Usability Study on Different Visualization Methods of Crime Maps

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Abstract
There are many GIS applications available on the internet showing crime statistics all over the world. The usual visualization methods for these statistics are generally pictograms representing individual crime locations. The visualization of individual crimes raise two problems: they are not able to transmit the real crime situations to the users, because it is not easy to interpret the content of it; the other problem is that they may harm the confidentiality of the victims. Therefore in this study the author tested the applicability and effectiveness of 3 visualization methods: contiguous cartogram, choropleth maps and graduated symbols. The results shows that each of them can be applicable for this purpose but for solving most complex problems contiguous cartogram method must be improved with using other cartographic variables, also further investigations should be done with nonprofessional people with the other two methods.

1. Introduction

Crime mapping recently has become an important communication platform between citizens and police. This type of visualization of crime data is widespread all over the world. In some countries it is also used among citizens when they would like to buy property, to decide about a school for their children etc. If someone browsing the web the usual visualization method for crime maps is point symbols in Hungary as it can be seen on Figure 1. (Pődör, 2013). Leitner and Curtis (2006) and Leitner et al., (2007) had found that point symbols can be reverse geocoded from maps, and that the preservation of someone's spatial confidentiality depends on population and structure of the neighborhood independently from the scale of the map. From the visualization point of view using point symbols is not a very good solution as spatial patterns cannot be revealed. On the contrary, the public opinion requires that spatial patterns of crime should be available for safety purposes. Therefore it is necessary to test the applicability of other visualization methods for crime maps. Also building a surface using geostatistical methods like kernel density estimation, has been already used (Wolff and Asche, 2009). With using this method spatial differences between blocks become smooth. This method is mostly used in hot spot detection. For citizens it would be interesting to see the spatial patterns in their surroundings, not only the density itself. Therefor the aim of this study is to test other visualization methods for crime mapping. In this context the purpose of this study is to analyze the effectiveness of two common and essential cartographic methods for visualizing quantitative crime statistics referenced to polygon: graduated colors (choropleths) and graduated point symbols, and the rarely used cartogram method. In the study author investigate:

- how these three methods can be applied for visualizing crime data in municipal surroundings and
- how well users can define differences according to the classification used on the maps.
- how well the participants can discover the municipal blocks after distorted to be a contiguous cartogram and whether they are able to see difference in the value of the blocks

2. Methods

The author conducted a series of experiment aiming at analyzing the usability of these three methods. The city of Székesfehérvár was used as a pilot area. The city is a medium sized Hungarian settlement typical for Hungarian cities. Crime statistics show that usually there are 6-7000 crimes happening yearly. In semester 2012, 42 land surveying BSc students participated in the introductory course on Geographical Information Systems. The age of students taking part in the survey was 18 to 30. This semester was the second semester at the university for the 90% of the students. The majority of the test participants did not have the study area of Székesfehérvár as a home town.

This test consisted of two parts (1A, 1B). In the first part the participants got two maps. One of the maps was a geographically undistorted map, as some previous research showed that cartograms only are understood if there is a map showing original spatial reference (Dent, 1975 and Griffin, 1983). On this map all the blocks inside the city were indicated and labelled with an ID number. The second was a cartogram of the same area depicting the same blocks without ID numbers. The student task was to find some blocks using the original and the distorted map. The second task was fulfilled by 12 participants. They had to make a comparison of the distorted blocks. In the second part test persons used the same maps, but the blocks on the cartograms were also labelled. In next semester in 2013, 24 land surveyor BSc students participated in the introductory course on Cartography. The age of students taking part in the survey was 18 to 25. This semester was the fourth semester at the university for 90% of the students. This second test consisted of two parts (2A, 2B). In the first part the participants got the map using graduated colours where the reference polygons were coloured according the total number of crimes, then they should process the second map with graduated point symbols. On both maps all the blocks inside the city were indicated and labelled with an ID number. In the spring semester in 2015 all the test except Test 1B were repeated by 24 BSc students aged between 21-26 years; seven females) from land surveying at last semester (Óbuda University, Alba Regia Technical Faculty Institute of Geoinformatics).

1.1 Preparation of the Test Maps

First the author processed the crime data which was the main thematic attribute of the map. In the test all types of crime data was used. The crime data were geocoded and stored as a point layer. The main purpose was to see how certain areas are affected by all types of crime in the city of Székesfehérvár and how effectively test persons can retrieve information of the cartogram and choropleth and graduated symbols map. Usually contiguous cartograms are used for polygons which are tightly connected, there are no gaps between them, and they are not overlapping each other, so map users can identify them by their spatial locations, they can use the neighbouring polygons as identifiers, too. In preparing the test maps the starting point was that the author created polygon blocks using the street network. Then applying spatial join between crime data and polygon blocks of the city, crime data became the attribute of the polygon blocks. The structure of the city is irregular. In the inner city a medieval part has narrow streets, but also blocks of houses are located there. This structure causes a lot of irregularly shaped polygons with a great variety in size, though regular forms are also presented. Not the entire city was used in the study. There were 724 blocks of polygons appeared on the maps. The maps were prepared in ArcGIS at a scale of 1:20000. The contiguous cartograms were created by ScapeToad Software which is using the Gastner and Newman diffusion algorithms (http://scapetoad.choros.ch) in case of test 1B. Colour was used to help to discover the polygon blocks on the test maps, but it was not involved as a graphic variable. In the case of test maps 2A, 2B the same Jenks classification method of natural breaks was used, and the data were sorted into 5 categories in order to be able to compare the result. The 5 categories were: 0-14; 14-46; 47-119; 120-270; 271-736. On 2A (Figure 4.) the "Orange Bright" colour range was used. On 2B (Figure 5.) graduated symbols were coloured by dark blue and the symbol size varied from 4 to 20 points.

2.2 Experimental Task

In the case of each test the participants conducted the experiment in a computer lab. In the first test the participants had to identify 8 blocks, indicated on the original map of the inner part of the city. There were a total 724 blocks of polygons on the test maps. The test blocks were in different areas and with different degrees of distortion on the cartogram. The original blocks had different shape and size also. Two out of the eight had regular geometric shape (Figure 2) the highest number of crime per blocks was 1434, the lowest was 0. The test time allocated was a maximum of 20 minutes. The second test consisted of the same map, and the blocks on the cartograms were labelled with their ID number. The participants had to identify 5 of those blocks which suffered the biggest distortions, thus crime is the highest and they also had to arrange them in ascending order. The legend of the cartograms was not included on the map, so students had to estimate the degree of distortion (Figure 3). The purpose of the test 2A and 2B was to simulate the experimental phases when users studying the structure of crime map and they try to reveal information connected to spatial patterns. An e-learning platform was used to store the maps, also the test participants had to upload their results to that platform. The test participants took from a minimum of 17 to a maximum of 68 minutes. In the test they had to study 2A and when they were finished had to continue with studying 2B. In the test their task was to define five polygons using the ID number of the polygons written on the maps within each classification category used on the maps.

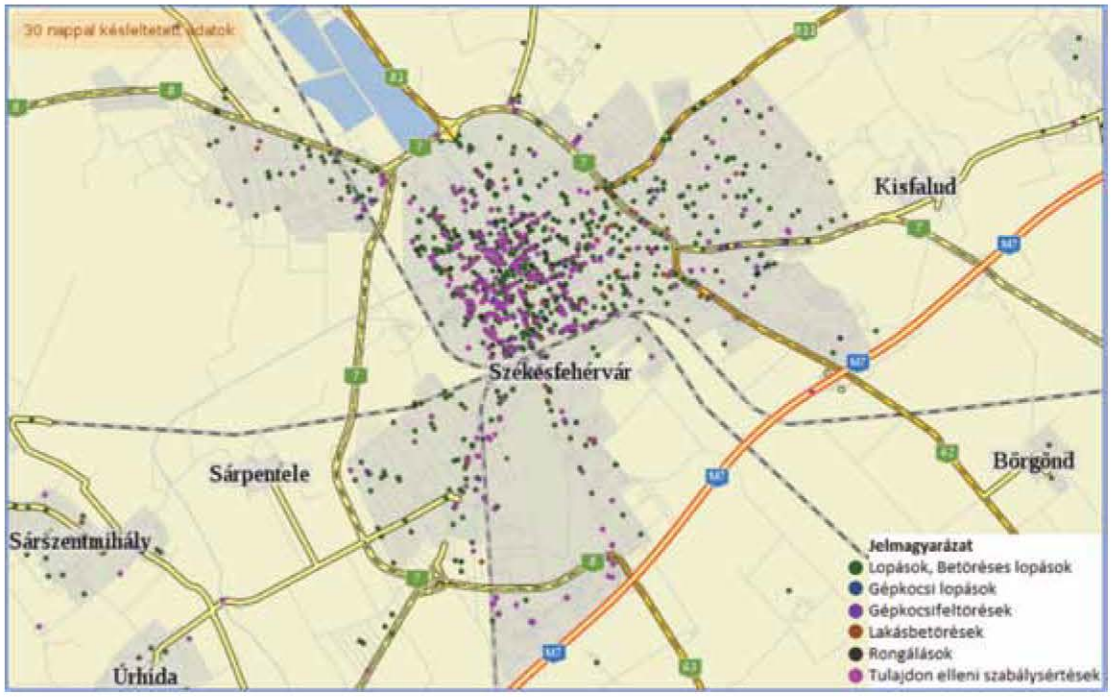

Figure 1: Hungarian interactive crime map (source: www.police.hu)

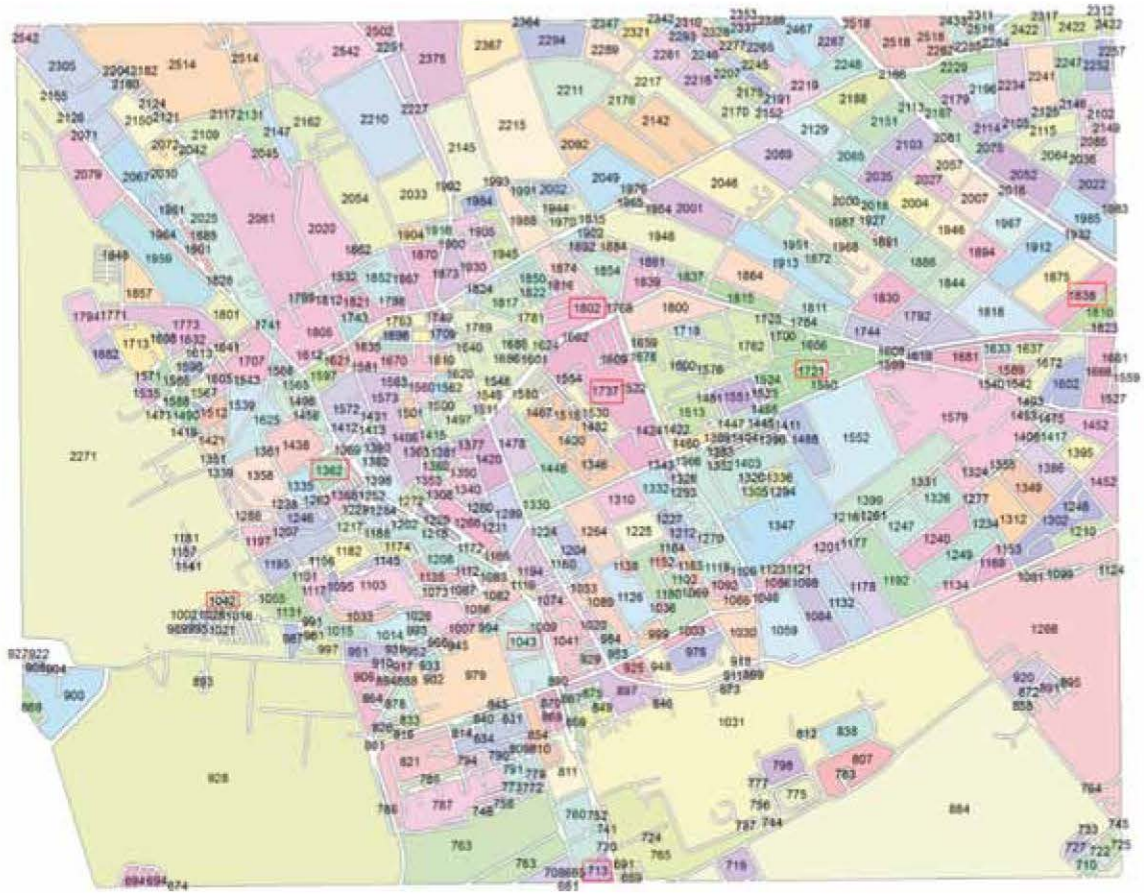

Figure 2: Map 1A

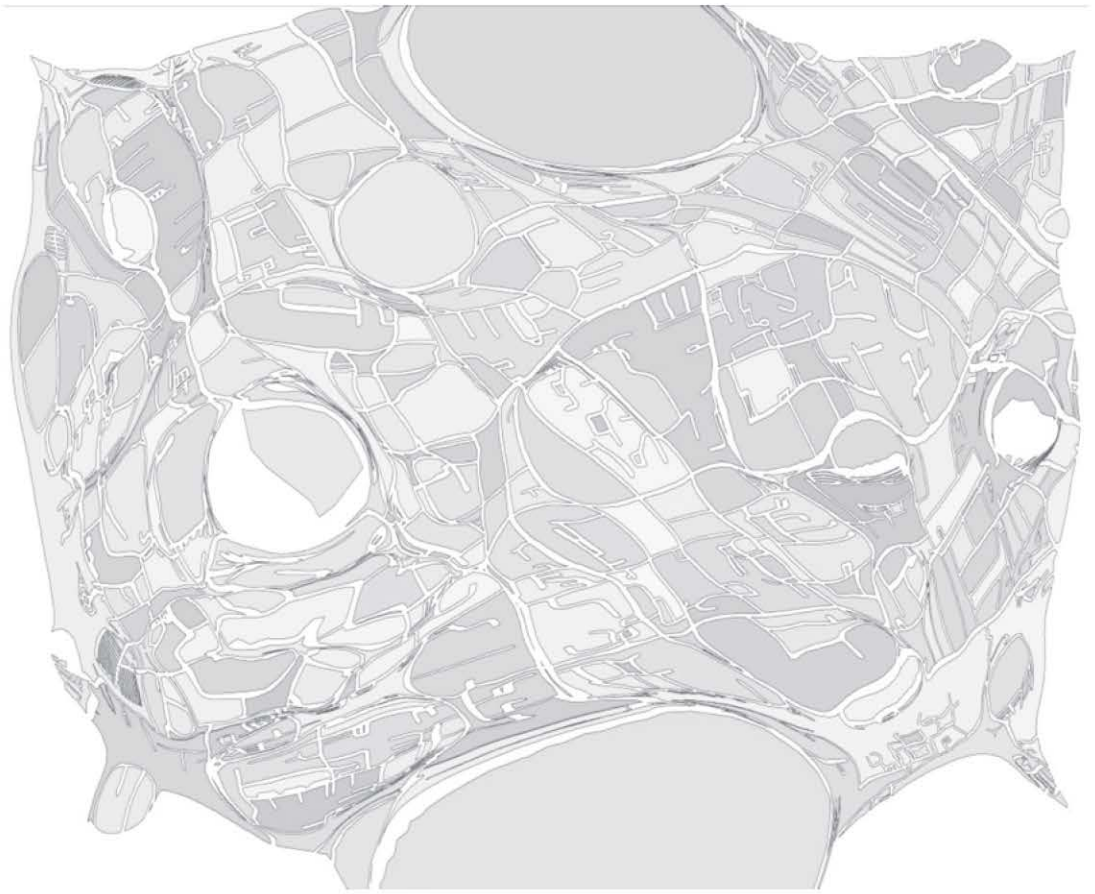

Figure 3: Map 1B

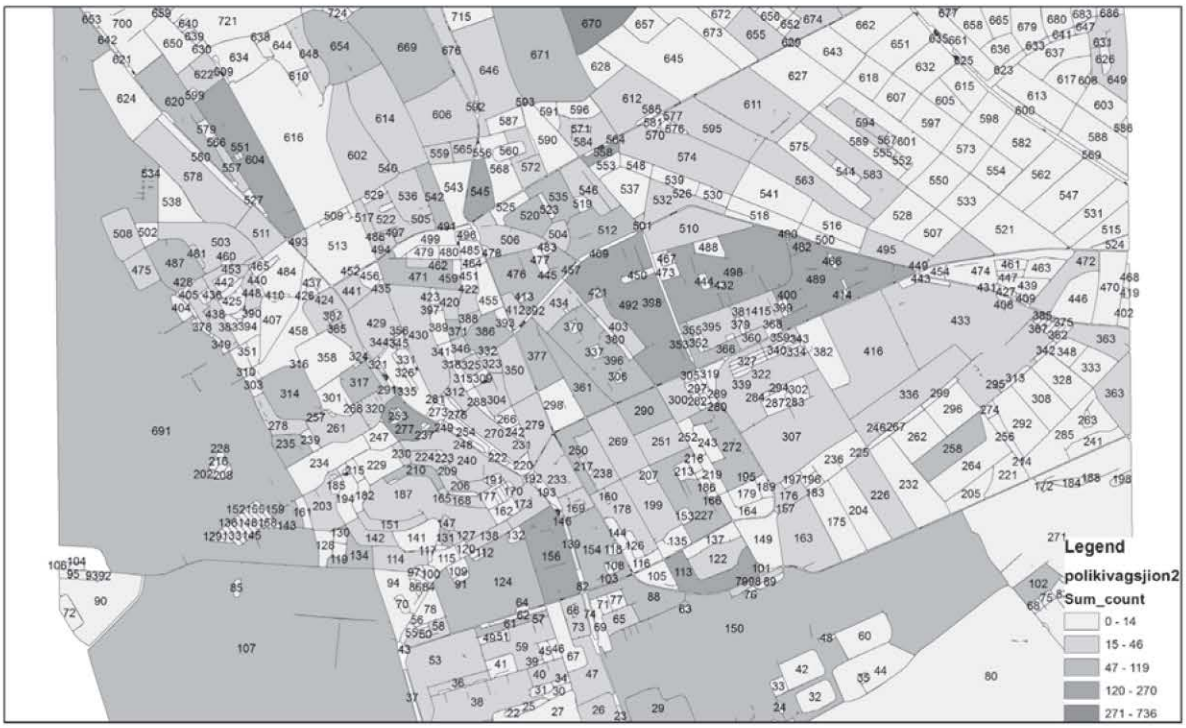

Figure 4: Test map 2A

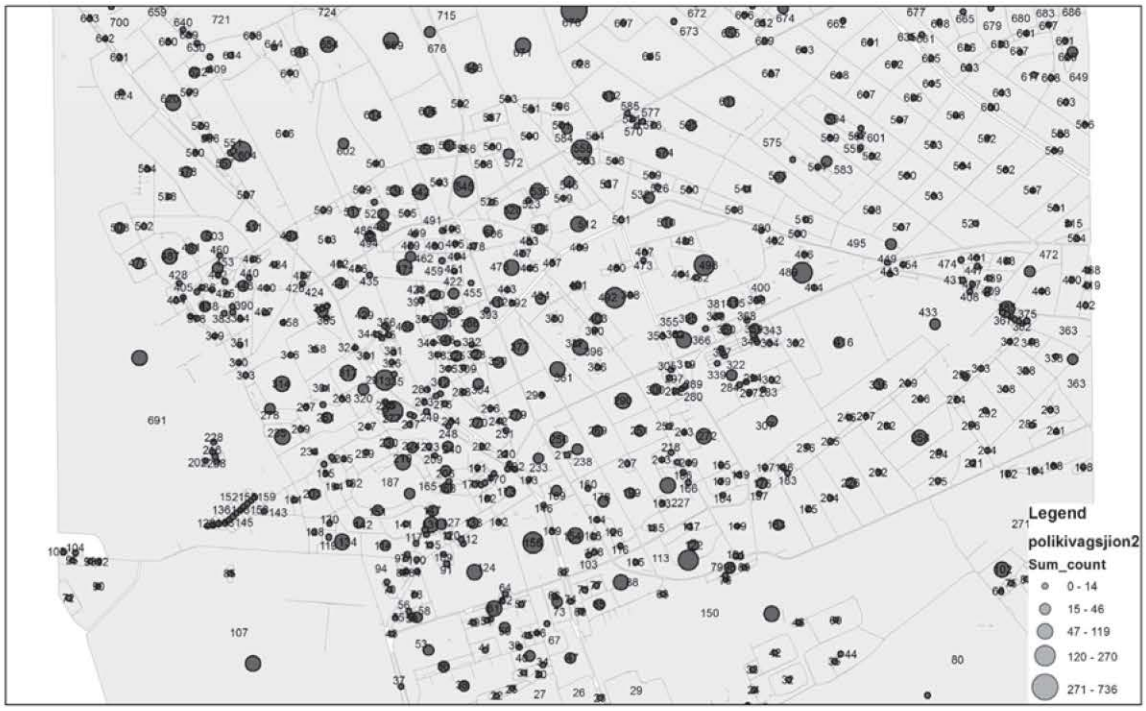

Figure 5: Test map 2B

They had the freedom to choose any polygon was classified into a certain class according their number of crimes. On the 2A map they could use the colors as a graphic variable to identify each category and discriminates between polygons, on the other map they could refer to the size of the symbols generated according to the previously mentioned classification method. In the case of the second map with graduated symbols showing the quantities, the maximum and the minimum size of the symbols were dependent on the size of the blocks inside the city. As it was mentioned before the sizes of the blocks were distributed over a great variety and therefore could not be too much difference generated in the size of the symbols, because the most crime are usually occurs in the inner cities where blocks are relatively small.

3. Results

The results of the first type of test clearly indicates as another researcher detected (Dent, 1975), in the case of contiguous cartograms most of the students could identify the given polygons, even though on the test map they had to choose from more than 700 polygons differing in size and complexity. 69% of the students could identify almost all the polygons, 16% of the students had found only 1-4 polygons on cartogram map in 2013. After repeating this test in 2015, the results showed that around 79% could identify almost all polygons.

The result of test 1B (Table 1), where students had to choose the five most distorted polygons, shows that only the biggest distortion was unambiguous for the students, Although most of them recognized the most distorted polygons, none of them could arrange them in the right order. The results of the overall performance of each participant can be seen on Figure 6. Investigating the simplest statistical values of the two data files, it is evident there are big similarities between them. Concerning mean values in case of 2A it is 68 in 2013; 91 in 2015 in the case of 2B it is 71 in 2013 and 82 in 2015. Also the values of standard deviations are quite close to each other 24,43 in case of 2A in 2013 18, 59 in 2015 and 24,46 in case of 2B in 2013 and 22,26 in 2015. If we analyze in detail both results we can see that in case of 2B there were 7 persons in 2013 and 14 in 2015 whose scores was above 95%, although in case of 2A only 4 of them in 2013 but 12 in 2015 were able to reach this result. Analyzing the personal performance of the test persons the result is very interesting because it shows that only 3 persons were able to fulfill both task at the same level, which means that only 3 persons were able to produce the same results in both tasks in 2013 11 persons in 2015, others completed the task with different effectiveness, almost half of them were more successful with the graduated colors method in 2013 (Figure 7.) and more than the half in case of the test in 2015, the others were more efficient with graduated symbols method.

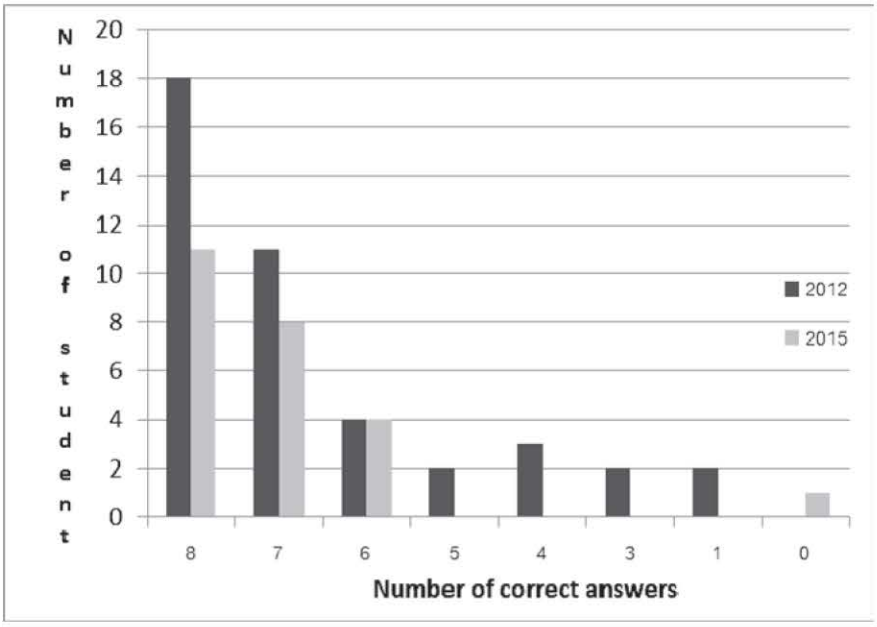

Figure 6: The result of matching task of 8 polygons between original and distorted

Table 1: The result of sorting the most distorted poligons into descending order

ID number of the polygons suffered from the highest distortions in ascending order	Nr. of students who ranked the given polygon on the right order	Nr. of students marked the given polygon among the most distorted polygons independently from the hierarchy
713	4	11
2211	2	11
1311	3	8
1721	1	3
1873	0	10
1737	0	0
948	0	5
2271	0	2
2025	0	1

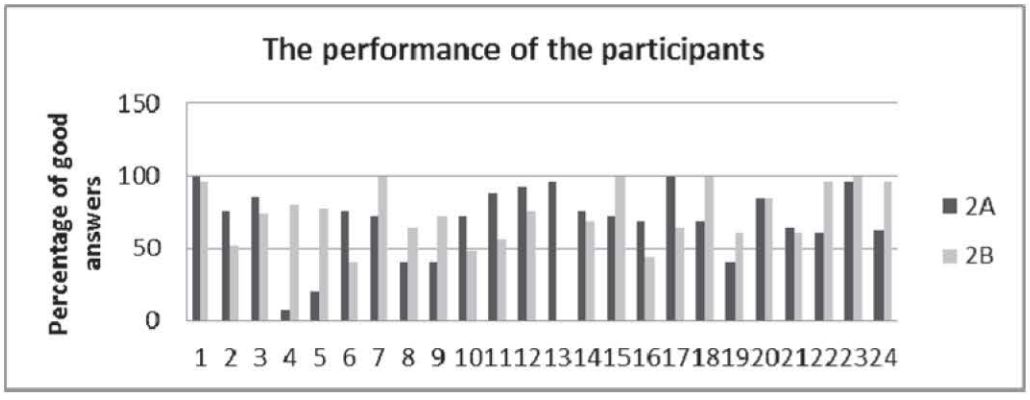

Figure 7: Comparison of the results of the test participants in 2A and 2B test in 2013

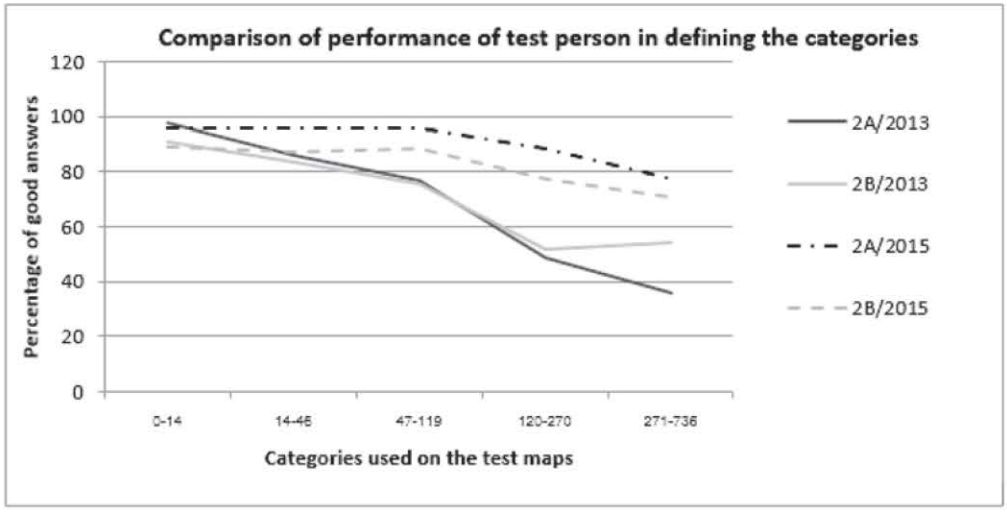

Figure 8: Overall results of the identification of different categories on the test maps

In 2015 graduated colours were more effective among students, but most of the students who were successful in test 2A also perform well in test 2B. The explanation behind this is that they were more trained in their last semester that students in 2013. If analyzing the effectiveness of the test participants with defining the different categories, it can be seen that 2A proved to be a little bit more effective in the case of small quantities, on the contrary in case of high values of crime graduated symbol methods (2B) could be more helpful for analyzing the map for the participants. For the participants the task of identifying small values first and second categories on the maps proved to be the easiest task. As we can see from Figure 8 the higher the values of crime statistics on the map, the lower the performance of the test participants.

4. Conclusion

The results of tests justifies that contiguous cartograms can be a good solution to visualize crime statistics. The test verifies that in the case of more complex structured cities like Székesfehérvár, where the shape of the blocks are irregular, this method also can be employed, but it is evident that additional graphic variables must be applied in visualizing crime statistics. At the case of a more complex task, like ordering polygon blocks by their distortion, the results supported the hypothesis that it is very difficult for nonprofessionals to identify the differences. The results of test of more traditional methods identified some essential problems in visualizing crime data. As analyzing the result of the experiment it can be clearly seen that with higher values (with more crimes) it was more difficult to identify the categories on maps although in this case, from the two tested methods, graduated symbols proved to be more effective, so this second finding support the idea of using contiguous cartograms in visualizing crime combining with the method of graduated symbols can eliminate the uncertainty in identifying differences between degrees of distortions and the usage of symbols or colors as a graphic variable would improve the results. The results also indicate that the combination of other visualization method with the tested ones can be a good solution in visualizing crime data on blocks in the cities. The findings of the research support the idea that it is worth to substitute the usual point symbolization method with other cartographic visualization. These methods prevent reverse geocoding and allow users to reveal spatial patterns and crime in the city.

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