Computation of Source-to-site Distance Distributions for Seismic Hazard Analysis

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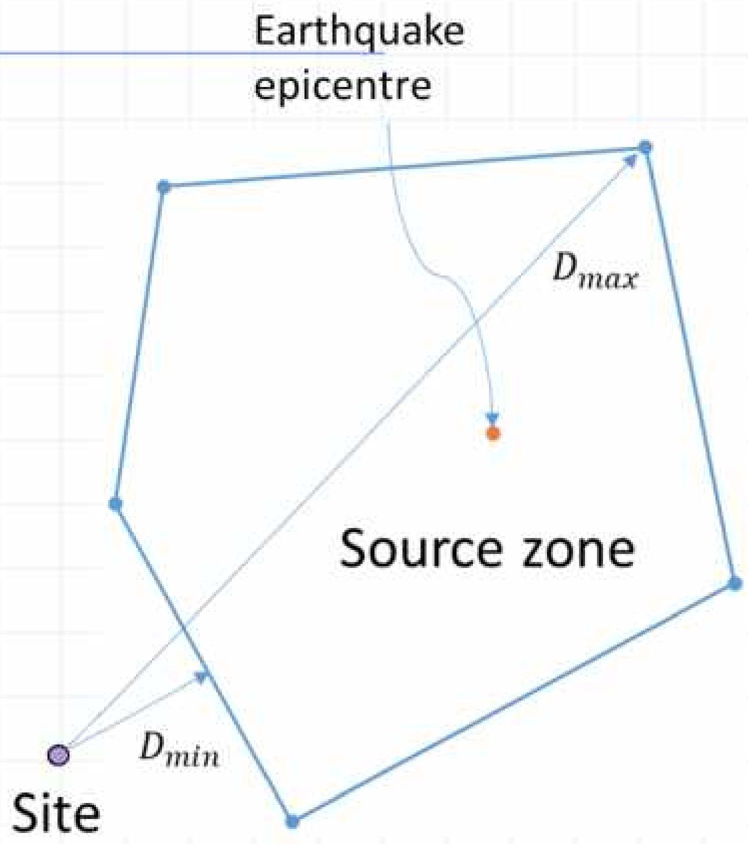
Introduction; problem statement

- An earthquake epicenter is equally likely to be anywhere inside a source zone (a region with uniform seismicity).
- When doing Seismic Hazard Analysis (SHA) for a particular site, the probability distribution of possible distances between the site and the epicentres is needed.
- An algorithm for computation of the probability distribution is proposed and verified.



$$P(D_{min} < D < D_{max}) = 1$$

$$P(D \approx D_i) = ? \quad (D_{min} < D_i < D_{max})$$

Computation method.
A. Generation of a point cloud

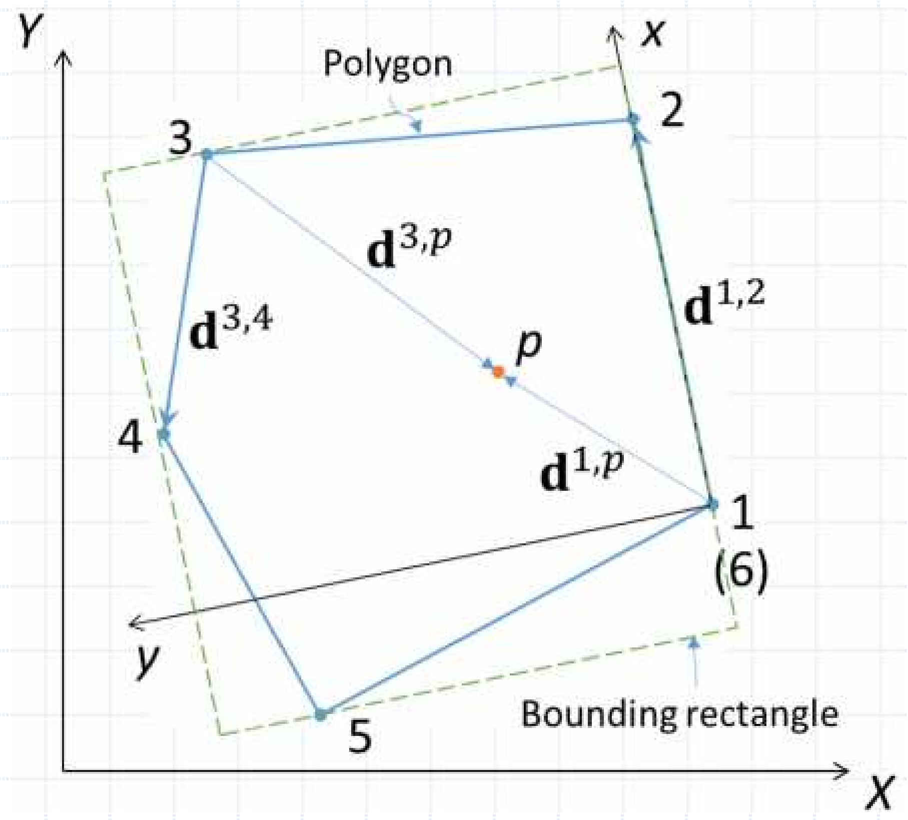
The Z component of

$$\mathbf{P} = \mathbf{d}^{i,p} \times \mathbf{d}^{i,i+1} \quad \text{is}$$

$$P_z = d_x^{i,p} \cdot d_y^{i,i+1} - d_y^{i,p} \cdot d_x^{i,i+1}$$

If it is negative for all vertices, then the point is inside the polygon.

The computation is carried out for points inside the bounding rectangle, and if the check is satisfied, the point is kept in the point cloud representing the polygon.



Computation method.
B. Distance probabilities

Compute the range width,

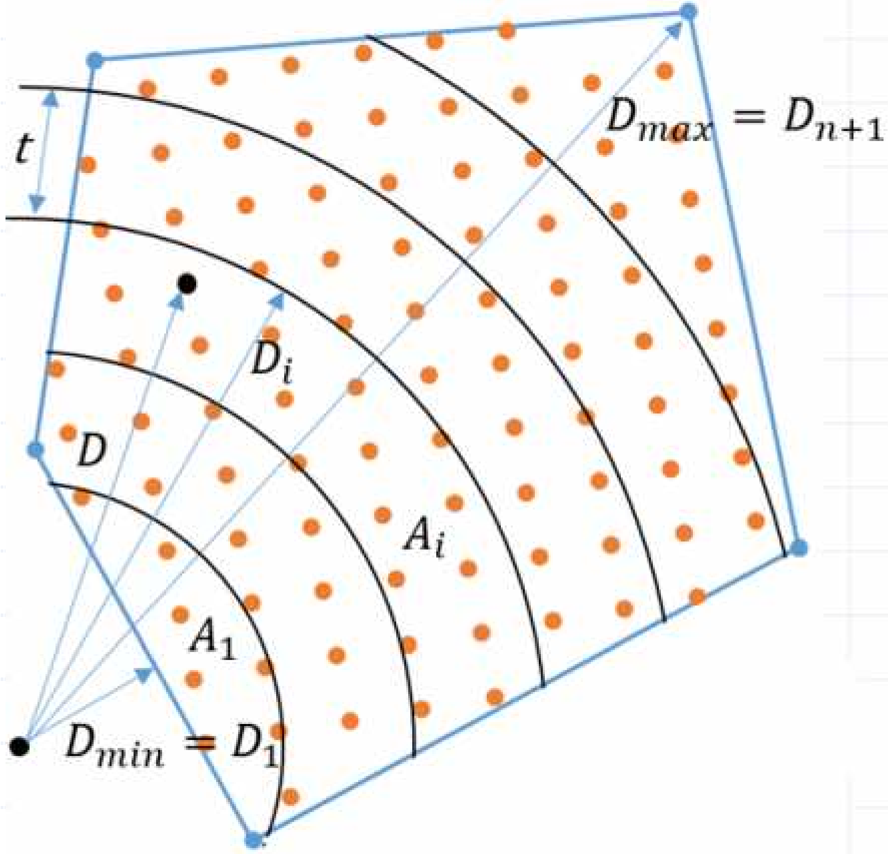
$$t = \frac{(D_{max} - D_{min})}{n}$$

where n is input and controls the resolution of the computation.

Compute the distance probabilities,

$$f_{D_i} = \frac{A_i}{A} = \frac{N_i}{N}$$

where N_i and N are the number of points inside a range and the total number of points respectively.



Verification and testing.
A. Circular zone, site at centre

Theoretical solution available,

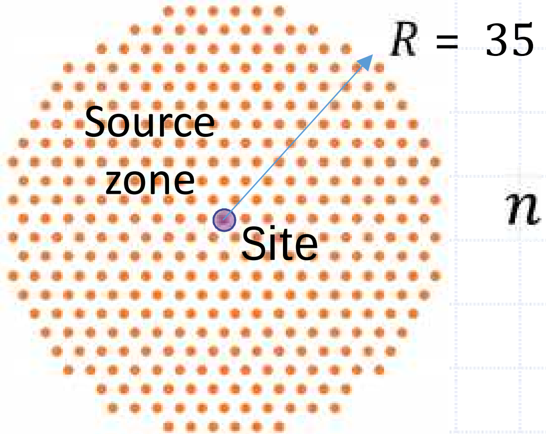
$$f_{D_i} = \frac{A_i}{A} = \frac{2i+1}{n^2}, i = 0 \ldots n-1$$

$n = 10$ for all analyses.

$10 \leq \rho \leq 100$ at step 10.

ρ is the density of packing (number of points along the shorter edge of the bounding rectangle). Both square and triangular packing are used.

An improved algorithm which allows fraction of a point to be counted towards a particular range is implemented as well.



Triangular packing

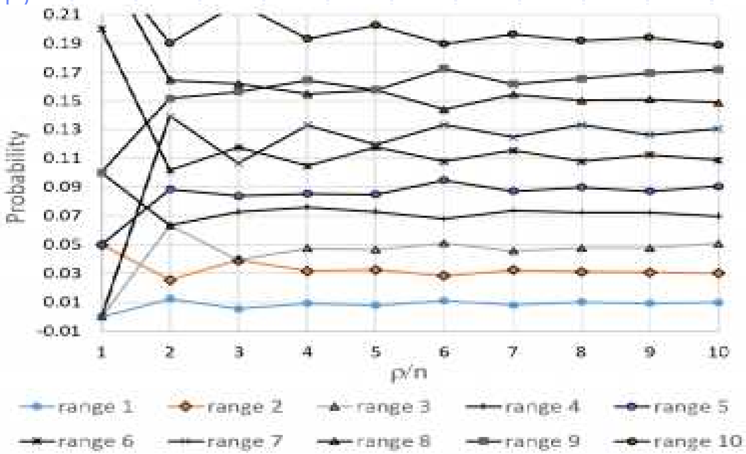
$n = 20$

Square packing

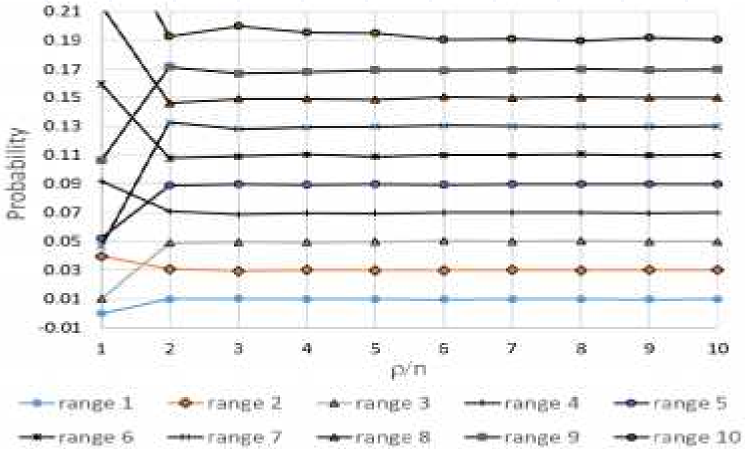
$n = 30$

Verification and testing.

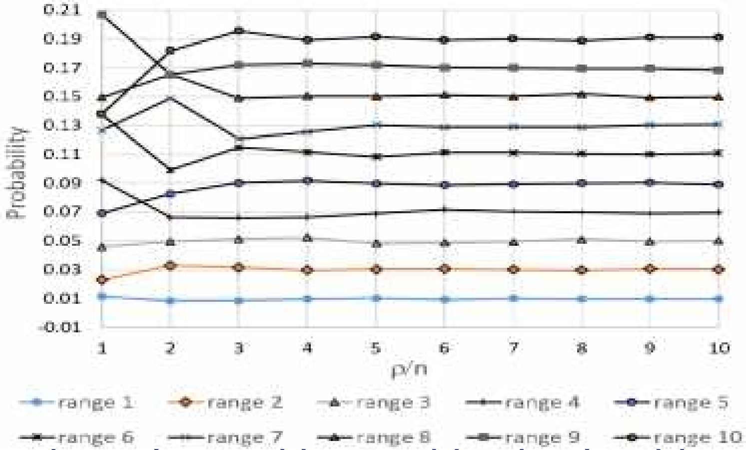
A. Results -probability f_{D_i}



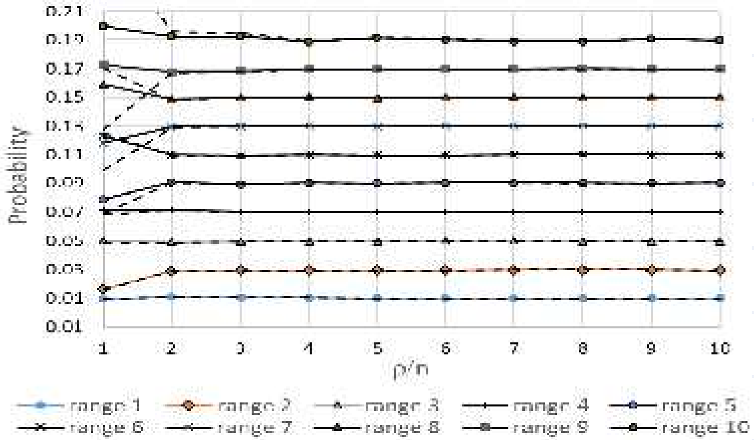
Square packing and basic algorithm



Square packing and improved algorithm



Triangular packing and basic algorithm

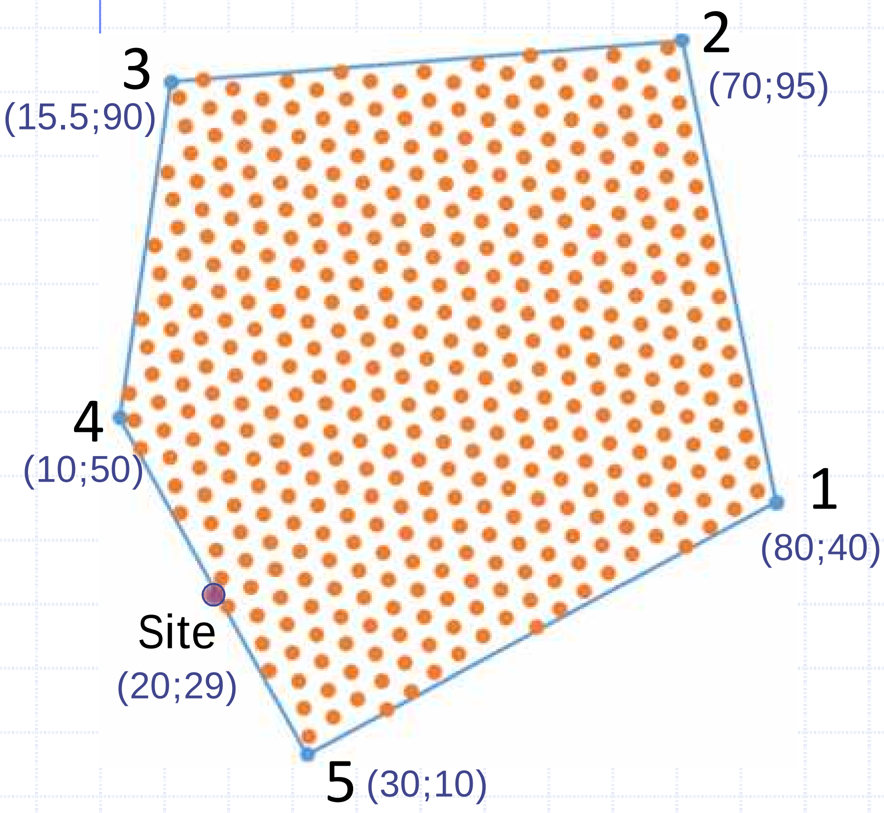


Triangular packing and improved algorithm

Verification and testing. A. Polygonal zone

$n = 10; \quad 20 \le \rho \le 100$

Two options for determining D_{min} and D_{max}: with or without using the vertex coordinates



Triangular packing only

Range No.	Probability	Difference relative to column 2 [%]					
		Ratio ρ/n, Polygon vertex coordinates used or not					
		10, Yes	6, Yes	2, Yes	10, No	6, No	2, No
	2	3	4	5	6	7	
1	0.0260	0.4	2.0	-7.0	-4.7	-33.4	
2	0.0762	0.0	0.1	-0.6	0.2	-2.9	
3	0.1171	-0.1	-1.7	0.9	1.1	0.7	
4	0.1231	-0.1	0.3	1.2	1.3	3.8	
5	0.1347	0.1	-1.0	1.3	1.6	2.7	
6	0.1476	-0.2	1.5	1.4	1.5	5.5	
7	0.1612	0.2	-0.7	1.5	1.9	3.7	
8	0.1353	0.0	0.2	-1.5	-2.3	-2.2	
9	0.0607	0.3	-0.1	-3.4	-4.5	-5.5	
10	0.0181	-0.9	5.5	-13.7	-18.9	-32.2	

Conclusions

- An algorithm for computation of source-to-site distance probability distributions for SHA is proposed and verified;
- Triangular packing leads to faster convergence compared to square packing;
- An improved algorithm, considering fractions of points contributing to the number of points inside a distance range leads to faster convergence;
- A combination of triangular packing, use of vertex coordinates and ratio $\rho/n > 2$ would be sufficient for practical purposes.