

EXPLORATION OF VARIOUS VISUAL DISPLAY METHODS FOR GEOVISUALIZATION PURPOSES

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Abstract

Visual display is a technique that utilizes tools on the computer to explore and to present information. There are some variation of visual display methods that have been developed and widely used in the needs of geovisualization and cartography such as Parallel Coordinate Plot (PCP), Space Time Cube (STC), Self-Organize Map (SOM) and Cartogram. This research uses these methods includes definitions and functions, recommendations for using an application and their respective advantages and disadvantages. Applying the right visualization is based on the needs or goals of geovisualization because each visual display has unique characteristics.

Keywords: visual display, geo-visualization, PCP, STC, SOM, cartogram.

Introduction

The rapid development of information and communication technology and computer hardware raises awareness of the importance of solving a problem by utilizing geospatial data and information. Geodesy and geography professional activities basically consist of measurement and imaging which processed to be able in identify, analyzing, presenting and doing simple models (Wikantika, 2008 in Rassarandi and Christianto, 2016). This activity is carried out to determine the condition of an object or phenomenon that exists under the earth, on the earth and above the surface of the earth. The temporal aspect is also a study of activities either monitoring and evaluation or predictions in the future.

At this time, geospatial information in the form of maps are considered as a form of scientific visualization which existed before visualization was developed into the different field of science. The purpose of visualization is to analyze information graphically while cartography aims in presenting geospatial. A

cartographic perspective of the evolving synthesis results geovisualization (Hearnshaw and Unwin, 1994 in Kraak and Ormeling, 2007). Geovisualization integrates the approaches of scientific visualization, cartographic exploration, image analysis, information visualization, explorative data analysis and geographic information systems (GIS) to obtain theories, methods and tools for visual exploration, analysis, synthesis and presentation of geospatial data. In the geovisualization environment maps are used to stimulate (visually) thoughts about patterns, relationships and tendencies about geospatial.

Visual display is a technique that utilizes tools on the computer to explore and to present information. There are a variation of visual display methods that have been developed and are widely used in the needs of geovisualization and cartography. However, the application of appropriate visualization is also based on the needs of visualization because each visual display has unique characteristics. There are various visual display methods including Parallel

Coordinate Plot (PCP), Space Time Cube (STC), Self-Organize Map (SOM) and Cartogram. This paper uses an exploration of these methods includes definitions and functions, recommendations for using the application, and their respective advantages and disadvantages. In another word cartographers results visualize geospatial information in accordance with consideration of their presentation needs.

Definition and Functions

A. Parallel Coordinate Plot (PCP)

Parallel Coordinate Plot is a modification of a (classic) plot that can visualize the high dimensions of geometry and analyze multivariate data. The benefit of this parallel plot are when connected dimensions and trends / pattern can be seen in limited space of the data. Both of these benefits, in particular will be applied by seeing how the trends / patterns of freedom and dependence of two random variables are formed in parallel plots.

Parallel Coordinate Plots describe each row in the data of the table as a line or profile. PCP that is dynamic, interactive and customizable is perfect for exploring the temporal and big spatial data to know the pattern / tendency.

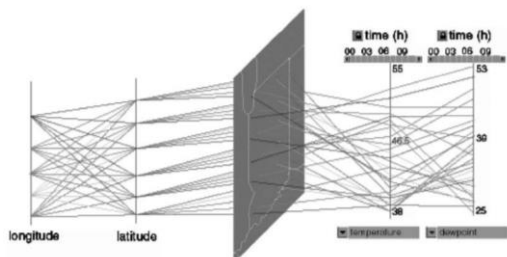


Figure 1. Parallel Plane concept (Source: Edsall, 2003).

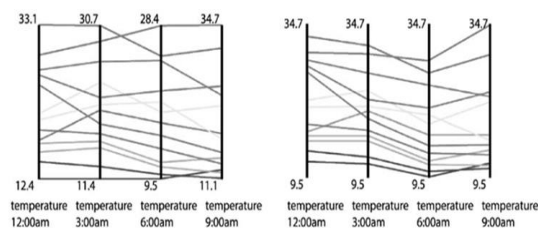


Figure 2. Typical axis value designation hides temporal trends (left), Axis values that are consistent across time axes temporal features (right) (Source: Edsall, 2003).

Variables are shown on parallel axes. Each axis has a different scale. The value of the variable is plotted as a collection of lines that

connected through all axes. The relation among each variables will be seen in the following situation:

- 1) The variables are next to each other;
- 2) if colors are assigned for variable levels to track certain groups;
- 3) if a line is selected to track a particular group;

B. Space Time Cube (STC)

Space Time Cube (STC) is a combination of the data visualization that connects space and time. The X and Y axes represent 2D space while the Z axis represents time (years, days, or hours). Visualization display where data points are mapped into cubes. Space time cube is useful for revealing complex spatio-temporal patterns in data for users. STC is considered as an approach in analyzing the behavior of various object movements and understand the dynamic processes that are taking place in space and time (Miller, 2004).

The Figure 3 below explains an example of the visual appearance of the STC in the case of Napoleon's trip to Russia during March 1812.

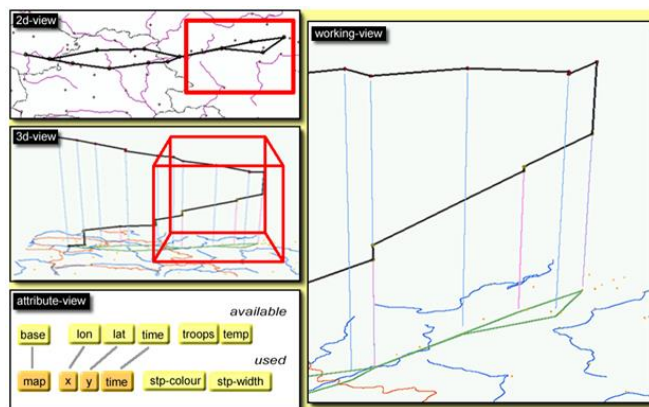


Figure 3. The Space-Time-Cube's basic viewing environment. 2D display (top left), 3D display (middle left), attribute display (bottom left) and work display (right) (Kraak, 2003).

C. Self Organize Map (SOM)

SOM, also known as topology-preserving map is one of the techniques in Neural Networks that aims to visualize data by reducing data dimensions through the use of self-organizing neural networks. For the reason humans can be understand high-dimensional data that mapped in the form of low-dimensional data.

Self Organized Map is a method that used in grouping objects and rearranging them in a 2D

map display based on the similarity of attributes owned. SOM is also used in classifying and arranging data based on the similarity of spatial distribution patterns.

SOM uses Euclidean distances to assess multivariate similarities among each spatial objects. Weight with the shortest distance is the winning neurons. In another meaning the method of SOM is used without guidance or unsupervised learning which assumes a structured topology makes the class units / clusters or named as Kohonen Network (Kohonen, Schroeder, and Huang, 2001).

SOM architecture is a network which consists of two layers such as the input layer and the output layer. Each neuron in the input layer is connected to each neuron in the output layer. Each neuron in the output layer represents the class (cluster) of the given input.

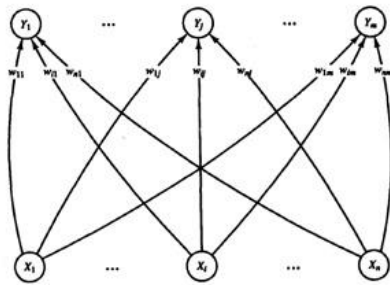


Figure 4. Self-Organizing Map ANN Architecture (Source: Fausett, 1993).

As a topology, SOM has 3 types of neighborhood topologies, such as linear array, rectangular and hexagonal grid.

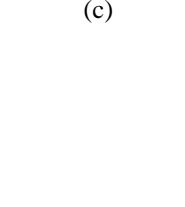
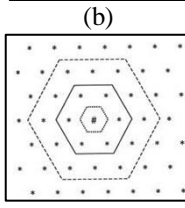
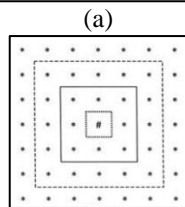
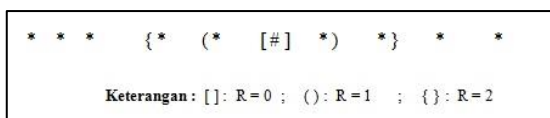


Figure 5. Linear Array (a), Rectangular Grid (b) and Hexagonal Grid (c) (Source: Fausett, 1993).

D. Cartogram

Cartogram as a diagrammatic maps is a modification of the relations that are normally seen on maps. Cartograms are made by enlarging or reducing the size (distance or size) of the area proportionally for the data represented. For the reason, the changes of the unit size can make the area are not the same as its original condition. In another meaning the differentiation between the map and cartogram must be kept in the reader's mind while interpreting the cartogram. In general, there are two types of cartograms namely linear cartograms and cartogram areas.

Linear cartograms that is called distance transformation maps or distance cartograms that are designed to display a form among distances that are not as actual distances. It is actually a terms of relative distance based on a measure. Cartogram area often called value-by-area cartogram is a cartogram that is designed to display the size of data values by proportionally representing the size of the unit area. For the reason the size of the area size of an area unit in the cartogram area is not the same as the size of the reality in fact.

Cartograms do not use additional symbols as the data visualization but it refers to change the size of the area in accordance with the data represented.

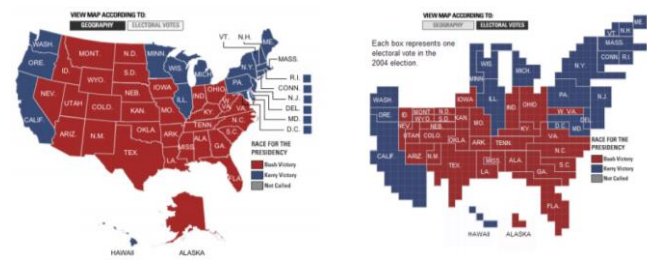


Figure 6. Geographical Map (left) and Cartogram (right), at the 2014 Presidential Election (Nusrat etc, 2017).

Recommendations for Use of the Application

A. Parallel Coordinate Plot (PCP)

The key to PCP activity is the ability to present data that can test temporal data such as spatial data, attributes, and patterns. It is used to compare many variables and to find the relation among variables.

The software that is used to perform the PCP method is xdat (x-dimensional data analysis

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tool). The software displays PCP graphics that is based on the data entered (.txt format). Except displays PCP graphics, xdat software also displays 2D Scatter Graphics. The software is able to access free of charge by visiting the address (<https://www.xdat.org/>).

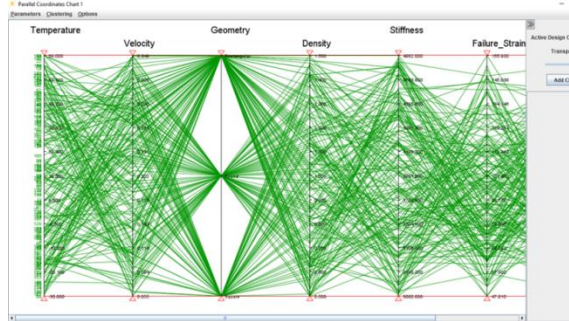


Figure 7. Use xdat software to display PCP
The data used above are (Temperature, Velocity, Geometry, Density, Stiffness, Failure_Strain, and Failure_Load).

Other software that can be used to visualize the appearance of PCP is the Geoviz Tool that has the input of data format .shp. The following is an example of a simple PCP display of a spatial pertanian.shp data with the ID attribute and the amount of its production.

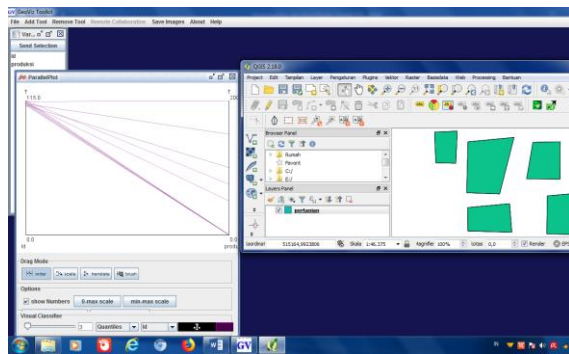


Figure 8. PCP display of a spatial data that has two attributes in the Geoviz Toolkit and the original data (shapefiles) in QGIS.

Alternative Software for PCP methods, including Geoda, SOMVIS (desktop), d3.js, d3 API (web based)

B. Space Time Cube (STC)

Space Time Cube is perfect for representing a chain of events that has a relationship between space and time. STC can manage spatio-temporal data, in the form of events, time series, flows between places and trajectory.

Software that can be used for visual display techniques with STC can be done using ArcGIS Pro. In the software there are special tools for visualizing data in the form of spatio-temporal cube.

ILWIS also has the ability to display spatio-temporal data using STC. The data structure is formed from a 3-dimensional cube in the form of a space-time bin with dimensions x and y representing coordinates and dimension t representing time. The cube can contain features such as Space Time Path (STP) that represent the spatio-temporal track of a moving object, or stations that represent a static object's spatio-temporal track. The STC can be plotted on the ILWIS window map, a tool called 'Space Time Cube' is available in the '3D' tool (Schouwenburg, 2013). Figure 1.6 shows the cube display for moving objects. There are three objects that move simultaneously (A, B, and C) in space (X, Y) with respect to time (T). Object simultaneously starts to move at each initial location A (X_1, Y_1, T_0), B (X_2, Y_2, T_0) and C (X_3, Y_3, T_0) to the final location A' (X_a, Y_a, T_N), B' (X_b, Y_b, T_N) and C' (X_c, Y_c, T_N). The process of moving from 3 (three) objects starts Z (T_0) and ends at Z (T_N), where the start time (T_0) = 08:00:00 02-02-2013, and the end time (T_N) = 08:53:00 02-15-2013.

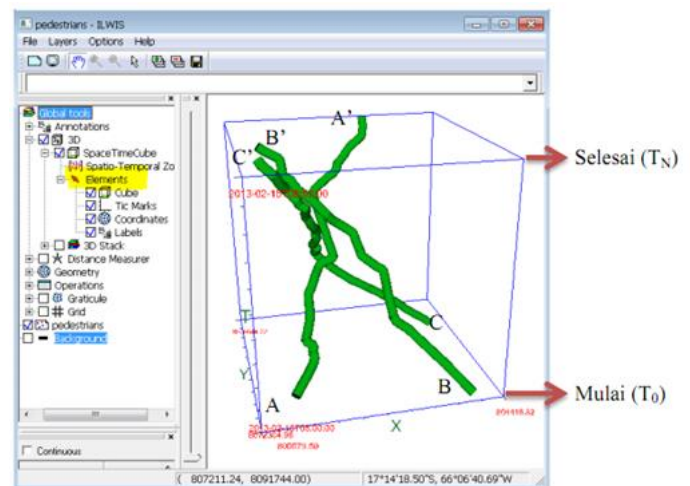


Figure 9. Space Time Cube Tool for STP in ILWIS 38 Display (Source: Schouwenburg, 2013).

Alternative software for the STC method, including STEMgis, GRASS GIS (desktop), i2maps (Javascript dan Python), timemap.js (Javascript Library) (web based).

C. Self Organize Map (SOM)

SOM is suitable for the topology of data visualization because the principle of SOM uses the neighborhood aspect. In other words, SOM can be used as an algorithm for cluster formation. The following figure 10 is an example of SOM application.

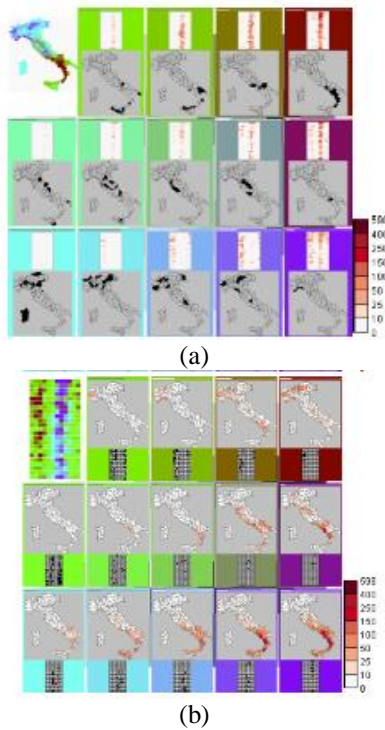
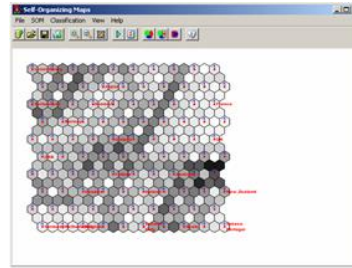


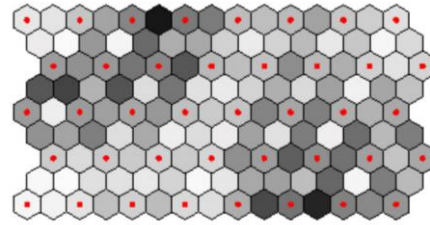
Figure 10. SOM method helps in exploring the spatio-temporal distribution of forest fires. (a) spatial distribution of the temporal variation patterns. (b) temporal variation of the spatial distribution patterns (Source: Andrienko, 2010).

Figure 10 shows the use of SOM computational methods to study the spatio-temporal distribution of forest fires in Italy over a 25-year period. In case (a), the SOM group arranges districts / regencies in accordance with the similarity of the temporal pattern of forest fires, in case (b), the SOM group arranges intervals according to the similarity of the spatial distribution patterns of forest fires.

Software that can be used to visualize the SOM technique is the Knocker SOM.



(a)

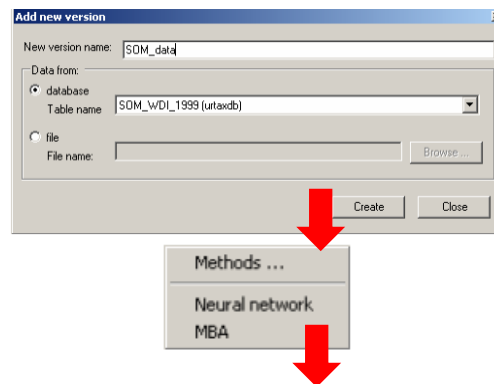


(b)

Figure 10. Main window Knocker SOM (a) and Representasi Matriks-U on SOM (b).

Here are the short steps to visualize it (Pich, 2016).

- 1) Creating a new data from input data of a database or file,
- 2) Determine the SOM method used, for example Neural Network,
- 3) Run SOM module,
- 4) Creating a set of columns used for network training,
- 5) Setting parameters for each training (neighborhood rules, number of iterations, network size etc),
- 6) Classifying for clustering (hierarichal clustering).



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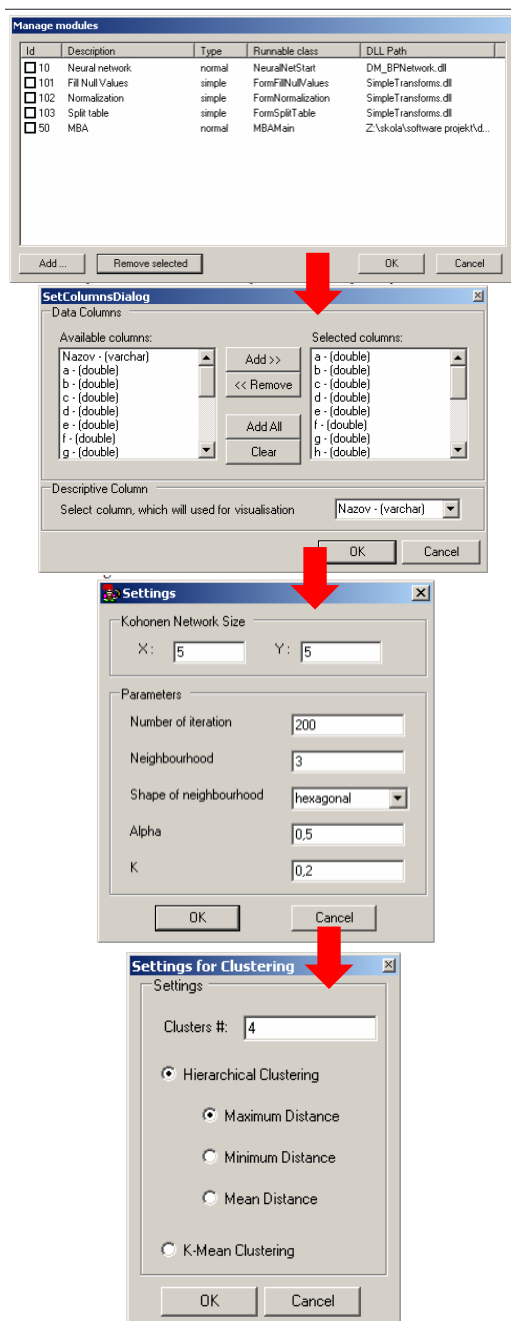


Figure 11. Stages to visualize SOM using K-Means SOM.

The final algorithm product of visualization using SOM technique is as follows,

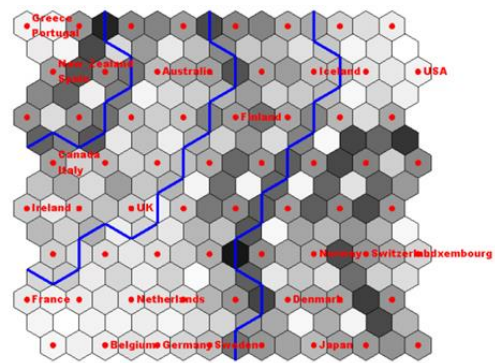


Figure 12. Classified data with K-Means algorithm (Source: Pich, 2016).

Alternative software for the SOM method including Matlab and SOM PAK, SOMVIS, SOM Analyzer, ArcGIS: Arc-SDM (Spatial Data Modeller) (desktop), Python Library (clusterPY) (library).

D. Cartogram

Cartogram is suitable in getting information that is reviewed from distribution of the spatial data and statistic data. Cartograms apply visual shapes, size, color and value variables.

Software that can be used to visualize Cartogram display is the Geoviz Tool with input the data in .shp format. The following is an example of a simple Cartogram display of spatial pertanian.shp data with the ID attribute and the amount of its production.

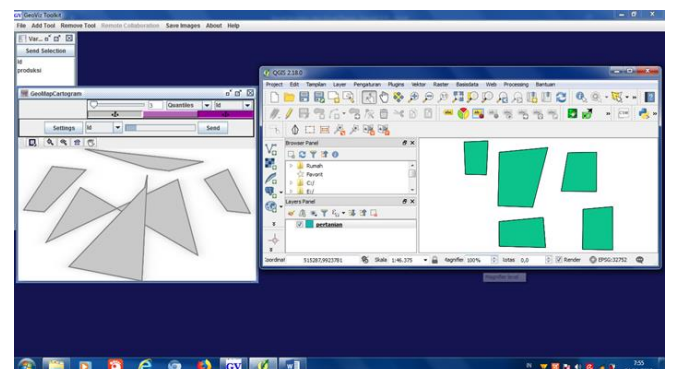


Figure 13. Cartogram display of spatial data that has two attributes in Geoviz Toolkit and original data (shapefiles) in QGIS

Alternative software for the Cartogram method, including ArcGIS, ArcView, Mapinfo, Cart (C++ Program) (desktop), d3.js (Javascript Library), ScapeToad (web based).

Advantages and Disadvantages

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A. *Parallel Coordinate Plot (PCP)*.

1. Advantages:
 - a) PCP is useful for searching / knowing patterns in certain data sets
 - b) PCP is a good option for presenting numerical data that has many variables.
2. Disadvantages:
 - a) The more variations of the data, the level of finding data patterns will find the difficulties.
 - b) If there are many data records, there will be a lot of overplotting which make it difficult to see the pattern of the data.
 - c) This technique cannot be used for categorical data or data with multiple values per axis.
 - d) Spatial elements are less visible.

B. *Space Time Cube (STC)*

1. Advantages:
 - a) Time is visualized on a ratio scale in making it suitable for exploring the analysis of spatio-temporal.
 - b) The response time is not too high for spatio-temporal queries.
 - c) Speed and direction can be directly visualized.
 - d) STC is quite effective in visualizing object changing, the use of this technique provides high flexibility for users in viewing and querying data. Then, if STC is integrated with geovisualization, it will produce temporal activities in space and time that will be easier for the reader in exploring and understanding object changing.
2. Disadvantages:
 - a) STC limits the number of items that can be represented.
 - b) Only a limited number of variables can be visualized.
 - c) Elevations and gradients are difficult to visualize (if the data contains spatial elements x, y, z will be difficult to display).
 - d) For simple spatial queries, a higher error rate will be obtained.
 - e) Demanding computer specifications for the convenience of data visualization.
 - f) Sometimes the users lose their orientation if it is not controlled.

C. *Self Organize Map (SOM)*.

1. Advantages:
 - a) Easy to understand and simple.

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- b) Mapping can produce well-organized clusters.
 - c) Comparison of clear datasets.
 - d) Classifying data well then easily evaluating the quality of the component in the data. For the reason it can be found how good the map and the similarities among each objects.
2. Disadvantages:
- a) It is difficult to determine the weight of an input in its use.
 - b) Sometimes clusters will get split and form two groups of colors that are identical that make the user confuse.
 - c) Demanding computer specifications that support for smoothing and relieving the data visualization.
 - d) The requirement to define the structure of neural networks and the number of neurons or number of classes. In addition, random determination of initial neuron weight values results in different clustering.

D. Cartogram

1. Advantages:
- a) Visualizing data absolutely becomes more flexible because the cartogram emphasizes the modification of the area. Its application can be addressed with varied data characteristics better than the map method that focuses on giving symbols.
 - b) Suitable for displaying quantitative data.
 - c) Relations between boundaries and orientation are maintained.
2. Disadvantages:
- a) The results of the cartogram that cause the location, distance and area are not the same as the actual original condition.

- b) Differentiations in visualization on the cartogram also encourage the emergence of the different visual perceptions. It will create the differentiation in the level of effectiveness in reading an information absorbed by the user.
- c) The differentiation of the effectiveness in presenting the data will affect the accuracy of the data presentation method used.

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