Spatial Properties of Lineaments Using a Computer Software

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Abstract: An interactive software, *Spatial Analysis of Lineaments*, has been developed, that calculates the spatial properties azimuth, length, spacing, and unidirectional frequency of lineaments, provided that the starting and end coordinates of the lineaments are given. The software accepts a large number of lineaments. The different statistical properties are derived in series of steps and spatial outliers are removed in an interactive way. The software allows the user to sub-divide the azimuth group in to two or more if necessary. The nearest lineament is found based on the rules developed by Ekenligoda, & Henkel, 2004. The results are presented in graphical form for all spatial properties mentioned above together with mean, mode and standard deviation of each property and the number of lineaments involved for the derivation of spatial properties and the unidirectional lineament frequency.

Key words: Azimuth, Length, Spacing, Spatial outliers, Spatial properties, Uni-directional lineament frequency

1. Introduction

The study of spatial properties of lineaments has attracted research interest in the past because it can provide valuable information about natural resources as well as hazard assessment. Linear features found in different data sets can, as an example, represent discontinuities in a mineral, in the rock mass, or in the earth's crust. The length of these can vary over a wide range of 10 orders of magnitude from 10^5 to 10^{-5} m (i.e. from continental scale to mineral scale). Linear features are usually approximated by straight lines and are in this study for simplicity categorized as "lineaments". In rock engineering the corresponding name would be "fractures". In both nomenclatures, the 3-d aspect is frequently neglected due to lack of information.

Lineaments as well as fractures are thus expressions of the intersection between planes and the observation surface (Figure 1). Studies of lineaments to locate geological hazard zones have been carried out by some researchers.

In Koike et al. (1995) and Koike and Ichikwa (2006), lineaments that appear in satellite images can be related to tectonic features.

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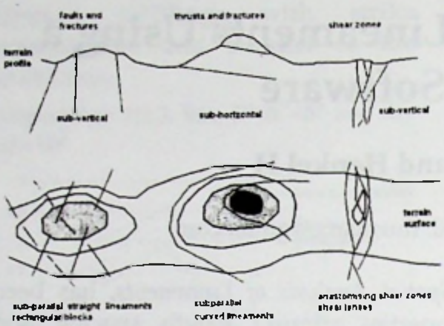


Figure 1. Steeply inclined faults (like normal faults) resulting straight traces (in geophysical or morphological data) enclosing angular blocks. Inclined faults (thrusts) result in curved lines. Steeply inclined shear zones may produce astomosing traces enclosing shear lenses

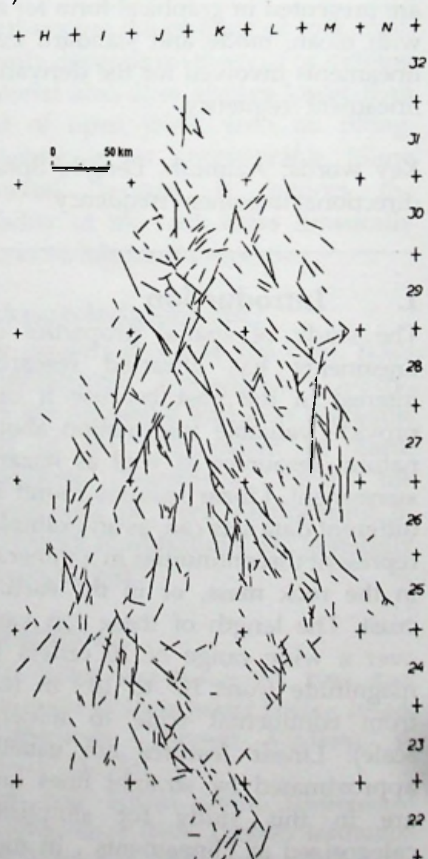
Hudson and Priest (1979, 1983, 1976) studied rock joint distributions in detail and tried to relate the discontinuity frequency in an image with the rock quality designation (RQD) value

An interactive software tool, here called Spatial Analysis of Lineaments (SAL), has been developed for calculating the spatial properties azimuth, length, spacing, and unidirectional frequency of lineaments which are defined by their start and end coordinates. In a series of steps the user is guided by displays of relevant statistical distributions, which can be user designed.

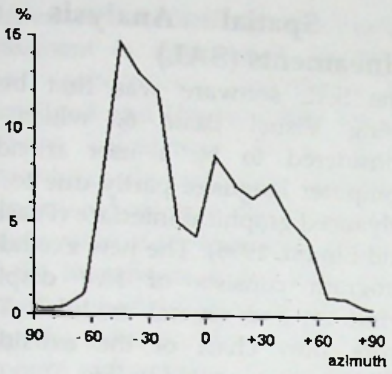
2. Definitions

Map area: The study area is specified by giving the lower left and upper right corners in planar coordinates. The user can select any type of units, but it is recommended to use SI units.

Lineament: The term lineament is used to cover any type of linear feature in any kind of data. These could be traces of discontinuities in a rock mass or in the earths crust. Lineaments are approximated as straight lines and are represented by their planar start and end coordinates, respectively as seen in the left part of (Figure. 1) and (Figure. 2).



(a)



(b)

Figure 2. (a) Example of a traditional lineament interpretation based on aero-magnetic data in a 250 x 500 km region in Northern Sweden (from Henkel, 1979, numbers and letters along frame denote national map sheet identifications). (b) Corresponding azimuth distribution. (the vertical axis shows frequency in %, and horizontal the azimuth in degrees, respectively.)

Azimuth: The azimuth is defined as the angle between a lineament and the grid north and can vary within a 180 degree interval. The *azimuth distribution* of lineaments in a given map area may contain several *azimuth sets* of lineaments with similar azimuth as seen in (Fig. 2b). The azimuth distribution for a single set is considered to be a normal distribution which can be representatively described by the mean value and the variance. The observed distribution may be skewed or contain a few members with a non-characteristic azimuth. Such *azimuth outliers* can be analysed as a separate set.

Length: The lineament length is the distance between the start and end coordinates, scaled to a systematic unit (preferably in m). The *length distribution* for given azimuth set is in theory exponentially decreasing and would contain values from 0 to infinity. In practice, the lineament length is restricted to the smallest spatial resolution (like the spacing between flight lines) at the low end, and to the diagonal of the study area at the high end. In this case the distribution is best represented by the mode value. The distribution may contain atypical members, *length outliers,* for which the user has to decide if they should be included or excluded in the analysis.

Spacing: The spacing is the perpendicular distance to the nearest lineament of the same azimuth set, and is scaled to the same unit as length. The spacing between two lineaments is not constant throughout their lengths (Fig. 3). Since the lineaments usually are not exactly parallel, the spacing is calculated for lineaments within a restricted azimuth range. The *spacing distribution* depends on the configuration of the search window which the user has to define. With a large search window, the spacing distribution tends to be bi-modal with an increase of the number of multiples of the first mode.

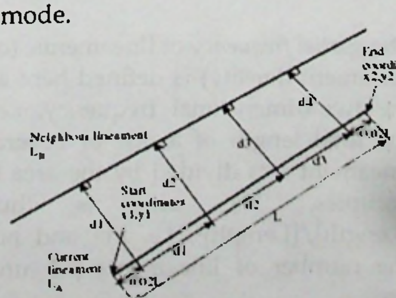


Figure 3. The definition of spacing and how it is calculated.

Lineament occupancy area: A user defined circumscribing polygon, that covers the lineament set studied, is the lineament occupancy area. The rules for the definition of the construction of the circumscribing polygon are given in the methods section. It is quite common that some lineaments of an azimuth set are located outside their main spatial cluster as *spatial outliers* (Fig 4). In connection with the spacing calculation, such spatial outliers should be excluded. If the lineament frequency for several direction sets within an area is required, a separate determination of the common polygon for all lineament sets has to be made.

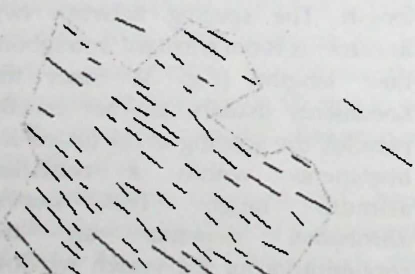


Figure 4. Examples of spatial outliers (dark gray and outside polygon encircling the main spatial cluster).

The *spatial frequency* of lineaments, (or lineament density) is defined here as the two-dimensional frequency, *i.e.*, the total length of a one or several lineament sets divided by the area it occupies. The unit is thus [Length]/[Length]^2, i.e. m^{-1} and not the number of lineaments per unit area.

3. Spatial Analysis of Lineaments (SAL)

The SAL software was first built using Visual Basic 6, which is considered to be a user friendly computer language partly due to its advanced graphical interface (Peasley and Simon, 1998). The new extended program consists of five display windows and several modules. The work flow chart of the extended program is presented in (Fig. 5).

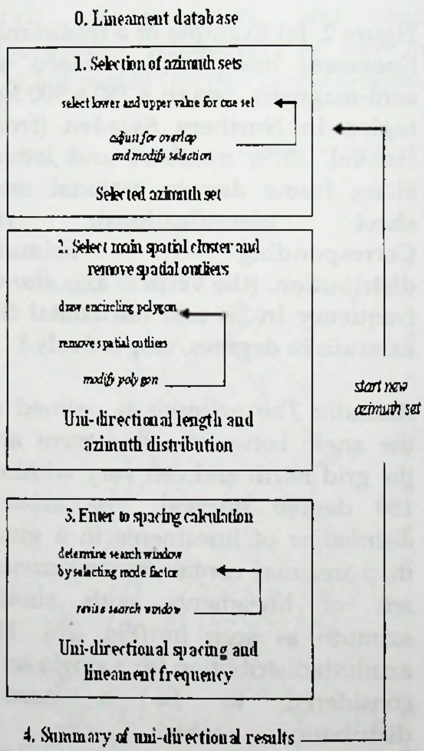


Figure 5. Work path for lineament analysis using SAL tool.

Statistical outliers can be excluded and the total sample of lineaments can be subdivided into azimuth sets and, if required, into spatial clusters. The removal of spatial outliers is carried out interactively. The nearest lineament is determined according the procedure described by Ekneligod and Henkel (2004) for the spacing calculation. As a default procedure, the program defines a window whose size depends on the mode value of the length distribution of the lineaments in the study area. Another special feature of the tool is that the software can accept a large amount of lineaments (3000) and can analyze the spatial properties of each azimuth set avoiding the repetitive calling of the original database. The spatial properties are presented as histograms for each azimuth set together with the mode, mean, standard deviation and number of involved lineaments (Fig. 6).

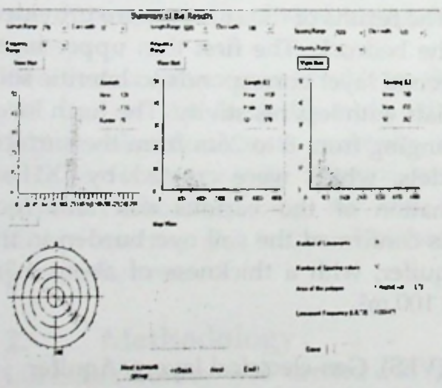


Figure 6. Summary of results uni-directional azimuth(histogram and rose diagram), length and spacing distribution together with map view of lineaments and polygons involved in the lineament frequency calculation are presented. Also, unidirectional lineament density is shown.

4. Conclusions

The presented tool for spatial analysis of lineaments (SAL), is a versatile interactive software tool for detailed characterization of lineaments based on statistical criteria. The software can handle a large amount of any line features at any scale and presents the results of an analysis in quantitative properties that are spatially and statistically representative.

Our software would be useful in building a fully automated interactive analysis tool starting from the lineament extraction level.

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