

Name: [Random Point Generator 1.3](#)

AKA: randpts.avx

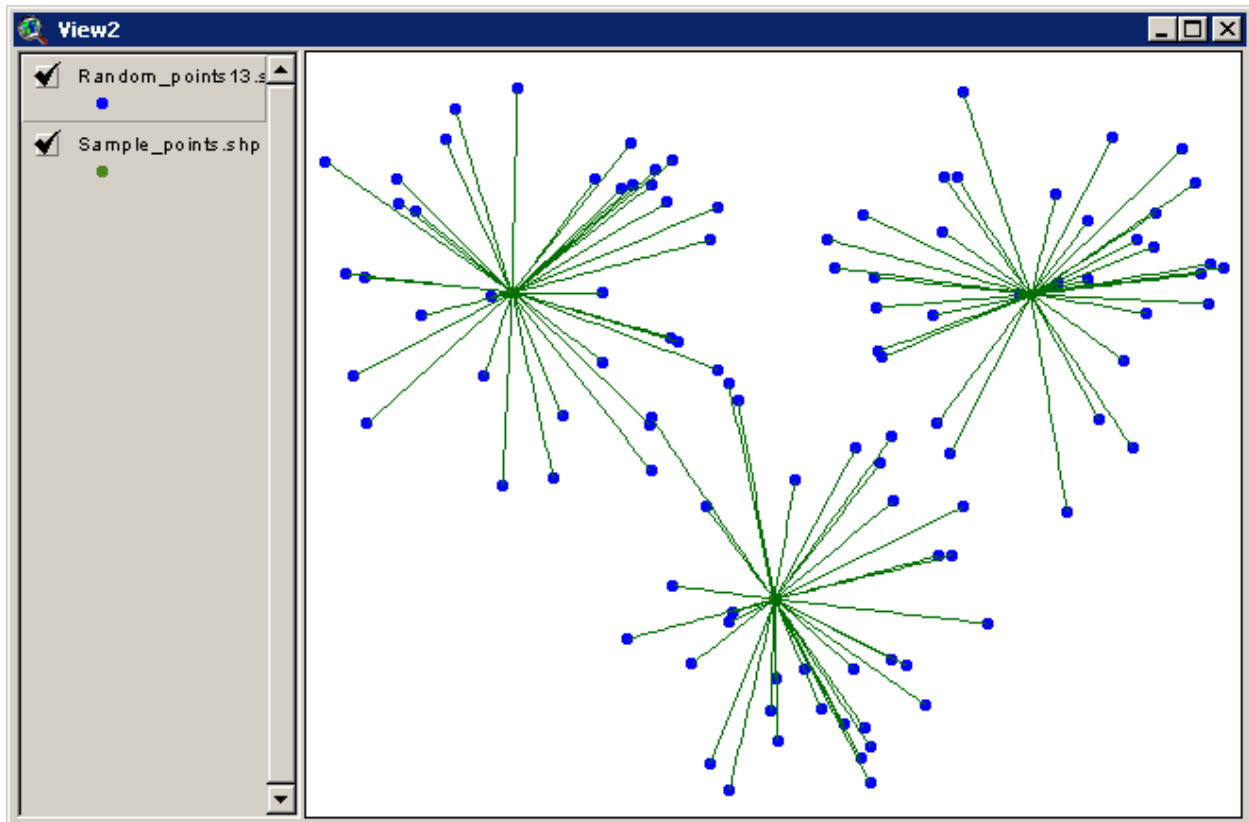
Last Modified: February 7, 2005



Topics: ArcView 3.x, Random Point, View, Analysis, Tools, Statistics, Point, Line, Polygon, Extent, Select

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Description: This extension enables you to generate a set of random points within a specified distance of a set of input features (points, lines or polygons). You can also generate a set of random points within the extent of any particular theme, the extent of all themes, or the extent of the display. This is a useful tool when trying to determine random sampling locations to compare to some feature or set of features.



All or Only Selected Features: You can generate random points based on every feature in the Input theme or only a selected subset of those features. If any features in the theme are selected, then only those selected features in that theme will be used in the analysis. If no features in that theme are selected, then random points will be generated with respect to all features in that theme. Alternatively, you can generate a specified number of random points within the rectangular extent of any of the themes, within the extent of all the themes combined, or within the Display extent.

Variable Numbers of Random Points: If you choose to generate random points based on features in an input theme, then you have the option to generate a constant number of random points for each feature or a variable number based on values in the attribute table.

Set Minimum Distance Between Points: You have the option to set a minimum separation distance between your random points. If you generate random points along a line, you have the option to set a minimum separation distance along the line as well as a separation in 2-dimensional space.

Projected vs. Unprojected Views: If your original data are in Lat/Long coordinates (the Geographic Projection) and your View has been projected, then you have the option of calculating Output data based on either the Geographic Projection or the your View Projection. If your view is projected, and you choose to create a new shapefile in the View projection, the new shapefile will only be saved to the hard drive and it will not be added to the view.

Output: You have the option to create a RESULTS table containing attributes of the random points or a new shapefile of the random points. In either case, you have the option to include various fields in your output table, including the name of the input theme, the ID of the input feature, the X- and Y-Coordinates of the random points, and (when the Input theme is a Point theme), the Distance and Bearing from the Input point to the Random point.

Randomly Select Features or Records: Randomly select points, lines or polygons from a feature theme, or records from a table. If selecting features from a feature theme, you also have the option to set a minimum separation distance.

Recommended Citation Format: For those who wish to cite this extension, the author recommends something similar to:

Jenness, J. 2005. Random point generator (randpts.avx) extension for ArcView 3.x, v. 1.3. Jenness Enterprises. Available at: http://www.jennessent.com/arcview/random_points.htm.

Please let me know if you cite this extension in a publication. I will update the citation list to include any publications that I am told about.

Requires: This extension requires that the file "avdlog.dll" be present in the ArcView/BIN32 directory (or \$AVBIN/avdlog.dll) and that the Dialog Designer extension be located in your ArcView/ext32 directory, which they usually are if you're running AV 3.1 or better. The Dialog Designer doesn't have to be loaded; it just has to be available. If you are running AV 3.0a, you can download the appropriate files for free from ESRI at:

http://support.esri.com/index.cfm?fa=downloads_patchesServicePacks.viewPatch&PID=25&MetalD=483

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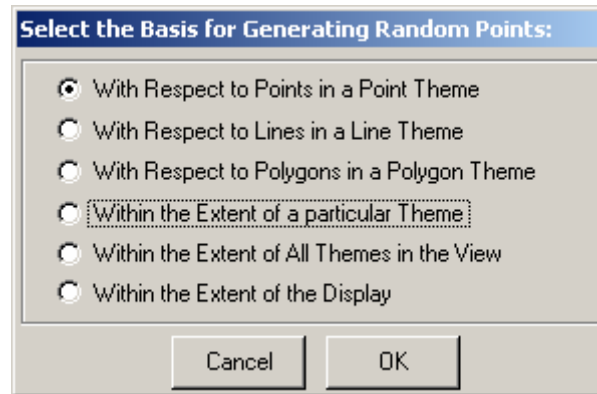
General Instructions:

1) Begin by placing the "randpts.avx" file into the ArcView extensions directory (../Av_gis30/Arcview/ext32/).

2) After starting ArcView, load the extension by clicking on **File --> Extensions...**, scrolling down through the list of available extensions, and then clicking on the checkbox next to the extension called "Random Point Generator"

3) From a View, select the  button from the View Button bar.

4) **Select the Location Basis for your Random Points:** You may generate random points based on a specified proximity to a set of input features (points, lines or polygons), or within the rectangular extent of a particular theme, the set of all themes, or the display.



Depending on which option you choose, you will then be taken to a new window where you will select more options related to that choice. You might see some of these options grayed out, so that you can't select them. This extension will check to see if you actually have any Point, Line or Polygon themes in your view before it makes that option available.

5a) If you select "With Respect to Points in a Point Theme": You will see the following dialog box illustrating your options for generating random points based on points within a Point theme.

First select the Point Theme you wish to use and pick an ID field that contains values that individually identify each point in your Point theme. This ID field is only important if you wish to know which specific Input point the Random point is related to. If knowing that is not important to you, then pick any field.

Next enter the number of random points you want to generate for each Input point. You have the option to specify a constant number of random points for each Input point, or a variable number based on values in the Input theme attribute table. If you choose to generate a variable number of random points, then you will need to pick the appropriate field from the drop-down box.

Next enter the maximum distance you want the random points to be from their respective Input points. The distance must be in Map units, which are the units of your coordinate system and are the units of the X/Y coordinates in the upper right corner of your View.

If you wish to have a minimum separation distance between your random points, check this option and enter in the minimum distance you would like to use. Keep in mind that this minimum distance forces an order on the points, so larger separation distances reduce the randomness.

Next, decide which output fields you want included in your RESULTS table and/or your Shapefile Feature Attribute Table. Lastly, decide whether you want your output to be a RESULTS table, a Shapefile, or both.

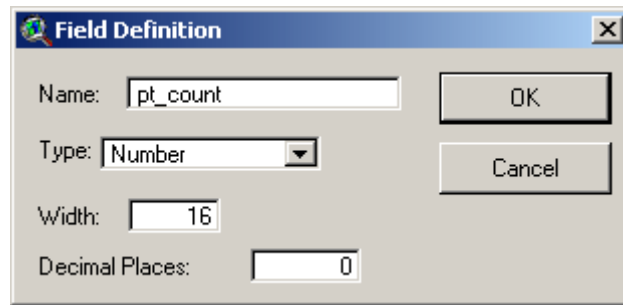
5b) If you select "With Respect to Lines in a Line Theme": You will see the following dialog box illustrating your options for generating random points based on lines within a Line theme.


First select the Line Theme you wish to use, and pick an ID field that contains values that individually identify each line in your Line theme. This ID field is only important if you wish to know which specific Input line the Random point is related to. If knowing that is not important to you, then pick any field.

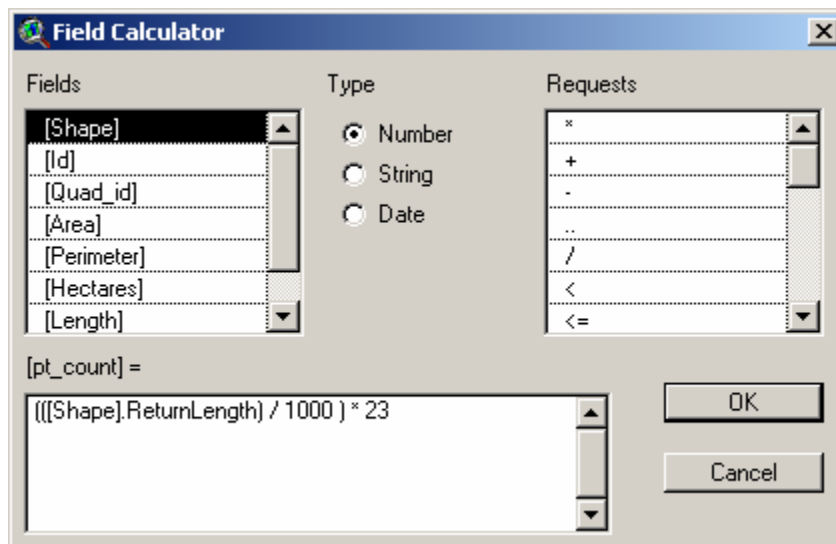
Next enter the number of random points you want to generate for each Input line. You have the option to specify a constant number of random points for each Input line, or a variable number based on values in the Input theme attribute table. If you choose to generate a variable number of random points, then you will need to pick the appropriate field from the drop-down box.

Generating random points at a particular density: If you wish to generate random points along all your lines such that the average density of all the points is equal to, for example, 23 points per kilometer, then you can do so with a little preparation.

- 1) Open your polyline attribute table and set it to "Editable" by clicking the "Table" menu item, then "Start Editing".
- 2) Add a numeric field to your attribute table that will contain the number of random points you want to generate along each line. For this example, we'll call the new field "pt_count":



- 3) Select your new field by clicking on the field name, then click the Calculator button  to open the Calculator window and enter the following Calculate string (this example assumes that your map units are in meters):



- 4) The calculation string " $(([\text{Shape}].\text{ReturnLength}) / 1000) * 23$ " can be understood as follows. The "ReturnLength" request calculates the length of each polyline. Assuming this length is in meters, the value is then divided by 1000 to get the length in kilometers. This length is then multiplied by 23 to get the number of points necessary to produce an average density of 23 points per kilometer. **IMPORTANT:** Make sure none of your polylines are selected before making this calculation! If any polylines are selected, then only those selected polylines will be calculated.
- 5) Then, when you run the Random Point generator, just choose the "Use Values from Field" option and pick the "pt_count" field.

Next enter the maximum distance you want those points to be from their respective Input lines, or click the "Random points located on lines" option if you want them to lay directly on the lines. Any distance values must be in Map units, which are the units of your coordinate system and are the units of the X/Y coordinates in the upper right corner of your View.

If you wish to set a minimum distance between random points, you can do so by either setting a separation distance along the line or in any direction on the X/Y plane. You can also set both options if you wish. Keep in mind that setting a minimum distance will automatically impose order on the arrangement of points and therefore reduce their randomness.

Next, decide which output fields you want included in your RESULTS table and/or your Shapefile Feature Attribute Table. Lastly, decide whether you want your output to be a RESULTS table, a Shapefile, or both.

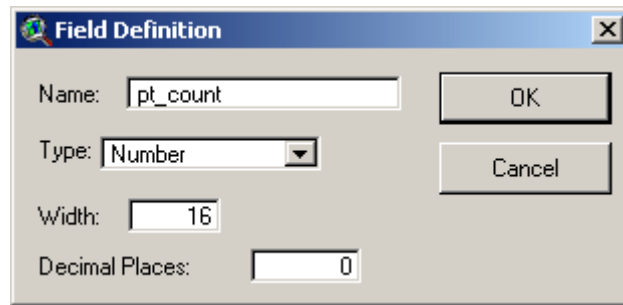
5c) If you select "With Respect to Polygons in a Polygon Theme": You will see the following dialog box illustrating your options for generating random points based on polygons within a Polygon theme.


First select the Polygon Theme you wish to use, and pick an ID field that contains values that individually identify each polygon in your Polygon theme. This ID field is only important if you wish to know which specific Input polygon the Random point is related to. If knowing that is not important to you, then pick any field.

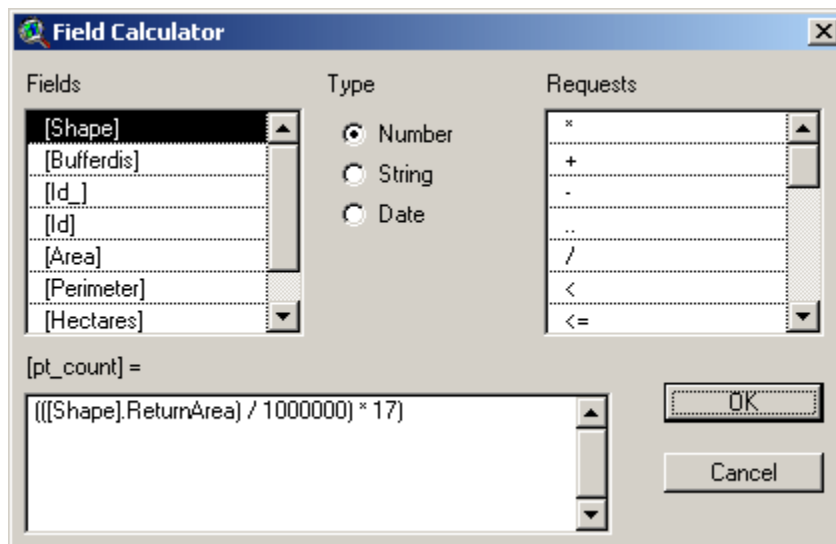
Next enter the number of random points you want to generate for each Input polygon. You have the option to specify a constant number of random points for each Input polygon, or a variable number based on values in the Input theme attribute table. If you choose to generate a variable number of random points, then you will need to pick the appropriate field from the drop-down box.

Generating random points at a particular density: If you wish to generate random points within your polygons such that the average density of all the points is equal to, for example, 17 points per square kilometer, then you can do so with a little preparation.

- 1) Open your polyline attribute table and set it to "Editable" by clicking the "Table" menu item, then "Start Editing".
- 2) Add a numeric field to your attribute table that will contain the number of random points you want to generate along each line. For this example, we'll call the new field "pt_count".



- 3) Select your new field by clicking on the field name, then click the Calculator button  to open the Calculator window and enter the following Calculate string (this example assumes that your map units are in square meters):



- 4) The calculation string " $(([\text{Shape}]. \text{ReturnArea}) / 1000000) * 17$ " can be understood as follows. The "ReturnArea" request calculates the area of each polygon. Assuming this area is in square meters, the value is then divided by 1000000 to get the area in square kilometers. This value is then multiplied by 17 to get the number of points necessary to produce an average density of 17 points per square kilometer. **IMPORTANT:** Make sure none of your polygons are selected before making this calculation! If any polygons are selected, then only those selected polygons will be calculated.
- 5) Then, when you run the Random Point generator, just choose the "Use Values from Field" option and pick the "pt_count" field.

Next enter the maximum distance you want those points to be from their respective Input polygons. The distance must be in Map units, which are the units of your coordinate system and are the units of the X/Y coordinates in the upper right corner of your View. You have three options regarding the position of the points in relation to the polygon edge:

- 1) *Inside polygons, at least X units from polygon edge:* This forces the random points to be inside the polygon within a specified distance from the edge. If you wish your points to potentially appear anywhere within the polygon, including right next to the edge, then enter a "0" value here.
- 2) *Outside polygons, within X map units from polygon edge:* This forces the random points to be outside the polygon within a specified distance from the edge.

- 3) *Inside polygons, or outside within X map units from polygon edge:* This option forces the random points to be either anywhere within the polygon, or outside the polygon within a specified distance from the edge.

Next, decide which output fields you want included in your RESULTS table and/or your Shapefile Feature Attribute Table. Lastly, decide whether you want your output to be a RESULTS table, a Shapefile, or both.

5d) If you select "Within the Extent of ...": You will see the following dialog box illustrating your options for generating random points within some rectangular extent.

Random Points within Extent:

Random Points will be generated within the Rectangular Extent enclosing the selected Theme(s). Use the [SHIFT] key to select multiple themes.

Random_points18.shp
Random_points17.shp
Random_points6.shp
Random_points4.shp

Number of Points: 500

Output Format:
☒ New Shapefile
☐ RESULTS Table

Minimum Distance Between Points:
☐ Set minimum distance between points?
Minimum Distance = map units

Back Cancel OK

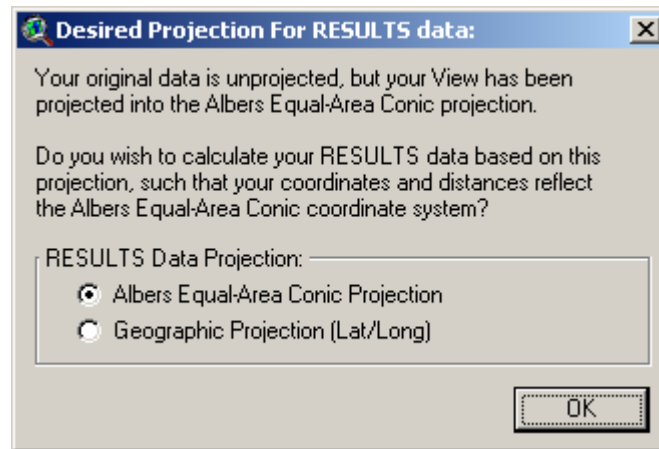
If you select "Within the Extent of a particular Theme", you will need to select the theme you want to use from the list of themes. Otherwise this list box will be inactive and you will see either "Extent of All Themes" or "Extent of Display" entered in it.

Next enter the number of random points you want to generate within your selected extent, and whether you want your output to be a RESULTS table, a Shapefile, or both. Regardless of your output format, you will have four attribute fields in your table:

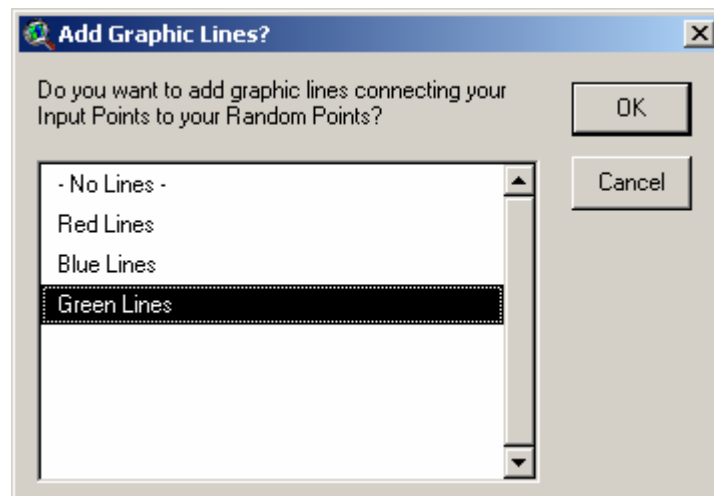
- 1) *In_Theme:* If you chose to generate random points within the extent of a particular theme, this field will contain the name of that theme (or the words "Multiple Themes" if you selected more than one theme). Otherwise it will contain either the words "All Themes" or "Display Extent", depending on your choice.
- 2) *Point_ID:* This field assigns a unique numerical value to each random point.
- 3) *X-Coordinate:* The X-Coordinate of the random point, in Map Units.
- 4) *Y-Coordinate:* The Y-Coordinate of the random point, in Map Units.

If you wish to specify a minimum separation distance between random points, check this option and enter your distance in the box provided. Keep in mind that setting a minimum distance forces an order on the points so that higher separation distances lead to less randomness.

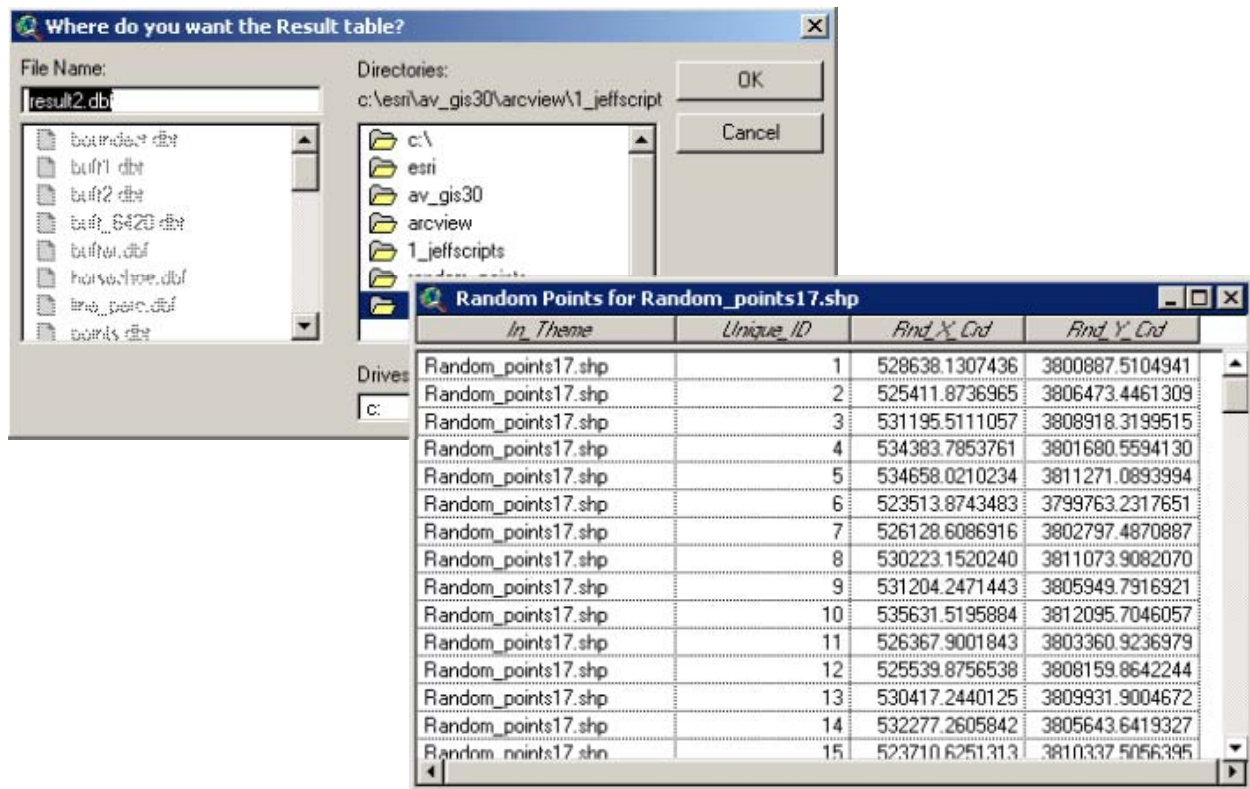
6) Select Projection for RESULTS data: At this point, you may possibly be asked what projection should be used to calculate the RESULTS data. This option only applies if your original polygons are in Latitude/Longitude coordinates (i.e. the "Geographic" or "Unprojected" projection) and your View is set to some user-specified projection. In this case you have the option of generating random points with Lat/Long coordinates or coordinates from your View projection.



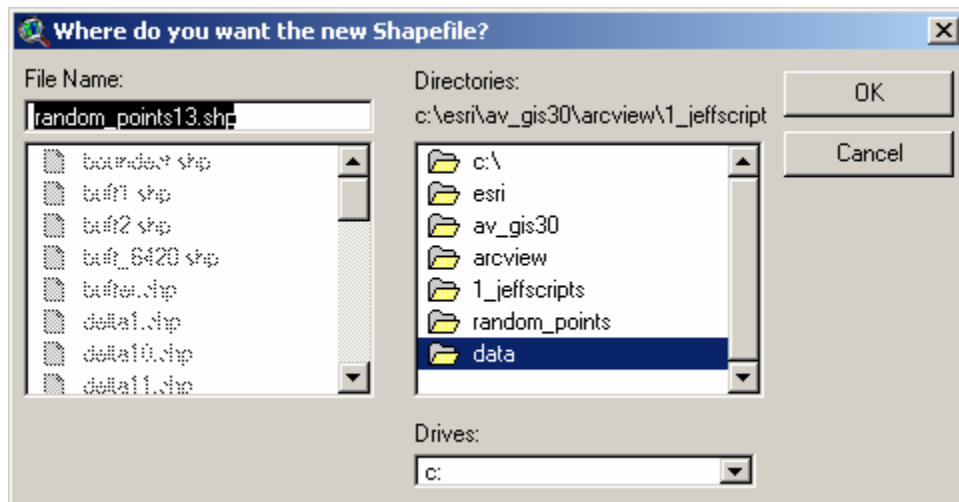
7) Add Graphic Connection Lines: You may have the option to create a graphic line on your view that connects your Input point to your Graphic Point. You will be given this option if your input theme is a Point theme, you select "Shapefile" as one of your output formats, and if the shapefile can be displayed in the view (i.e. if it is in the same coordinate system). You can choose from a small number of line colors to display this line.



8) Specify Hard Drive Location to save the RESULTS table: If you choose "RESULTS Table" as your output format, you will be prompted to specify a location on the hard drive to save the table. This is a standard ArcView Dialog Box and should be familiar to most users. This table is a permanent table and will not be deleted when ArcView is shut down.




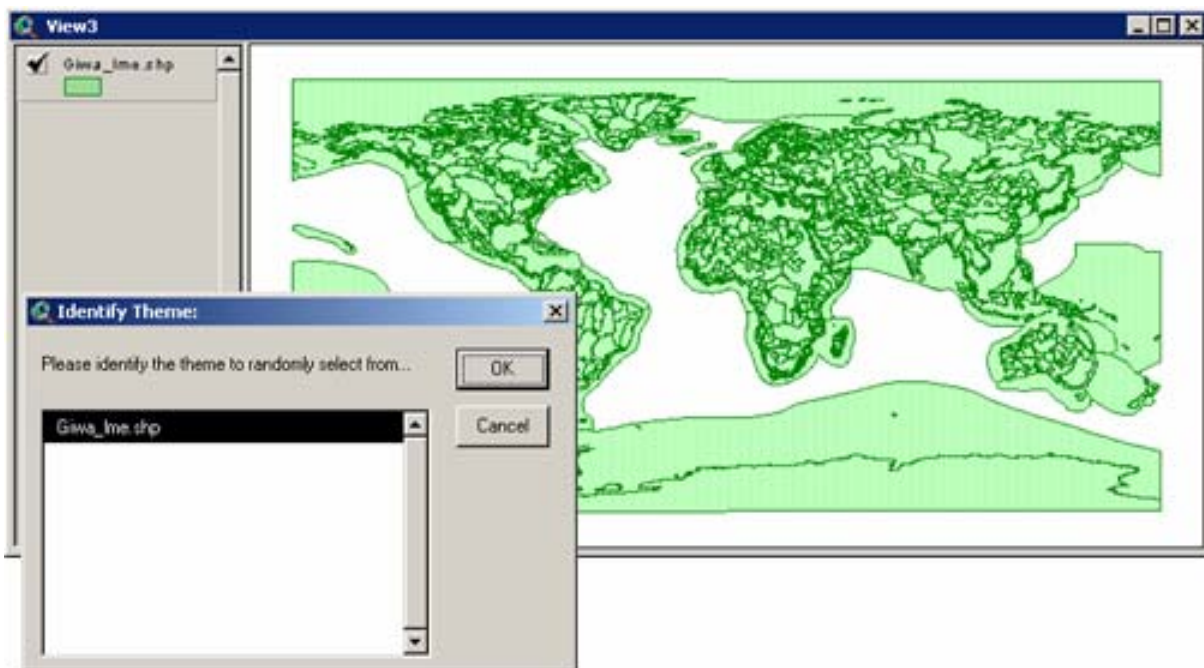
9) Specify Hard Drive Location to save Shapefile: If you choose "Shapefile" as your output format, you will be prompted to specify a location on the hard drive to save the shapefile. This is a standard ArcView Dialog Box and should be familiar to most users. This shapefile is a permanent shapefile and will not be deleted when ArcView is shut down.



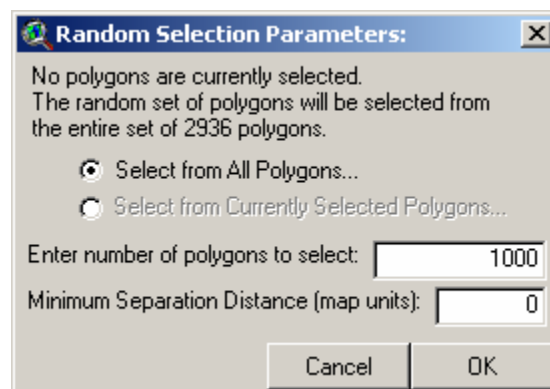
Randomly Selecting Features or Records

This extension also allows you to select random features from a feature theme or records from a table.

Click the  button from either the View or Table button bar to start the process. If you are randomly selecting features from a theme in a view, you will first be asked to identify your theme:

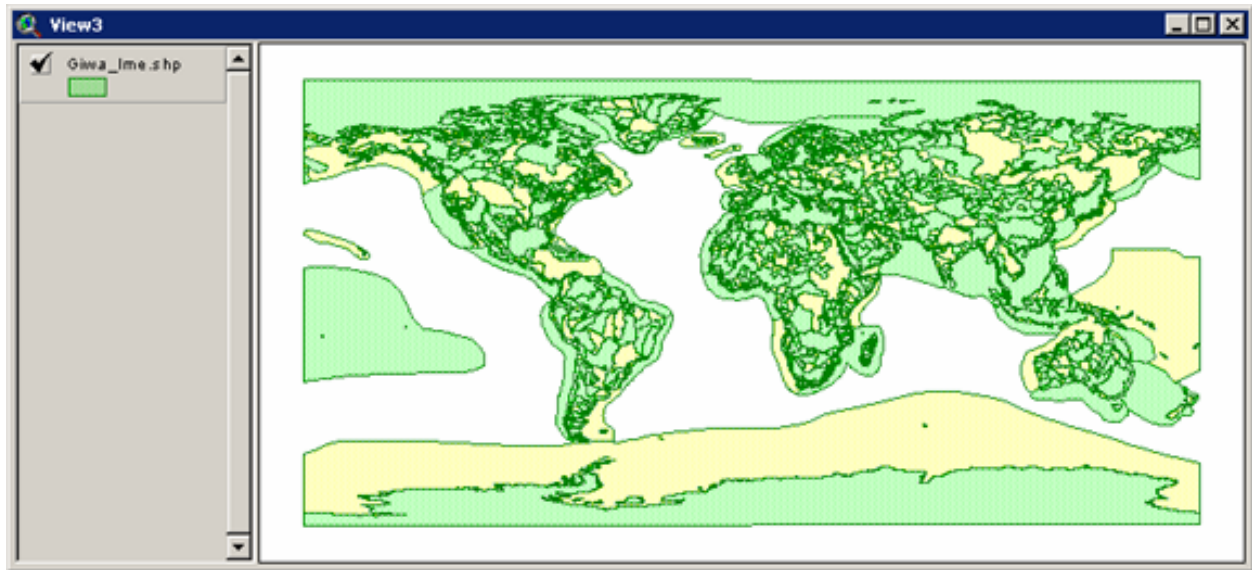


Next, specify how many features or records you would like to randomly select. If you have any features currently selected, you will have the option to restrict your random selection to that current selection. You also have the option to set a minimum separation distance between randomly selected features:



NOTE: Complex polygons and polylines can cause this extension to run slowly if you set a minimum separation distance > 0. In the example above, on the author's computer, selecting 1000 random polygons with a minimum separation distance of 0 took 2 seconds. Attempting to select 1000 random polygons with a minimum separation distance of 1 took 14 minutes, and only 819 were able to be selected. Setting a minimum separation distance between points does not increase the time very much. If it is taking too long and you need to manually terminate the process, click the "Stop" button in the bottom right corner of the ArcView window.

Click 'OK' and the features or records will be randomly selected:



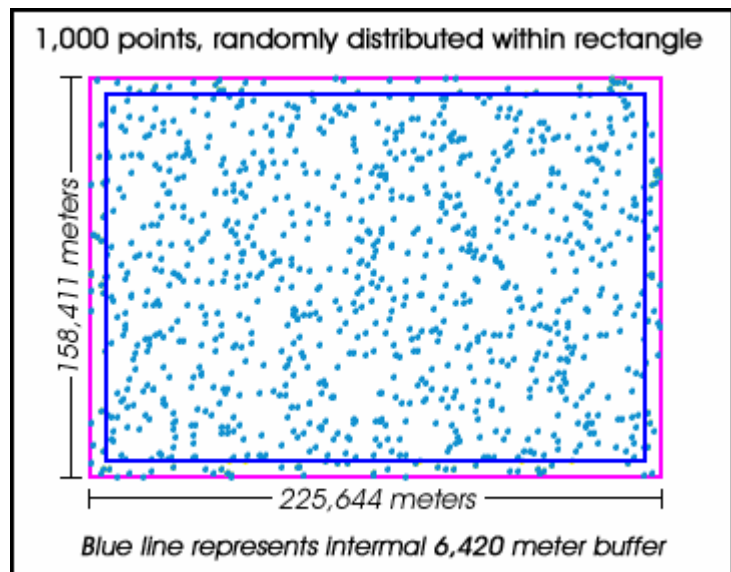
Tests of Randomness

The author ran the following tests of randomness using the Random Point Generator v. 1.1, with ArcView 3.2 on a Windows 95 operating system. CAUTION: ESRI includes the following warning regarding the MakeRandom request on UNIX systems: "*UNIX systems base MakeRandom on the system service rand() which is not a great random number generator (see man pages for details).*" The author doesn't know exactly what types of problems UNIX has with random numbers, but users should be aware of potential non-randomness with this extension if they use UNIX systems.

Randomness of Points within Polygons:

This test reflects the randomness of the distribution of points within or around polygons, near lines, or within a specified distance of points, assuming no minimum separation distance. To test the randomness, I created a rectangle measuring approximately 158,000 by 256,000 meters and generated 1,000 random points within it:

I checked for a random distribution using a basic Nearest Neighbor point pattern analysis as described by Lee and Wong (2001; p. 72-77) and Boots and Getis (1988). I calculated the distance from each point to its nearest neighbor, and the distance from each point to the polygon edge, using the [Nearest Features v. 3.4](#) ArcView extension (Jenness 2001). I adjusted for boundary effects by drawing an internal buffer area and only conducting the Point Pattern Analysis on those points that lay within the smaller internal rectangle, and adjusting my sample area to reflect the buffered rectangle (Boots and Getis 1988; p. 40-42). I selected a buffer size by identifying all those points who were closer to the rectangle boundary than they were to their nearest neighbor, and then determining the maximum point-to-rectangle distance of this subset of points (6,418 meters) and rounding that up to 6,420 meters. This process ensured that all the nearest neighbor distances for the points used in the analysis truly reflected the distance to the nearest neighbor. This left 872 points for the analysis.



I calculated the mean and standard deviation of nearest neighbor distances for all of the 872 points in the sample, and the mean nearest neighbor distance of a perfect random distribution of 872 points within the same area. Using these values, I computed an *R*-score, a *Z*-score and *P*-value to describe the randomness of the distribution:

Average Nearest Neighbor Distance:

$$\overline{NND} = \frac{\sum NND}{n} = \frac{2,573,535.5}{872} = 2,951.3022$$

Perfectly Random Nearest Neighbor Distance:

$$\overline{NND}_R = \frac{1}{2\sqrt{\text{Density}}}, \text{ where}$$

$$\text{Density} = \frac{n}{\text{Area}} = \frac{872}{30,978,269,233} = 2.814876 \text{ e}^{-8}$$

$$= 2,980.1652$$

Clustered vs. Dispersed: *R*-score

$$R = \frac{\overline{NND}}{\overline{NND}_R} = .990315$$

Nearest Neighbor Distance Standard Error:

$$SE_{\overline{NND}} = \frac{0.26136}{\sqrt{n(\text{Density})}} = 52.753492$$

Test Statistic: *Z*-score

$$Z = \frac{\overline{NND} - \overline{NND}_R}{SE_{\overline{NND}}} = -0.547130$$

***P*-value for *Z* = - 0.547130:**

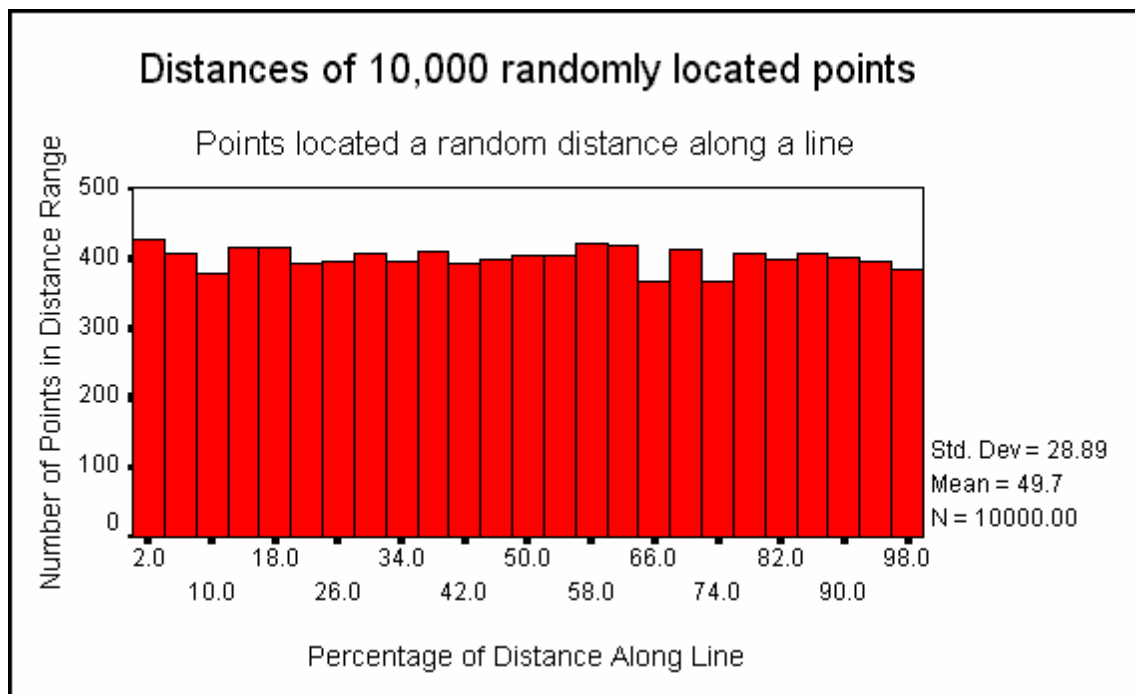
$$P = 0.2921 \text{ (SPSS 9.0, 1999)}$$

The *R*-score < 1 indicates that the distribution of points leans very slightly toward a clustered pattern, but the *P*-value of 0.2921 indicates that this trend is not statistically significant. In other words, these points do appear to be randomly distributed.

Randomness of Points along a Line:

This test reflects the randomness of the distribution of points that lie along lines. To test the randomness, I generated 10,000 random points along a sample line. I took the percentage of each point along the line, where a point at the beginning of the line would have a value of 0% and a point at the end of the line would have a value of 100%. This gave me 10,000 values ranging from near 0% to near 100%.

I make the assumption that, if these points are truly randomly distributed along the line, then they must follow a uniform distribution. In other words, there must be approximately the same number of points lying within the first 10% of the line as there are within all other 10% sections of the line. I used SPSS 9.0 to conduct a Kolmogorov-Smirnov test (aka the KS or "Vodka" test) to see if the points followed a Uniform distribution.



One-Sample Kolmogorov-Smirnov Test		
Statistics		Distance Measures
N		10000
Uniform Parameters ^{a, b}	Minimum	.0000000
	Maximum	99.9938965
Most Extreme Differences	Absolute	.007
	Positive	.007
	Negative	-.001
Kolmogorov-Smirnov Z		.702
Asymp. Sig. (2-tailed)		.709

a. Test distribution is Uniform.

b. Calculated from data.

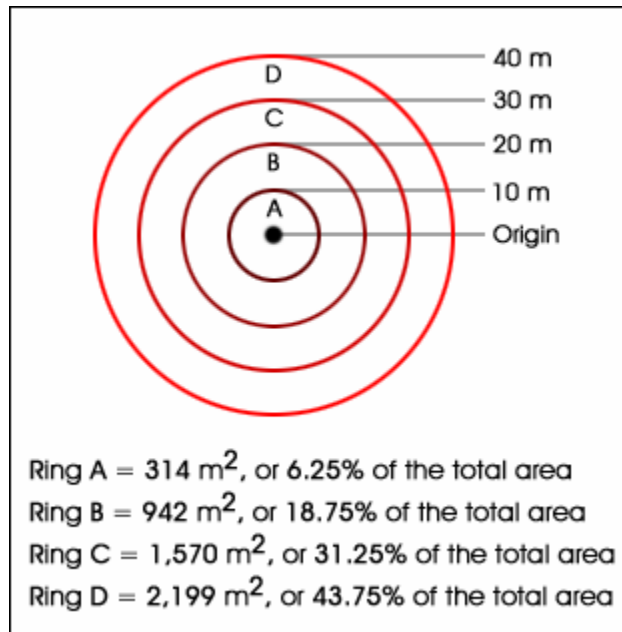
(Calculated with SPSS 9.0)

The *P*-value of 0.709 indicates that the distribution of these 10,000 points is not significantly different than a uniform distribution, and therefore these points are randomly distributed along the line.

Important Note regarding Random Points around a Central Point:

This note is intended for those who, like myself, used to determine the location of a random point by taking a random distance and bearing from the origin point. Personally, I used to stand at the origin, spin a compass dial once to get the number of paces, and then spin it again to get the bearing. If you are interested in selecting a random point in which all possible points within a particular distance of the origin have the same chance of getting picked, then this method DOES NOT WORK. Random points selected by this method tend to cluster near the origin.

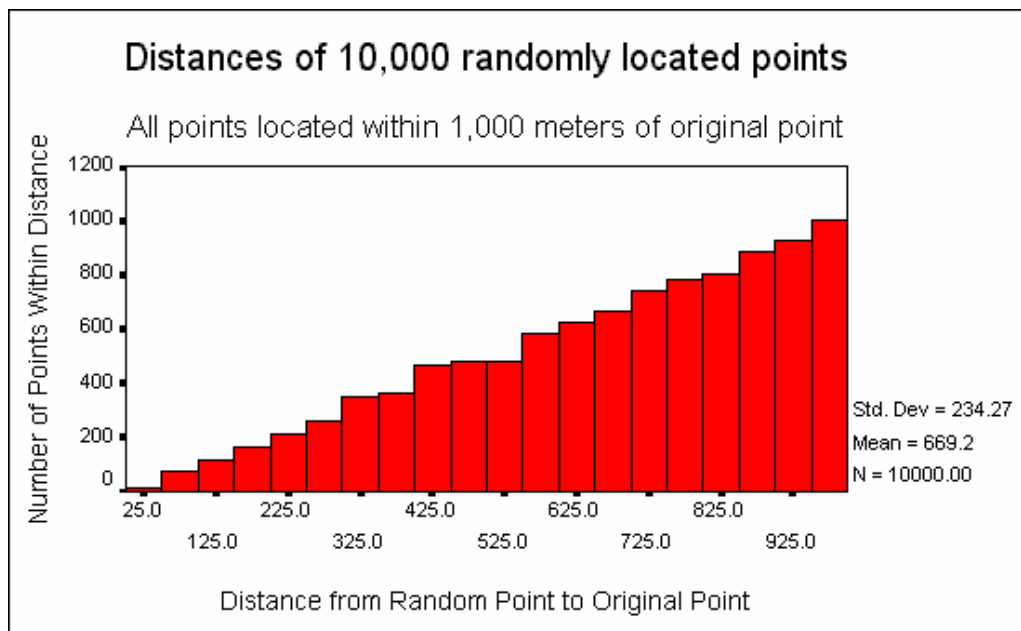
The problem is that this method randomly selects distances, but these different distances do not reflect equal land areas. The following illustration shows a situation in which random points are to be generated within 40 meters of an origin point. There are four rings surrounding the origin point, representing 10-meter increments in distance from the origin:



If you select a random bearing and then a random distance between 0m and 40m, then each ring has the same 25% chance of receiving the point. However, the rings do not represent equal proportions of the total area available for the point. For example, each random point has a 25% chance of landing in Ring A, but Ring A only comprises 6.25% of the total area available to the point. Therefore approximately 25% of all random points generated by this method will be clustered within the 6.25% of the potential area nearest the origin. By the same token, 25% of all random points generated with this method will also be dispersed within the 43.75% of the potential area represented by the outermost ring.

This Random Point Generator extension does not use random bearings and random distances to generate random points around a central point. This extension generates random points within an area by generating random X- and Y-coordinates within the extent of the feature, then combining those coordinates to make a point. This method produces reliably random distributions of points (see description of *Random Points within a Polygon* above).

If you generate random points by taking random bearings and distances, then your distance values will have a uniform distribution because those values will be truly random. A histogram of these values will look similar to the histogram of *Distances Along a Line*, from the description of *Random Points along a Line* above. A truly random set of points, however, will have a very different distribution of distances. The following histogram illustrates the distribution of origin-to-point distances of 10,000 points randomly generated within 1,000 meters of an origin point, and shows that the numbers of points within each distance increment should increase proportionally with the distance from the origin:



References:

Boots, Barry N. and Getis, Arthur. 1988. Point pattern analysis. SAGE Publications. Newberry Park, California, USA. 92 pp.

Jenness, Jeff S. 2001. Nearest Features v. 3.4 - ArcView Extension for determining distances to nearest features. Available for review and download at http://www.jennessent.com/arcview/nearest_features.htm.

Lee, Jay and Wong, David W. S. 2001. Statistical analysis with ArcView GIS. John Wiley and Sons, New York, New York, USA. 192 pp.

SPSS, Inc. 1998. SPSS For Windows. Version 9.0. 444 North Michigan Avenue, Chicago, IL, USA, 60611:

Updates:

V. 1.1: Improves the randomization procedures for points along lines and includes a work-around for a bug in the Avenue MakeRandom request that occurs when generating random numbers within a small range of values (both improvements suggested by Bill Huber). This update also adds a unique numeric ID to each random point, removes the "Shape" field from the ID Field List (so users won't inadvertently select the "Shape" field as the Input Theme ID field), and updates the progress meter to include a clock with the current time.

V. 1.23 - Aug. 3, 2003: Allows you to specify a minimum separation distance between random points.

V. 1.24 - Aug. 25, 2003: Allows you to specify the number of random points generated for each feature in a point, line or polygon theme based on a value in the attribute table. Also modified the code to add a point theme to your view regardless of the projection you choose.

V. 1.27 - Nov. 4, 2003: Provides tools to randomly select features or records.

V. 1.28 repairs a bug in which random points generated within polygons, with a minimum separation distance, might reach a saturation point too quickly.

V. 1.3 (February 7, 2005) adds the option to set a minimum separation distance between randomly selected features.

Enjoy! Please contact the author if you have problems or find bugs.

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Updates to this extension and an on-line version of this manual may be viewed at:

http://www.jennessent.com/arctview/random_points.htm

Please visit *Jenness Enterprises* [ArcView Extensions](#) site for more ArcView Extensions and other software by the author.

