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Mapping election results in proportional electoral systems

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ABSTRACT
The paper presents a technique for efficient visualisation of election results in proportional electoral systems. Three cartographic methods (cartogram, inward-oriented buffer and proportional striping) are combined to produce a static map that gives an overview of the distribution of voting power, the electoral abstention and the election results. Unlike the conventional design that shows only the winning subjects, the proposed technique allows reader to analyse the results within a district as well as in the context of the whole country. Regional differences and patterns not present on conventional election maps can be observed. The proposed technique is demonstrated on a map of Slovak parliamentary election held in 2012.

1. Introduction

Maps are a major tool for depicting election results in countries with various electoral systems. A conventional election map, produced either by a national statistical office or media, employs colour hue to indicate the winning subject in each electoral district. Despite certain perceptual limitations, this method works reasonably well for *majority electoral systems*. For example, a map of the UK general election gives a quite precise idea about the composition of power resulting from the election. The winner in a constituency becomes a member of parliament; therefore the number of seats gained by a party can be established from the election map simply by counting constituencies of the corresponding colour.

The aforementioned method is far less adequate for *proportional electoral systems*. In such systems, winning in a particular district is not as important as the number of gained votes. In parliamentary elections, the party that won in the majority of districts is often unable to secure the majority in parliament against the coalition of other parties. The number of votes gained by parties in each district is therefore an important fact that is hidden on conventional election maps.

In an attempt to address these limitations, I propose an alternative technique that combines three cartographic methods to produce a static map that:

- shows the number of registered voters in every district,
- shows the turnout in every district and
- shows the proportion of votes gained by individual political subjects in every district.

The proposed technique is demonstrated on the map of the results of Slovak parliamentary election held in 2012.

2. Related work

Electoral cartography has often been a forefront of innovative approaches to map design. However, the specific problems of visualising election results in proportional electoral systems have not been fully examined, perhaps because English-speaking countries, which produce the majority of cartographic literature, predominantly use majority electoral systems. This does not mean that election maps have not been a subject of thorough critique, mostly pointing out the under representation of population on conventional election maps. The second branch of critique is concerned with ways to visually represent parties that ranked below the winner.

The issue of underrepresented population on (not only) election maps was articulated in Dorling (1993), together with a suggestion for improvement:

> By trying to minimise visual bias, cartograms can be claimed to have advantages in census mapping, being more sensible statistically and more just socially. This is because, theoretically and respectively, every elector's vote is equally important to the outcome of an election (…). If you believe that every individual's circumstance is equally important in the spatial make-up of a society, then you should use area cartograms in mapping census data (pp. 171–172).

Dorling proposed his own method for creating cartograms based on scaled circles in (1996), which he demonstrated on elections data. The same paper contains a concise history of cartograms, revealing that

they are coupled with elections from the early algorithmic beginnings – for example, the physical accretion models by Hunter and Young (1968) were inspired by cartograms of British general election results drawn in the *Times Newspaper* in 1964 and 1966.

Visualisation of election results is regarded as a suitable use case for applying cartograms and several authors have done so to demonstrate their algorithms, including Dougenik, Chrisman, and Niemeyer (1985) and Gastner and Newman (2004). The visual parameters of contiguous cartograms were criticised by Roth, Woodruff, and Johnson (2010), who also proposed an alternative method based on using transparency as a visual variable, again using elections data for demonstration purposes. Rectangular cartograms that provide more schematic representation of regions can also be used to visualise election results (Heilmann, Keim, Panse, Sips, & others, 2004; Kreveld & Speckmann, 2007).

The issue of displaying more than the winning party is highly relevant for proportional electoral systems. For this purpose Long, Lovitskii, and Thrasher (1993) devised a method called *drill-down map*. By manually creating copies of district polygons, scaling them down and placing them on top of the original districts, they are able to display the three most successful parties in each region. The level of downscaling corresponds with the proportion of votes gained by the parties. This method is relatively sufficient in the context of UK general elections that served as an example in the paper, but it cannot scale further beyond three depicted parties.

Stoffel, Janetzko, and Mansmann (2012) proposed an algorithmic extension of the solution by Long et al. (1993). They employ polygon scaling only once to show the first two parties in rank as well as the difference in the number of votes between those parties. If this difference is too subtle, the second party can visually dominate the map. To moderate this problem, authors apply a bipolar colour gradient and reduced colour brightness. Both scaling approaches, by Long et al. (1993) and Stoffel et al. (2012), are in principle similar to non-contiguous cartograms by Olson (1976), although there is no direct reference in none of the two papers. The outputs are also akin to the 'structural cartogram' method by Kudrnovská (1964) that served as a model for the inward-oriented buffer technique used in this paper.

Additional complexity arises with a requirement to visually compare several elections in a time sequence. Healey (2014) compares US presidential elections by dividing each constituency into four parts (to visualise four elections). For each subdivision, colour hue represents the winning party and colour saturation the percentage of votes gained by the winner. Incumbent losses are highlighted using texture, and 3D visualisation depicts the voting potential.

It is generally believed that the cognitive limits of visualisation methods can be overcome in the virtual environment by adding interaction. There is a breadth of examples of interactive election maps from the Internet media, notable examples including C.Fardel, Clarke, Nardelli, Straumann, and Zapponi (2015) and Cox, Bostock, Watkins, and Shan (2014). The interaction allows readers to view the underlying numerical data, but the experience of the overall spatial pattern still depends on classic cartographic techniques.

3. Study area and data overview

The proposed technique is demonstrated by mapping of the results of Slovak parliamentary election, held on 10 March 2012 (see the Main Map).

Slovakia is a semi-presidential democracy with a single house parliament of 150 seats. A proportional electoral system is employed for the country's parliamentary elections (more precisely, it is a list proportional representation system using droop quota with largest remainder method for distributing remainder seats, Bormann & Golder, 2013). For statistical purposes, the country is divided to electoral districts; however, the results are summed for the whole country as for a single constituency.

Electoral data used for the map (the number of registered voters, the number of valid votes and the number of votes gained by individual parties) come from the Statistical office of the Slovak Republic (2012). Statistical districts were chosen as territorial subdivisions providing suitable granularity for the resulting map. The district outlines were taken from the Open Street Map project via OZ Freemap Slovakia (2013).

4. Methods

The resulting map combines three cartographic methods: the *cartogram* for depicting the number of registered voters, the *inward-oriented* buffer for depicting the turnout, and the so-called *proportional striping* for depicting the amount of votes gained by parties.

4.1. Cartogram for depicting the number of registered voters

When mapping social or economic phenomena, not only the base map provides topological information on how spatial units relate to each other, but also determines the perception of the overall spatial pattern. The visual weight of a unit on such map is given by its area, even though the physical extent bears no relevance to the mapped phenomenon. This has been criticised by Dorling (1996), who called for increased usage of cartograms for statistical mapping.

Conformal projection ▪ = 10 km2

Cartogram ▪ = 10 000 people

District A (Bratislava II)   District B (Medzilaborce)   District A (Bratislava II)   District B (Medzilaborce)
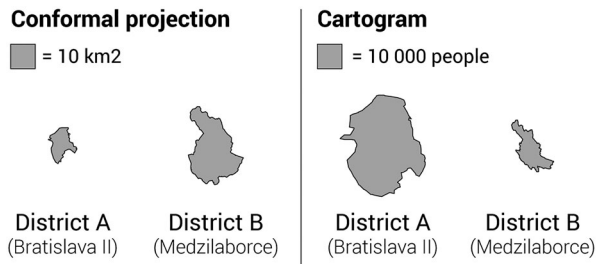
Figure 1. Comparison of two selected districts on conformal map and on cartogram. The latter gives prominence to districts with higher voting power.

A cartogram is a customised map projection that adjusts area or distance to reveal patterns not apparent on a conventional base map (Gregory, Johnston, Pratt, Watts, & Whatmore, 2011). A subtype called a *contiguous aerial cartogram* (sometimes also a density-equalizing map) transforms the base map so that the size of each enumeration unit corresponds to the value of selected attributes. For the purpose of this study, I applied the algorithm developed by Gastner and Newman (2004) to transform the base map in order to reflect the distribution of registered voters.

In proportional electoral systems, the number of registered voters in a particular district determines the potential of such district to influence the overall election results. In case of Slovakia, where voters are registered automatically according to their permanent residency, the number of registered voters approximately equals the adult population of a district. Figure 1 shows a comparison of two selected districts on a map using conformal projection and on a cartogram based on the number of registered voters. It is clear that the cartogram shifts the reader's attention towards areas with higher voting power.

4.2. Inward-oriented buffer for depicting turnout

Electoral abstention is a form of institutional criticism that must be taken into consideration when analysing political preferences of population. This factor is typically visualised separately from election results, usually by using a choropleth map. In an attempt to bring all the important statistics together into a single map, I utilise inward-oriented buffers to visualise the turnout.

The principle of this method is to draw an isoline inside a polygon in constant distance from the polygon border. The isoline divides the polygon into two parts and the size ratio between the inner and outer part is derived from the mapped data. This method was used in the Atlas of Czechoslovak Socialist Republic (1966) to show the proportion of urban and rural population, theoretically it was described by Kudrnovská (1964) under somewhat misleading title 'structural cartogram'. From the geographic information

systems (GIS) point of view, this is essentially an inward-oriented buffer with the width based on polygon attributes.

In the proposed design, I use the cartogram as an input for the inward-oriented buffer method. While the district area represents the number of voters, the buffer creates an inner polygon with an area representing the number of valid votes. In other words, the inner polygon is the subset of registered voters that attended the election. By comparing the size of the inner polygon to the original polygon, the reader should be able to assess the turnout in a given district.

4.3. Proportional striping for depicting election results

The final step of the proposed procedure is to partition the pool of votes represented by the inner polygon in a way that the size of each part equals the number of votes gained by the corresponding party. It would be possible to create additional inward-oriented buffers to further subdivide the inner polygon (similarly to Long et al., 1993). However, a different method was chosen – the inner polygon was divided by horizontal lines – in order to maintain readability.

To create subdivisions of a specified size from an irregular shape is not a trivial task. The implementation of such algorithm was unavailable at the time of writing, except for a tool by ViaMap, Ltd. (2015) that unfortunately failed to produce accurate results for the high number of partitions. To work around this problem, I converted the inner polygons into raster data format and applied a pixel-counting technique to create subdivisions of accurate size.

5. Discussion and conclusions

This paper proposes a technique for mapping election results in proportional electoral systems. The aim is to comprehensively visualise the relevant information so that the resulting map becomes an accurate snapshot of political climate at the moment of election. All three applied methods have certain disadvantages that may obstruct map reading. The severity of such issues largely depends on the nature of input data and can be moderated by good cartographic decisions.

In some studies, cartograms scored lower in cognitive efficiency tests compared to more established forms of visualisation (Nusrat, Alam, & Kobourov, 2015; Reyes Nuñez & Juhász, 2015; Sui & Holt, 2008; Sun & Li, 2010). It is questionable to which degree this result is caused by the lack of familiarity of the tested subjects with the method that is not yet widely adopted in atlases or public presentation. The algorithm by Gastner and Newman (2004) used for creating a cartogram in a Main Map provides a good level of shape preservation, a side map was added to ease the
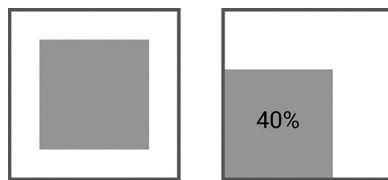
Figure 2. The central position of the inner part influences the reader's ability to assess its relative size compared to the larger square. The effect is stronger for more complex shapes.

identification of districts. A conventional election map was also included to enable comparison of distorted districts with their more familiar shape.

An alternative technique that attempts to deal with the same issues as cartogram is the *dasymetric method* (popularised by Wright (1936); see Mennis (2003) for application in population mapping). Dasymetric maps display statistical data in meaningful spatial zones (Eicher & Brewer, 2001). For example, population data can be projected onto a built-up area. This approach can be more effective than a cartogram, especially on the city scale. However, it is not usable in our case as the physical extent of settlements in Slovakia is relatively small compared to the country's area, which would make the final map mostly blank.

The inward-oriented buffer has not yet been tested for cognitive efficiency, but as humans visually estimate areas poorer than lengths, some assessment issues may arise, especially with complex shapes. Figure 2 illustrates that the central position of the smaller shape makes it harder to estimate its size in relation to the lager shape. On the other hand, the blank space created by the buffer helps to distinguish inner polygons from each other. Furthermore, the turnout in the 2012 election was relatively uniform, so the input data did not contain a notable variability for the method to depict.

In comparison with the so called *projector cartogram* method by Olson (1976), which produces visually similar results, the inward-oriented buffer permits no overlapping of the transformed areas and works reasonably well with the perforated regions (see Figure 3 for comparison). On the other hand, the inward-oriented buffer is highly vulnerable to self-intersection that leaves the inner polygon fragmented into several parts. Self-intersection usually appears in

irregular shapes that contain bottlenecks or highly convex parts, which are more likely to occur when employing a cartogram as a base map.

The horizontal proportional striping is naturally less effective for the polygons which are significantly stretched in the horizontal direction. This is not the case for the majority of districts on the Main Map, but for a different study area, vertical stripes could be used as an alternative. Different angles are also possible, but the orientation of stripes should be consistent across the map. Although high quality rasters were used for the pixel-counting method, individual pixels may still be perceivable on closer inspection, especially on stripe borders where small 'steps' may appear.

Similarly to the inward-oriented buffer, cognitive efficiency of proportional striping has not yet been tested. Cognitive testing for the proposed combination of methods also remains a topic for research in the future. Given the high information saturation of the resulting map, a breadth of experimental tasks could be derived for usability research.

Despite the above mentioned difficulties, the proposed combination of methods should allow for grater analytical insight, uncover regional differences and support advanced comparisons between regions. Unlike conventional election maps that have merely the illustrative function when it comes to proportional electoral systems, the Main Map has the following advantages:

(1) The reader is aware of the distribution of voting power across the country.
(2) The reader has an approximate notion of turnout in every district. In the case of 2012 election, the turnout was quite uniform, which is visible on the Main Map.
(3) The reader can compare the results of parties within the district. When focusing on a district separately from its surroundings, it can be interpreted as an irregular pie chart with horizontal rather than radial cuts. The proposed technique is not limited in the number of parties it can depict (unlike Long et al., 1993, with three and Stoffel
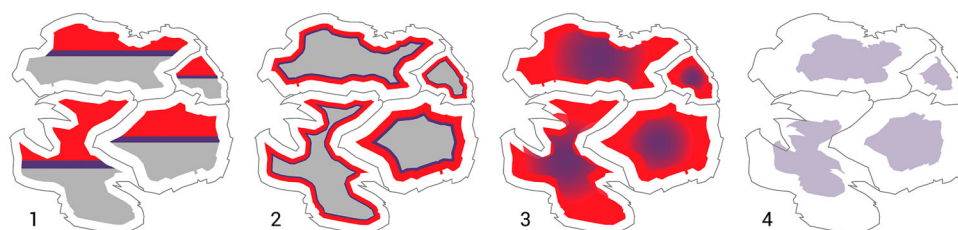

Figure 3. Maps 1–3 show the first two parties in four districts of the Košice city (red – winner, blue – 2nd place, grey – others); similar visualisation methods are compared: (1) approach proposed in this paper, (2) Long et al. (1993), and (3) Stoffel et al. (2012). All three maps use inward-oriented buffer to depict the turnout – map 4 demonstrates the problems arising when employing the method by Olson (1976) for the same task.
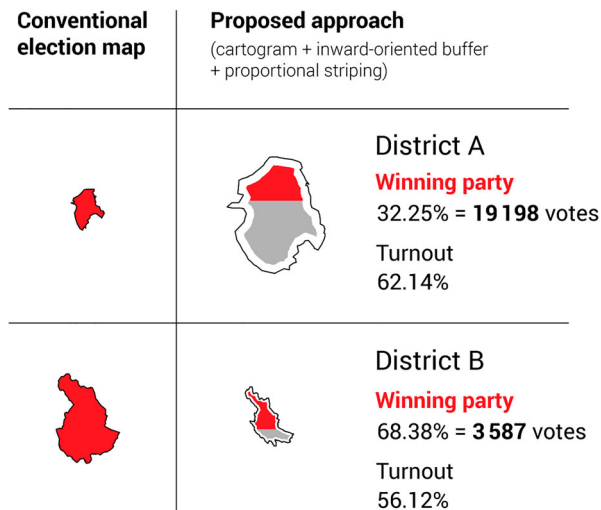
Conventional election map	Proposed approach (cartogram + inward-oriented buffer + proportional striping)

District A
Winning party
32.25% = **19 198** votes
Turnout
62.14%

District B
Winning party
68.38% = **3 587** votes
Turnout
56.12%

Figure 4. Districts from Figure 1 after applying all three proposed methods compared to conventional election map. For the winning party, the 32.23% gain in district A is much more valuable than seemingly higher gain in district B. This fact is not indicated by the conventional election map.

et al., 2012, with two parties – see comparison in Figure 3). Also the discrete stripes are easier to interpret than the colour gradient employed by Stoffel et al. (2012).

(4) The reader can observe the relationship between absolute and relative results. As demonstrated in Figure 4, small proportion of votes in a large district can help the party more than dominance in a small district.

(5) The reader can observe the variability of results for parties across the country. If we regard the horizontal stripes as proportional symbols, the map can be seen as an amalgam of proportional symbol maps for each party. This way we can observe regional differences in support. For example, the parties oriented on voters of Hungarian nationality (MOST-HÍD depicted in orange and SMK-MKP depicted in dark green) have the highest prominence in southern districts where this minority is concentrated. This is clearly visible in the Main Map.

The 2012 Slovak parliamentary election was unique because of the exceptionally convincing victory of the social-democratic party called SMER. The conventional election maps (see the side map in the Main Map) may suggest that the country is almost unified in its political preferences. This is however far from being the truth as the country's political landscape is more fragmented than ever before with the record number of 26 parties contesting the election (the Main Map shows just the 8 most prominent and sums the rest under the label of 'others'). Together with a relatively small turnout of 59.11%, we have much more complex picture of Slovakia in 2012. The

proposed technique hopes to provide a representation closer to reality that could support meaningful interpretation of election results.

Software

Scape Toad version 1.1 (Andrieu, Kaiser, & Ourednik, 2008) was used for cartogram creation and QGIS version 2.8 (QGIS Development Team, 2015) with BufferByPercentage plug-in version 0.2.3 (Dugge, 2014) was used to generate inward-oriented buffers. Esri ArcGIS version 10.3 (2015) was then used to calculate and draw the proportional striping.

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