

## Techniques for Statistical Data Visualization in GIS

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*This paper proposes an original solution to present statistical data using the facilities provided by the Geographical Information Systems, to improve the means of statistical data figure and distribution inside the territorial profile. The proposed solution allows to represent more statistical data sets, on the same map, using two different methods of data representation: using a color ramp to represent the territorial distribution of an aggregate indicator and a set of charts overlapped to represent the proportions of the variables that form the indicator. On the other hand, there is a way to represent statistical data using 3D cartograms. Thus, in GIS, the users can distinguish the intensity of the studied economic or social phenomenon because of the heights of the administrative units will be different.*

**Keywords:** *Geographical Information Systems, Spatial Visualization, ArcObjects, 2D and 3D Cartograms*

### 1 Introduction

In recent years, Geographical Information Systems (GIS) have become an important tool for statistical data representation. The huge amount of spatial data generated by GIS expansion, the increasing number of GIS applications available, the computerization of a large amount of information sources, and the availability of digital map has increased the opportunity and need for the usage of methods for spatial visualization of statistical data, for both research and applied purposes. Data graphical representation in GIS requests to use different symbologies to view more information in the same time on the map. The spatial perspective of data offer the advantage to locate the studied phenomena and the symbology offers quantitative details that are visual reflected in various forms. Software tools for modeling three-dimensional space can be adapted and used to build 3D cartograms. Thus, the quantitative details are visual reflected in the 3D cartograms by extrusion of spatial data using different values for the height but in according with the values of statistical indicator.

### 2 Techniques for Statistical Data Visualization in Geographical Information Systems

Cartograms are unique representations of geographical space. A cartogram is a type of graphic tool that describes attributes of geographic objects. Mapping requirements include the preservation of shape, orientation contiguity, and data that have suitable variation. Successful communication depends on how well the map reader recognizes the shapes of the internal enumeration units, the accuracy of estimating these areas, and effective legend design. Because a cartogram does not depict geographic space, but rather changes the size of objects depending on a certain attribute, a cartogram is not a true map. Cartograms vary on their degree in which geographic space is changed: some appear very similar to a map; however some don't look like a map. [4] There are three main types of cartograms, each having a very different way of showing attributes of geographic objects: non-contiguous, contiguous and Dorling cartograms.

A *non-contiguous cartogram* is the simplest and easiest type of cartogram. In a non-contiguous cartogram, the geographic objects do not have to maintain connectivity with their adjacent objects. This connectivity is called topology. By freeing the objects from their vicinity, the objects can grow or get smaller in size and still maintain their shape.

In a *contiguous cartogram* is maintained the true topology, the objects remain connected with each other, but this causes great distortion in shape. In this case, the cartographer must make the objects of the appropriate size, to represent the attribute value, but he or she must also maintain the shape of objects as best as possible, so that the cartogram can be easily interpreted.

A *Dorling cartogram* maintains neither shape topology nor object centroids, though it has proven to be a very effective cartogram method. This type of cartogram was named after its inventor, Danny Dorling of the University of Leeds. To create a Dorling cartogram, instead of expanding or distorting the objects themselves, the cartographer will replace the objects with a uniform shape, usually a circle of the appropriate size.

### 3 Informatics Technologies for Representing Symbologies in Geographical Information Systems

A geographic information system works with spatial data. These data are used to represent different elements of geographical reality, the types of vectors (spatial characteristics) and their location on the earth. The main vectorial spatial data types are: point, line and polygon.

In addition to the vectorial spatial data, geographical information systems operate with raster data. They are described by a grid of color (bit maps), covering a well defined area on the land area and are used to suggest more realism to the studied geographical space. Satellite images, terrain elevation model (DEM), orthophotoplan, and scanned maps are represented using raster formats.

The geo-relational data model involves the data storage using independent formats based on the division of attributes into two entities, and store them separately. Thus, a spatial data is made up of a spatial attribute, which is stored separately and non-spatial attributes. The link is made through an identification field (ID), which aims to combine consistently the two types of attributes. Spatial data storage using geobase data model supposes to store both the spatial

attributes and the non-spatial attribute, together in one table. The field containing the space attribute is a geometric, a vector field. The spatial features are implemented and processed through all classes of objects even they reside in tables, in a relational database. Thus, they contain properties and methods that operate on them.

#### 3.1 ArcObjects.NET SDK Framework for Geographical Information Systems Development

ArcObjects represents a framework based on COM (*Component Object Model*) used to build ArcGIS software product, developed by ESRI (*Environmental Systems Research Institute*)[1]. The three versions of ArcGIS software, ArcView, ArcEditor, and ArcInfo share the same applications: ArcCatalog and ArcMap. Geobase data model and ArcObjects are the foundation of the two desktop applications.

ArcObjects is composed from classes and objects. ArcObjects uses three types of classes [5]:

- *Coclasses* – used to create new objects, like *RgbColor* class having as the goal to define and to handle colors, defined in RGB model.
- *Abstract classes* -cannot be used to generate new objects, but are designed to build hierarchy of classes starting with an entity having a general nature. For example, classes that implement different color models are derived from an abstract class called *Color*;
- *Classes* – are not used directly to generate new objects, but they are build from other objects. For example, to access selected features on the map at a time, a *MapSelection* object can be build from the map object.

Using ArcObjects, we can develop applications in several ways [2]:

- GIS applications can be developed using the independent component *ArcEngine* and a software development environment like *Visual Studio.NET*;
- It is possible to develop extensions, which could be attached to the ArcGIS

applications and which contains interaction elements for different customized GIS processing;

- It is possible to develop Web applications.

### 3.2 Symbologies for Statistical Data Representation

One of the main applications of GIS is related to the possibility to display statistical information on the maps, so that, the users can have a geographical perspective on the represented phenomenon, too. We must build cartograms to display the results of the economic and social phenomena.

Another kind of symbology refers to the displaying of graphs on the spatial data, to capture the proportions of variables represented as statistical data.

There are several techniques implemented in ArcGIS, used to classify some items according with the value of one indicator (attribute). To achieve this, it's a must to identify disjoint intervals of values and the indicator used to form groups. For example, the simplest way to create ranges of values is the division of the values used to make the classification, into equal intervals.[6] The *NaturalBreaks* method, used to split the ranges, is based on the shaping of the groups of values, so that to have a minimum dispersion inside the group and a maximum dispersion between groups.

In ESRI's software, colors could be defined individually. In this case there are special classes for various color models, like *RgbColor* class used for RGB model, and as collections of colors, managed by color ramp classes, having the name *ColorRamp*. Collections of colors can be generated by the programmer or can be used the default collections that are defined by ESRI's style gallery.

In the *Results* paragraph we present the exemplifications of the usage of these symbologies.

### 4 3D Cartograms

The 3D cartograms are based on the extrusion of the spatial data. Thus, if the

spatial data is a point by extrusion operation becomes a vertical line, a line becomes a wall and a polygon becomes a block.

In order to represent statistical data by 3D cartograms, we can use spatial data of the point type that have the heights correlated with the values of indicator. In case that we want to apply this graphical representation for spatial data of the polygon type it is recommended to set up the reference point for the polygon as its centroid. Thus, the map will contain a lot of vertical lines having different heights, each line being located in the middle of the represented administrative units.

Another way is to build blocks by extruding of each polygon that represents an administrative unit space. Such of example is illustrated in the figure 2.

The height associated to the spatial data is computed based on the indicator values. Each administrative unit has a different height function of the values of an analyzed indicator. The spatial data heights can be different according to the indicator values. In this case, having a map with a lot of details, the users can't distinguish the spatial reality very well. A way to decrease the level of confusion is to group the administrative units in many groups. Thus, the heights will be established from the beginning and each administrative unit has the height function of the defined ranges of values. It is possible to obtain the groups using the implemented techniques, as the following: equal interval, natural breaks, quantile, geometrical interval, standard deviation [3].

There was used the ArcScene software application for statistical data representation using the 3D cartograms. ArcScene, is a part of the ArcGIS software package. The main functionalities implemented by ArcScene are: 3D modeling of a spatial data, 3D model visualization as well as the navigation in the 3D world built.

### 5 Results

From the relational model perspective, we create a personal geodatabase *bd\_ro.mdb*, with *judete* table containing Romania's

counties as spatial data and *populatie* table containing the data about the population of the counties, as follows:

- population in large towns (with 150000 inhabitants or more);
- population in towns (having between 10000 and 150000 inhabitants);
- rural population (with less than 10000 inhabitants).

The two tables contain a common field used to create the junction between them; it is the symbol of the county.

The first part of the statistical data representation supposes to color the counties on the map in a gradient color, based on their total population. Thus, by pressing the button from the toolbar built for this purpose, the map is colored based on the total population and the appropriate legend will be displayed too.

The source code contains several parts according to the steps that solves. In this paper we present only the specific steps:

- To identify the desired thematic layer - the counties layer:

```
int nl, i, nrg=3; // nl-variable
used to store the number of layers
// i -counter variable, nrg - number
of groups (ranges) used to divide
the counties, function on
// the population number
IMxDocument doc = ArcMap.Document;
// get the map document
IMap harta = doc.FocusMap; // get
the map
// declare the interface for the
layer - each contains properties and
methods needed in different
// contexts
ILayer lyr = null;
IFeatureLayer ifl = null;
IFeatureClass ifc = null;
// getting the number of layers from
the map
nl = harta.LayerCount;
// iteration of the layers to
identify the desired county
for (i = 0; i < nl; i++)
{
    lyr = harta.get_Layer(i);
    if (lyr.Name == "judete")
    {
        // the usage of IFeatureLayer
interface for the desired layer
```

```
        ifl = (IFeatureLayer)lyr;
        // using IFeatureLayer
interface we can access FeatureClass
property which contains properties
// and methods of the class
with spatial characteristics
        ifc =
(IFeatureClass)ifl.FeatureClass;
    }
}
```

- Building the intervals for counties classifying according with the population number.

```
// building a histogram based on the
attribute used to make the
classification
ITableHistogram ith = new
BasicTableHistogramClass();
ith.Field = "Total_populatie"; //
the field
ith.Table = tpop; // table with the
field
object vval, vfrecv; // vval -
attribute value, vfrecv -
frequencies
```

```
((IBasicHistogram)ith).GetHistogram(
out vval, out vfrecv); // loading
objects
// building an interface for
classification, based on
NaturalBreaks method
IClassify div_grupe = new
NaturalBreaksClass();
// assigning data used to generate
the ranges
div_grupe.SetHistogramData(vval,
vfrecv);
//loading the number of ranges which
will be generated
div_grupe.Classify(ref nrg);
double[] vecgr; //declaring an array
with the ranges limits
vecgr = (double
[])div_grupe.ClassBreaks; // limits
generation
```

- Coloring the map using colors from the color ramp and the classification in the three ranges of values, previously generated.

```
// defining an object for a
symbology based on the ranges of
values
IClassBreaksRenderer cbr = new
ClassBreaksRenderer();
// the field which contains the
values used to color the map
```

```

cbr.Field = "Total_populatie";
cbr.BreakCount = nrg; // the number
of range
// setting the minimum value, which
is the lowest limit of the first
range of values
cbr.MinimumBreak = vecgr[0];
// declare an interface which shows
the way to fill the polygons with
color
ISimpleFillSymbol fs;
for (i = 0; i < cbr.BreakCount; i++)
{
    fs = new SimpleFillSymbol();
    fs.Color = rcul.get_Color(i);
// getting filling color
    cbr.set_Symbol(i,
(ISymbol)fs); // associate the
filling symbol
    cbr.set_Break(i, vecgr[i+1]);
// setting the highest limit of the
range
    // labeling in the legend of
the map from Table of Content
    cbr.set_Label(i,
vecgr[i].ToString()+ "-" +
vecgr[i+1].ToString() );
}
IGeoFeatureLayer gfl =
(IGeoFeatureLayer)lyr;
// associate the symbology (cbr) to
the lyr layer, corresponding to the
counties, by Renderer property

```

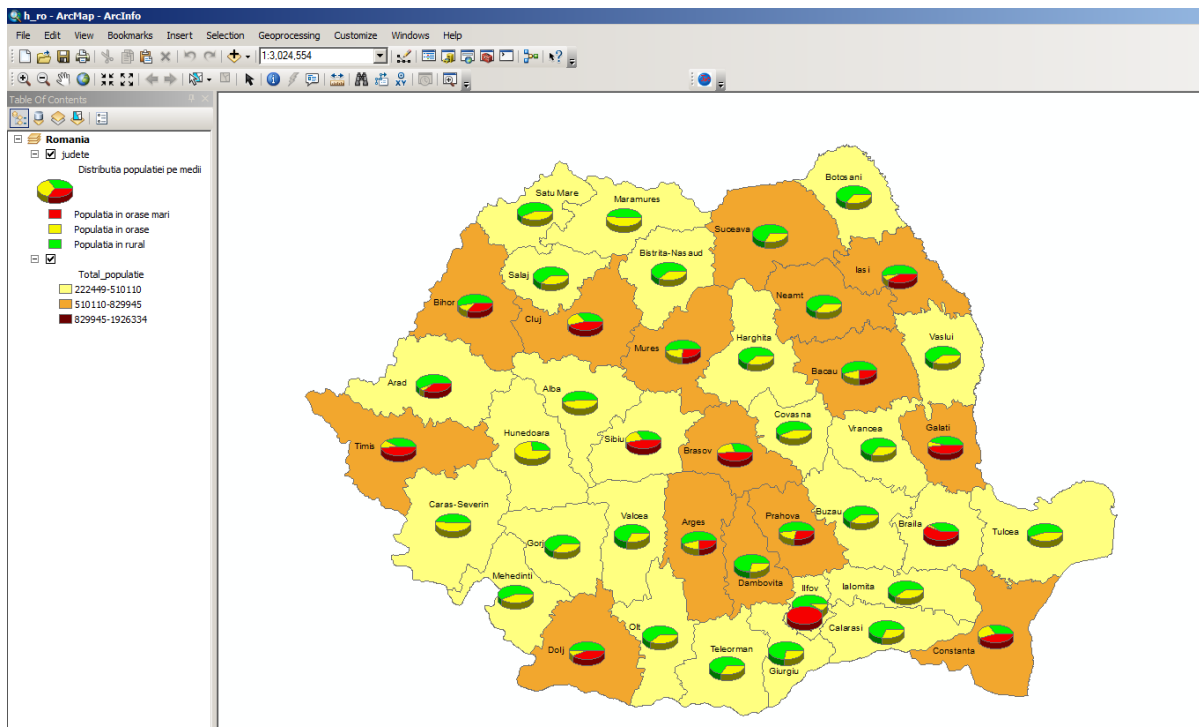
```

gfl.Renderer =
(IFeatureRenderer)cbr;
doc.ActiveView.Refresh();// redraw
the content of current view
doc.UpdateContents(); // update the
content of the Table of Content
window

```

This symbology is used as background for a chart symbology that is presented in the next item.

- The next step is to display the charts on the spatial data to figure the proportions of the variables inside the statistical data represented. To exemplify this, we choose to represent the proportion of the population from the cities, towns and rural areas in total population, for all counties, on the map using pie type charts, as shown in Figure 1. Data about the population, in counties, cities, towns and rural population are stored in the *populatie* table, from the *bd\_ro.mdb* database. To avoid the code duplication code comparing with the previous example, we will present only the specific code sequences.



**Fig. 1.** Coloring the map using the color ramp and the PieChart symbology based on counties' population

- To effectively display symbology of *piechart* type, on the thematic layer *counties* from the map, it is necessary to do as following:

```
// building a color ramp of nrg (=
3) colors, using Red to Green
color ramp from ESRI galery,
IColorRamp rcul = null;
EnumStyleGalleryItem vst =
doc.StyleGallery.get_Items("Color
Ramps", "ESRI.style",
"Default Ramps"); //doc= map
document
IStyleGalleryItem elem =
vst.Next();
while (elem != null)
{
if (elem.Name == "Red to
Green")
{
rcul =
(IColorRamp)elem.Item;
break;
}
elem = vst.Next();
}
rcul.Size = nrg;
bool vb;
rcul.CreateRamp(out vb);
ISimpleFillSymbol fs; //defining an
interface to describe the filling
types
IPieChartSymbol pcs = new
PieChartSymbolClass(); //building
an interface for piechart
symbology
// building the interface to display
the chart type symbology
IChartRenderer cr = new
ChartRenderer();
pcs.Clockwise = true; // setting the
direction for building of the pie
chart
((IMarkerSymbol)pcs).Size = 30; //
the symbol size (for the
piechart)
// the parameters for the nrg (=3)
variables which compose the
piechart
for (i = 0; i < nrg; i++)
{ // building a symbol for chart
filling
fs = new SimpleFillSymbol();
fs.Color = rcul.get_Color(i);
// associate the filling color
taken from the color ramp
previous build

((ISymbolArray)pcs).AddSymbol((IS
```

```
ymbol)fs); // adding the
symbol to the collection of
symbols

((IRendererFields)cr).AddField(nu
mec[i]); // adding the field
used to create the piechart
// associate the field label
used to display the legend

((IRendererFields)cr).set_FieldAl
ias(i, vs[i]);
}
cr.ChartSymbol = (IChartSymbol)pcs;
// associate the piechart type
symbology
cr.CreateLegend(); // building the
legend - will be displayed in the
Table of Content
cr.Label = "Distributia populatiei
pe medii"; // labeling the
symbology in the legend
cr.UseOverposter = true; //
avoidance the charts overlapped
// associate the symbology (cr) to
the lyr layer, corresponding to
the counties
IGeoFeatureLayer gfl =
(IGeoFeatureLayer)lyr;
gfl.Renderer = (IFeatureRenderer)cr;
doc.ActiveView.Refresh(); // redraw
the content of the current view
doc.UpdateContents(); // updated the
content of the Table of Content
window
```

The 3D cartogram illustrated in the figure 2 was built for graphical representation of the total population indicator. In the figure 1 the total population indicator was represented in GIS by coloring the counties. The color was picked up function of the value of the total population indicators belongs to a values interval. The example was realized using three values intervals that means the administrative units was grouped in the three categories according with the value of the total population indicator.

3D cartogram uses the same groups of administrative units and each group has a different height. The heights are stored in the *z* field that was added to the *judete* table. This field can contains one of the values:

- 1 – for the administrative units having population in the interval: 222449-510110;

- 2 – for the administrative units having population in the interval: 510110-829945;
- 3 – for the administrative units having population in the interval: 829945-1926334.

In ArcScene we use the  $z$  field to extrude the *judete* feature. In order to increase the significance of the graphical representation the  $z$  value was multiply by constant value.

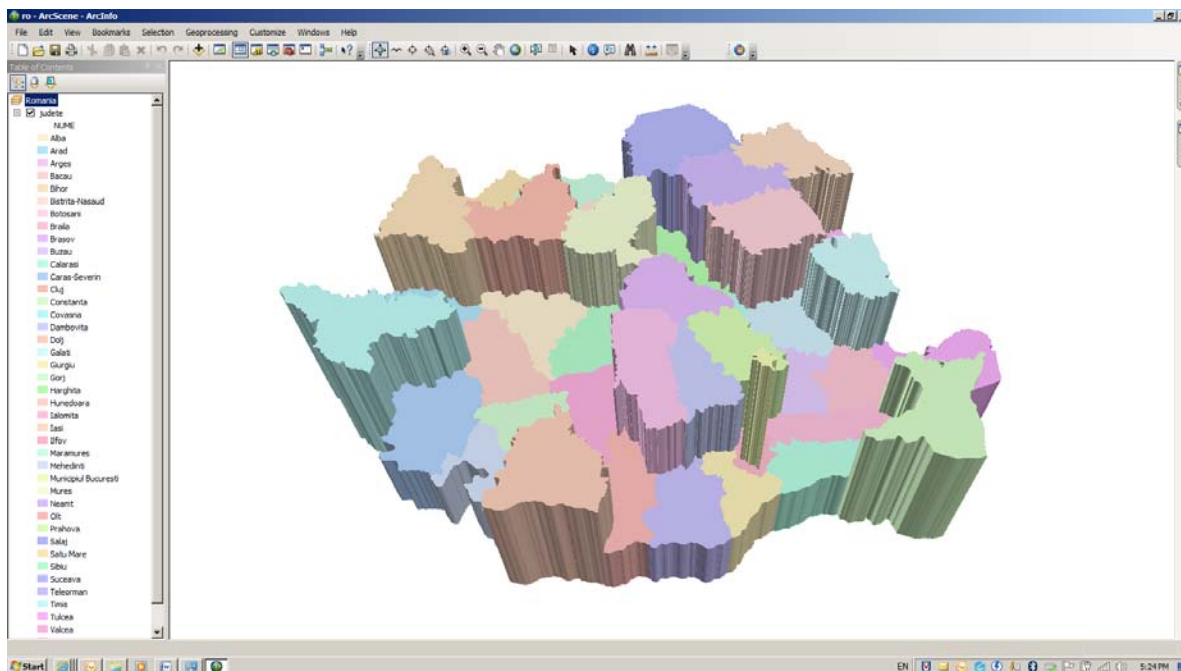


Fig. 2. 3D Cartogram based on the total population indicator

## 5. Conclusions

The proposed solution involves two symbologies that are overlaid and that reflect in two ways the same thing. The Class Breaks symbology reflect the total population indicator and plays role of background for a Chart symbology that reflect de proportion of the different categories of population in total population for each county. This type of cartogram is suitable in case of large enough regions because in this case the cartogram is more visible and the users easily can distinguish the results displayed by cartogram. The 3D cartograms are very attractive and reflect the impact of the studied phenomenon.

## Acknowledgments

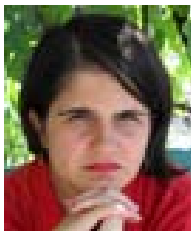
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