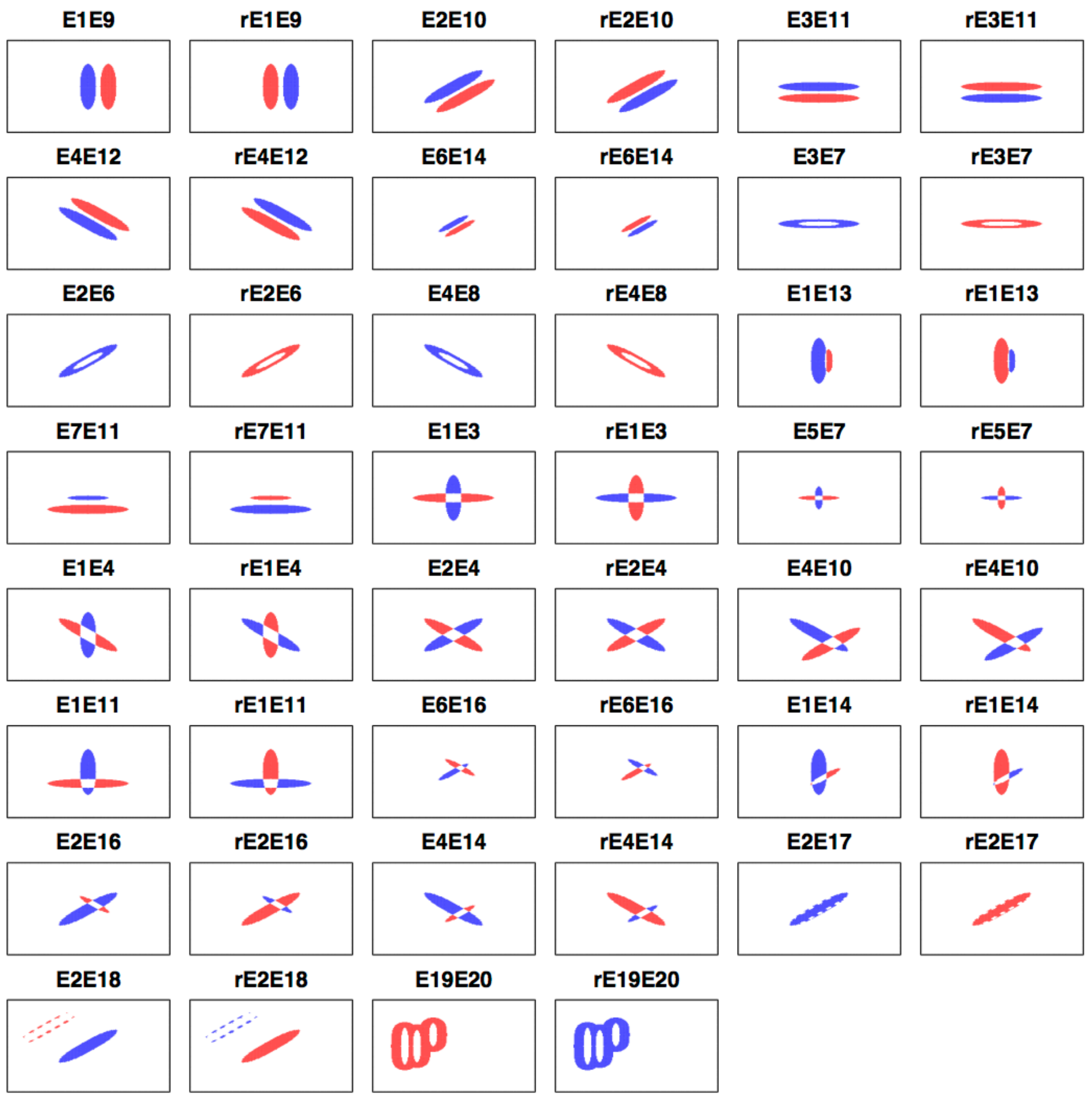
NEW GEOMETRIC CASES

C1 - C9



Baddeley's Δ = 38.13
Hausdorff = 43.43
Centroid distance = 0.00

MED(C1,C9) = 21.72
MED(C9,C1) = 0.00



NEW GEOMETRIC CASES

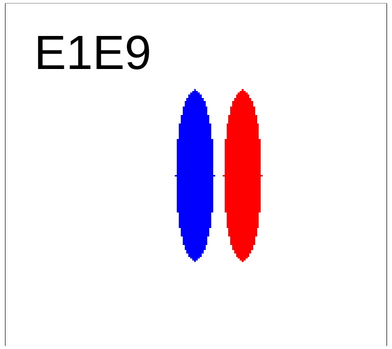
COMPLEX TERRAIN CASES

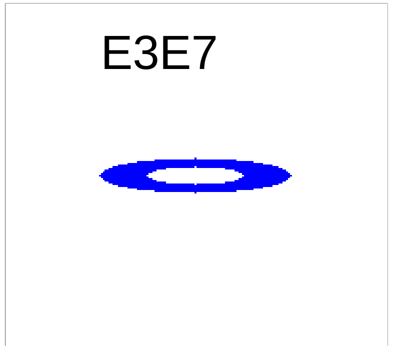
NEW GEOMETRIC CASES

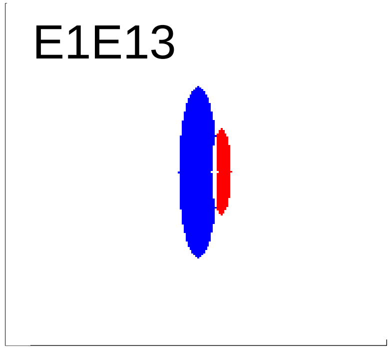
Δ = 14.15, H = 25.13
CD = 0.00, MED(E3,E7) = 0.00
MED(E7,E3) = 5.86

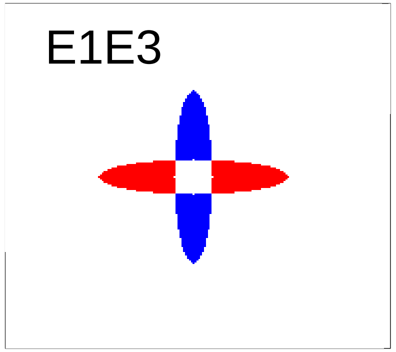
Δ = 17.98, H = 40.2
CD = 12.00,
MED(E3,E7) = 3.10
MED(E7,E3) = 12.01

Δ = 23.51, H = 40.2
CD = 0.00, MED(E1,E3)=MED(E3,E1) = 13.30

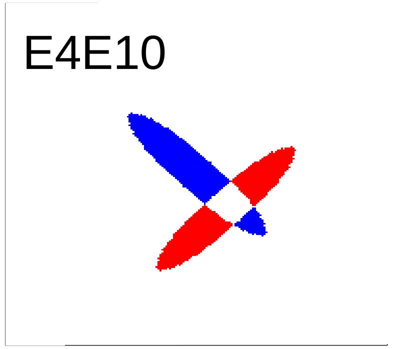








Δ = 22.53, H = 25.13
CD = 25.00,
MED(E1,E9)=MED(E9,E1) = 17.09



Δ = 32.16, H = 65.38
CD = 25.00, MED(E4,E10) = 14.08
MED(E10,E4) 20.76

SUMMARY

- SpatialVx (R package for performing many of the spatial methods; still in beta form—use at your own risk!)
- All test cases and other information (including preliminary results) available at MesoVICT web site (https://ral.ucar.edu/projects/icp/)
- Geometric cases help to identify strength and weaknesses of distance map measures
- New geometric cases available soon (paper in progress).