UNIVERSITY THOUGHT
Publication in Natural Sciences, Vol. 6, N^{o} 1, 2016, pp. 39-43.
doi:10.5937/univtho6-10411
Original Scientific Paper

MATRIX PIXEL AND KERNEL DENSITY ANALYSIS FROM THE TOPOGRAPHIC MAPS

Dragica Živković[1*]

[1]Faculty of Geography, University of Belgrade, Belgrade, Serbia.

ABSTRACT

Complex networks with building density play a significant role in many fields of science, especially in urban sciences. That includes road networks, hydrological networks, computer networks and building changes into geo-space through some period. Using these networks we can solve the problems like the shortest path, the total capacity of networks, density population or traffic density in an urban or suburban area. In this paper for quantifying the complexity of road networks and a novel method for determining building density by using a matrix pixel analysis and Kernel distribution with a concrete example of the city of Belgrade. Both of them represent geo-spatial data. In this case we have analyzed road networks, building density, with the help of specially created software for analyzing pixels on the maps from 1971, including the properties of geo-spatial data we have analyzed from old topographic maps in ratio 1:25.000.

Key words: matrix, pixel, analysis, networks, geo-spatial, Belgrade.

1. INTRODUCTION

Main The resilience and total capacity of many road networks and changes of geo-spatial data makes it possible to study their long period of evolution in space and time (Helbing, 2003). In addition human road networks present the progress of civilization and a degree of self-organized structures that respond to changes in internal and external pressure by gradual geometric changes. The other important view is the changes of building structures and their properties in the city (Gudmundsson & Mohajeri, 2013). The urban road network and building density have been displayed as the city growth through different methods of assessment.

Topographic map represent a frozen time point of geo-spatial data. The raster data from topographic maps are not good enough to fully explain potential geo spatial phenomena.

In this paper we used the new matrix pixel analysis method including the distribution of building density (according to the Kernel density estimator) for displaying geo spatial data of the city of Belgrade from the 1971 topographic map (Chen et. al., 2004). The pixel analysis serves for exploring the geospatial map data. Regarding that period, we observed urban changes in the city as well as the shape and properties of the road network in Belgrade (Knežević, 2010). By combining different methods, we explore the micro and macro features of the city road network. In that purpose we used Geographic Information System (GIS), which examines the road network and the city road network patterns. The other calculations of the road network changes of the city of Belgrade, where about the number of nods, the length and the shape of the road network. The source for creating a digital road map in 1971were topographic maps (used for military purposes) in the proportion of 1:25,000 and by the aero-photo images from 1963, 1965 and 1970. The data were digitized by software QGIS 2.6 Brighton (Open Source Software). The obtained digitized map was then used for the presentation of the city road network as well as for the presentation of the building density of the city of Belgrade. In this way, we get quantity and quality features of the urban city zones in 1971.

The city of Belgrade is the largest city and the capital of the Republic of Serbia. It is located at the mouth of Sava and Danube rivers. The city is divided into 17 municipalities; they are classified into 10 urban and 7 suburban whose centers are smaller towns. Most of the municipalities are situated on the southern side of the Danube and Sava rivers, in the Šumadija region. Only three municipalities are located on the north of the Srem region and Banat region.

2. METHODS

It gives, if In this paper we used the topographic maps from 1971, made by Yugoslav National Army and they were in HGS (Hermanns Kogel Datum) Gauss-Crueger zone 7 projection. The source for data of the 1971 population census was Statistical Office of the Republic of Serbia. After the scanning of the maps, we get the raster format. We marked all the map roads with the specially designed software (JS software for color properties) and by the matrix pixel analysis, and later we digitized them and converted into a vector format. All these maps were geo-referenced and digitized in QGIS 2.6. Brighton (Open Source Software), after the maps were imported into a GIS environment as a tif extension. Then the maps were reprojected in UTM (Universal Transverse Mercator, WGS84 datum) projection with help of open source QGIS 2.6. Brighton software. To align the different maps (geo-referencing) we used the main streets as the reference points on the images. The road network were drown in vector format on the geo-referenced maps in an QGIS 2.6. Brighton environment. Following this the *Geometry Tools*, *Extract Nodes*, *Road Graph Plug in Settings* and *Plug in Vertices Counter* was used to build the entire network datasets for every map. In this analysis, intersections of streets are regarded as nodes, and the streets are regarded as links between nodes. On Belgrade topographic maps, we have marked two kinds of the usually used road signs. Then we get entire Belgrade road network, which has been digitized. The road network is divided according to the azimuth, length, area and shape. After digitization, we divided all the road signs in categories. In the matrix pixel model we digitize the points inside the sub-pixel, separating the borders of two different pixels (see Fig. 1). After inserting the points we digitize the raster format pictures to get the vector format pictures. On that way we get points of the matrix analysis by pixels. The vectorized points, derived from the matrix pixel analysis, determine the positions of all the buildings on the map. Then all the points have been inserted and converted into the QGIS 2.6. Brighton (Open Source Software). Example of the vector format points inside the sub-pixel form on the raster format picture is given on the Fig.3b. Next, we made the layer that contains the points which represent the building density. Following this, the layers were converted into GIS shape – file format. We used *Heatmap plug in* and *Kernel shape* (quartic-bewight density function with radius of 100m between points). The obtained layer is in GeoTiff extension. To create a building density map we used *Create Heatmap* tool. In the layer *Style* we classify six belts of building density with dataset. In tool *Raster, Extraction* we choose *Contour lines* with interval between contour lines 1 (maximal value).

3. RESULTS

Munsell color system and the matrix pixel analysis**.** The Munsell color system was introduced by A.H Munsell. This system is especially used in map designing and includes three dimensions of color: hue, value and chroma. These equal steeps of hue, value and chroma were determined through a color difference experiment completed by thousands of people. In the Munsell color system, 100 equal visual increments of hue are arranged in a circle. Pairs of hues opposite each other on the circle are usually called the complementary hues (Munsell,1975). The Munsell colors are specified by value, the perceived lightness of a color relative to physically existing black and white endpoints. The Munsell value scale is divided into 11 equal visual steps of grayness from 0 (black) to 10 (white).

The reflectance of each steep has been measured carefully. The relationship among the three dimensions of color in the Munsell system can be visualized as forming a three dimensional color solid. Equation (1), defines the amount of reflectance per unit from the raster images and the equation (2) is the Chebyshev polynomial inverse equation for which we use the units from the Munsell color model *V*, (see Table 1.).

Table 1. Munsell color equation table with main data.

Reflectance Munsell Color equation in Chebyshev polynomial inverse form	
I	W_i
0	**-1.5323707**
1	**30.6459571**
2	**-97.1723668**
3	**292.9487603**
4	**-608.8463883**
5	**870.8293729**
6	**-840.7901111**
7	**521.7276980**
8	**-187.6371487**
9	**29.7284594**

$$R = 1.2219V - 0.2311V^2 + 0.23951V^3 -0.021009V^4 + 0.0008404V^5 \quad (1)$$

$$V = \sum_{i=0}^{9} W_i = \left(\sqrt{R}\right)^i \quad (2)$$

The matrix pixel analysis is a sub-pixel analysis of a pixel field. Basically, it is the term soft pixel classification that is used for sub pixel classification (Hurvich, 1957). One of the initial steps in this analysis is locating the sub-pixel field within the sub-pixel components. In this case, we used the algorithm *pixel-swapping*. The spatial resolution of all the pixels is divided into the 16 (4x4) cells. For all the sub-pixels we calculate the distance from the major pixel (given in percentage) and denote it with A_i (see Eq. (3)).

$$A_i = \sum_{j=1}^{n} \lambda_{ij} Z(u_j) \quad (3)$$

where n is the number of bordering pixels, $Z(u_j)$ is the percentage and represent the distance within the pixel j , and λ_{ij} is the pixel weight which depends on the major pixel distance (see Eq. (4)),

$$\lambda_{ij} = \exp\left(\frac{-h_{ij}}{a}\right) \quad (4)$$

where h_{ij} is the distance of the sub-pixels (i, j) from the border of the pixel, a is the nonlinear parameter of the exponential model (Levkowitz, 1997).

3.1. Cartographic signs of buildings

On topographic maps for a better perception a cartographer always inputs topographic signs of objects (Muslims, 2006). A point, a line and area marks constitute the primitive building blocks of pictorial representation. The signs on the maps mark the basic graphic elements because they can be used to create all visual designs on the map. The points and symbols are individual signs, usually they are represented like dots, triangles and so on, used to denote a position, the location of a feature and finally present a location for spatial summary data. For example, they include a coordinate location, a tower position or the centroid of some distribution. The line symbols are individual linear signs used to represent a variety of geographical phenomena. Lines usually represent rivers, roads, political boundaries, ocean currents. For instance, contour lines used to represent elevation and sometimes the line of sea depth. Area symbols are markings existing throughout a map area to indicate that the region has some common attributes, for example water, administrative jurisdiction, an area of mixed, coniferous, deciduous forest. Volume symbols represent the vertical or intensity dimension of geo-spatial data through space. In landform mapping for example the terrain surface may be marked with volume symbols. In our case, the building signs have been usually displayed in urban city zones. If a sign is not in the map proportion and projection, it will not be involved in processing. The majority of signs that mark buildings and industrial elements on maps are displayed in the gray scale color system. Their final digitization will produce an entirely new vector map. The total number of all the topographic signs in the urban parts of Belgrade is 234154 (Čolović, 1984). The most frequently used cartographic signs on maps are signs for buildings, building blocks and factories (see Fig.2).

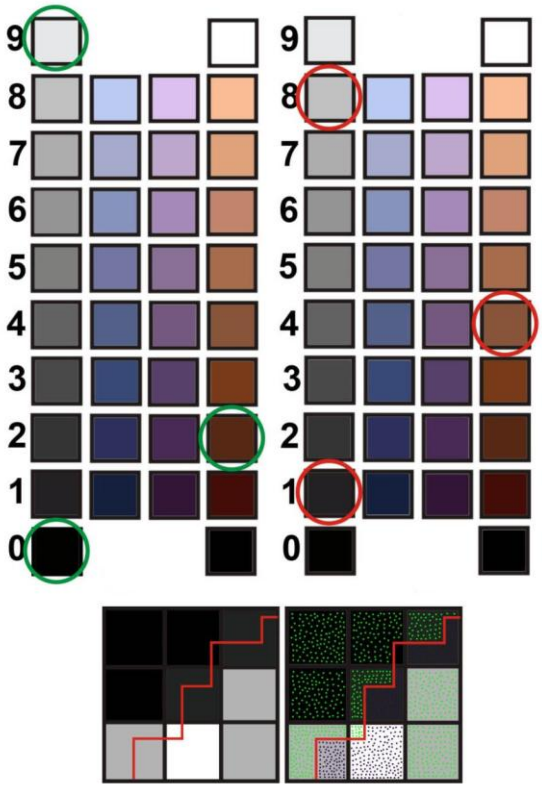

Fig. 1. The chart of the Munsell color model with the three main hues marked with green rings on the all topographic maps in the territory of Serbia. Fig.3b. The chart of the Munsell color model with the three main hues marked with red rings on the topographic maps of the urban area of the city of Belgrade. Fig.3c. Pixel field presented on the topographic map. Fig.3d. Matrix pixel analysis of the pixel field. The figure was generated using the specially created software in JS code for map color properties, AdobePhotoshop and Corel Photo-Pain..

The observed changes of the building density in the central zones can contribute to the conclusions of the fast growth of Belgrade. The data from the map are very important for many sciences dealing with past-based predictions. For instance, such research can be used in urban science for solving the traffic problems in spatially planning disciplines. By using precise techniques, such as the matrix pixel analysis, it is possible to magnify geo spatial data up to the five-meter precision level.

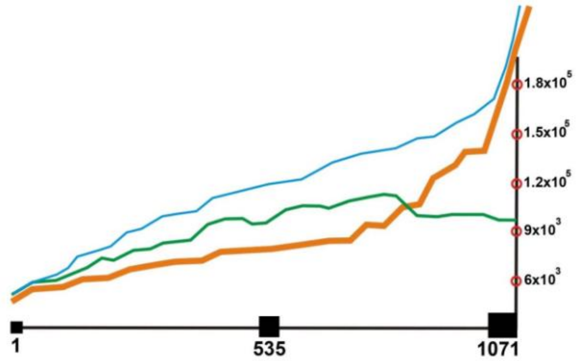

Fig. 2. Color analysis on the maps in the urban part of the city of Belgrade. The brown line is the total index of colors, blue is the color contrast, green is the ratio of color contrast. The X-axis is the number of tested maps, the Y-axis is the number of colors. The figure was generated with CorelDraw.

3.2. Results of software color analysis the Java Script software for map color properties.

Topographic maps in Serbia were made 50 years ago. They are the biggest achievement of the technical cartography era. Today, most of them are scanned and converted into a raster format (usually can be found in jpg, tiff, png extensions and etc). For an application of a matrix pixel analysis, we have created specialized software which evaluates the most frequently used colors on a maps. We have made the software for their analysis in the Java Script Code (JS software for map color properties).The JS software for map color properties explains basic color parameters including luminosity, contrasts and calculate the average color values in the RGB and hexadecimal system (DiBase et. al 1992). The formula for the assessment of the contrast parameter has been tested in a sample bigger than 10^6 of different colors which can be found on topographic maps in raster format. This software gives the color order when the two colors are compared, including the color index, a color map contrast among the map signs and the background and the ratio of color index. The color contrast is obtained by the Pogson Law at a micro level and it shows the color luminosity per pixel, while the Pogson ratio law on macro scales is used for the pixel shine of colors in images (Chen, 1999). The standard RGB color system is presented on the 8-bits color system, and define the 256^3 or 1677216 different colors. The image of the raster format inserted into the software is of the size 500 x 400 pixels or 17.64 x 14.11 cm. It is 29.35 pixels per centimeter. In minimal terms, it is 1x 1 pixels or 0.026 x 0.026 pixels or in maximal terms it is 118.11 pixels per centimeter. The most of the signs have been presented in grayscale hues (Saks,2008), (see Fig.1). This software was tested on the topographic maps of Belgrade and the total area included is equal 359960000m^2, which is at the same time the urban city area. The ringed colors on the Fig. 2a represent the most frequently used colors on the topographic maps of Serbia. Those colors are represented in RGB color system by (1, 1, 1; 84, 41, 24; 229, 229, 229) or (010101; 542918; E5E5E5) in the hexadecimal color system. The ringed colors on the Fig. 2b represent three usually used colors on the topographic map of urban part of Belgrade and that are the following colors (34, 34, 34; 138, 84, 60; 193, 193, 193) in the RGB color system or (222222; 8A543C; C1C1C1) in the hexadecimal color system. The formula for calculating the average color contrast is given in Eq. (5).

$$\frac{(299R_1 + 587G_1 + 114B_1)}{1000} \updownarrow \frac{(299R_2 + 587G_2 + 114B_2)}{1000} \qquad (5)$$

R_1 and R_2 are the values of red in the RGB color system from the first and second map sample, respectively; G_1 and G_2 are the values of green in the RGB color system from the first and second map sample, B_1 and B_2 are the values of blue in the RGB color system from the first and second map sample. The formula of index colors (Eq. 6) typifies the relative luminance for all the signs in the RGB system for the values of red, green and blue.

$$((R_{RGB} + 0.049)/1.035)^{2.5}$$
$$((G_{RGB} + 0.049)/1.035)^{2.5}$$
$$((B_{RGB} + 0.049)/1.035)^{2.5} \qquad (6)$$

$$C_1 / C_2 = \frac{(299R_1 + 587G_1 + 114B_1)}{1000} / \frac{(299R_2 + 587G_2 + 114B_2)}{1000}. \qquad (7)$$

Value C_1/C_2 is given in percentage (C_1/C_2 is multiplied with 100). The results of the complete color analysis on urban Belgrade topographic maps are given in Fig.6. There was observed 47 different parts of the map in ratio 1:25,000 for the urban part of the Belgrade. The average color of these maps is # 542918 in the hexadecimal color system and in the RGB color system (84,41,24). The average color contrast of building objects and the background color on the maps are 580, the index of the average color for building signs is 33.131, of background color it is 228.61.The ratio of average color on the maps when the color of building signs is compared with the background color is 0.86:1.

4. Results and discussion

Complex networks have an important role in many fields of science. These include computer, social, neural, road networks. But, comparing a road network with building density, there can be found the conditions that effect the city growth. A road network usually differs in the angles of major road span, including the length, azimuth, nods, shape and finally the total area. The road network on topographic maps is displayed through different line width and color.

In investigating the road network features, we have analyzed the entire Belgrade road network with the open source software QGIS 2.6. The studied situation of the urban part of Belgrade was observed in 1971. By the 1971 population census the entire number of people in the urban parts of Belgrade was 1209369.The entire road network in city urban and suburban area in 1971 was 4144.536 km^2 (or 4144536000 m^2). The urban area was 359.96 km^2 (or 359960000 m^2). Also, there was 141176 nods. The nod positions indicate the major crossroads of the road network. The main road directions are divided into 14 major directions. For the major road directions we calculated the total azimuth spanning from 0^0 to 360^0. The total azimuth of the suburban and urban part is 167.23^0, while road network azimuth of the solely urban part is 203.34^0. The road network feature presented by the polygon can answer the major roads features. The Belgrade road network is represented by the regular polygon tetradecagon (inner angle is 154.28^0, outer angle is 25.71^0). It is convex, cyclic, equilateral and isogonal. The total road network length in 1971 was 3949.8 km or 3949800 m.

References

Chen, S. 1999. Beta Kernel estimators for density function. Computational Statistics & Data Analysis, 31(2), pp. 131-145.

Chen, S., Hanzo, L., & Wolfgang, A. 2004. Kernel-Based Nonlinear Beamforming Construction Using Orthogonal Forward Selection With the Fisher Ratio Class Separability Measure. IEEE Signal Processing Letters, 11(5), pp. 478-481. doi:10.1109/LSP.2004.826509.

Čolović, M. 1984. Topographic signs.Belgrade: Geographic-Military Institute of Serbia, Military book press., pp. 11-34.

Dibase, D., Maceachren, A., & Kryger, J. 1992. Design in Scientific Visualization. Cartography and Geographical Information Systems, 19(2), pp. 201-256.

Gudmundsson, A., & Mohajeri, N. 2013. Entropy and order in urban streets networks. Scientific reports, 3(3324), pp. 1-7. Retrieved from http://www.nature.com/srep/2013/131125/srep03324/full/srep03324.html

Helbing, D. 2003. A section-based queueing-theoretical traffic model for congestion and travel time analysis in networks. Journal of Physics A: Mathematical and General, 36(46), pp. 593-598. doi:10.1088/0305-4470/36/46/L03.

Hurvich, L.M., & Jameson, D. 1957. An opponent-process theory of color vision. Psychological Review, 64(6, Pt.1), pp. 384-404. pmid:13505974. doi:10.1037/h0041403.

Knežević, A. 2010. Social position, residential problems and characteristics of household and families of Roma population in Belgrade. Glasnik Srpskog Geografskog društva, 90(1), pp. 257-276.

Levkowitz, H. 1997. Color theory and modeling for computer graphics, visualization, and multimedia application.Norwell, Massachusetts: Kluwer Academic Publishers., pp. 27-36.

Munsell, A. 1975. A color notation, 12nd ed.Baltimore: Munsell Color Co.., pp. 131-156.

Muslims, A., Foody, A., & Atkinson, M. 2006. Localized soft classification for super-resolution mapping of the shoreline,. International Journal of Remote Sensing, 27(2), pp. 2271-2285.

Saks, R. 2008. Job creation and housing construction: Constraints on Metropolitan area employment growth. Journal of Urban Economics, 64(1), pp. 178-195.

* E-mail: dragicanbgd@gmail.com