# Proportions in Categorical and Geographic Data: Visualizing the Results of Political Elections


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## ABSTRACT

Colorpleth maps are commonly used to display election results, either by using one distinct color for representing the winning party in each district or by showing a proportion between two parties on a bi-polar colormap, for example, from red to blue representing Republicans vs. Democrats. Showing only the largest party may disable insights into the data whereas using bipolar colormaps works only reasonably well in cases of two parties. To overcome these limitations we introduce a new technique for visualizing proportions in such categorical data. In particular, we combine bipolar colormaps with an adapted double-rendering of polygons to simultaneously visually represent the first two categories and the spatial location. Our technique enables the recognition of close election results as well as clear majorities in a scalable manner. We proof our concept by applying our technique in a prototype implementation used to display election results from the U.S. Presidential election in 2008 and elections of the German Bundestag in 2005 and 2009. Different interesting findings are presented, which would not be recognizable when visualizing only the winner. As we additionally represent the party with the second most votes, we are able to show changes in the spatial distribution of the votes as well as outlier regions with exceptional results. Our visualization technique therefore enables valuable insights into categorical data with a spatial reference.



## Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval; I.3.3 [**Computer Graphics**]: Picture/Image Generation

## Keywords

Visual Analytics, Information Visualization, Data Mining, Knowledge Discovery


## 1. INTRODUCTION

Communicating the results of political elections is a difficult undertaking since there is no straight-forward way of showing proportions of categorical data on a map. In some cases, relating this back to the election results of previous years even adds more complexity to it. Current analyses therefore mostly focus on certain regions of interest by highlighting continuity or significant changes. More advanced approaches for visualizing elections results either use cartograms or bipolar colormaps or combinations of both approaches. But cartograms distort the geographic topology noticeably and bipolar colormaps only work well for at most two categories since the neutral color cannot be differentiated well enough for more than two categories.

In this paper, we introduce a novel visualization technique, which can be used to display proportions in categorical data with a spatial reference. The core of our technique is to duplicate polygons of a map, scale them, color them using a gradient and overlay them on top of the original polygons. As a result, we obtain a visualization of the first and second ranked category for each polygon, which is able to convey meaningful patterns in election results and scales to a large number of polygons. Depending on the application and the data set, our technique can significantly improve visual analysis compared to existing methods by including not only, but at least two categories in the visualization. This is exemplified in the application section, where we gain insights from our visualization, being not available in traditional election visualizations.

The proportions of parties, or more generally, of different categories can be expressed as a type of comparative visualization in our application scenario, since we show the party which has won the election in a specific area and the difference of the election result towards the party with the second most votes. This kind of comparison is typically not displayed in election result visualizations, despite the fact that it is inherently contained in the data and possibly leads to further insights regarding the actual political balance of power. With our technique, we can show and identify trends or changes in the political distribution of the election results, which are not visible otherwise.

At first, we examine in section 2 the related work dealing with public data, such as election results, in particular with respect to geography and election result visualization. The third section presents our technique in detail and reasons about our design choices. Our method is implemented in a prototype presented in section 4. In this section our technique is applied to visualizing the results of the U.S. presidential elections in 2008 and to the outcome of the elections of the German Bundestag in 2005 and 2009. Afterwards, we discuss the properties of the proposed technique and compare it with a visualization based on glyphs, which shows the same data, but in a different way. Finally, we conclude our paper by summarizing our contribution and giving an outlook to future work.



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## 2. RELATED WORK

Public data exploration has recently received considerable attention both from the research as well as from the public side. Projects such as IBM's *Many Eyes* [15] allow their users to upload new datasets, visualize these or already existing datasets with a variety of common visualization techniques and to publicly discuss findings in web forums. The Google *Public Data Explorer* has its focus less on communication, but mostly on the data side. Users can select from hundreds of detailed data sets and visualize details out of them with line, bar and map charts as well as scatter plots. A nice feature is the animation interface for trend analysis in non-temporal visualizations (e.g. animated maps and scatter plots). In 2010, the New York Times launched a geographic interface for exploring the 2005 and 2009 U.S. census data sets in the project *Mapping America: Every City, Every Block*. The multi-resolution interface allows gaining a nation-wide overview as well as going into the details of a particular neighbourhood.

Geographic visualization has a long tradition and has been extensively studied. Books such as *Exploring Geovisualization* [1] or *Exploratory analysis of spatial and temporal data: a systematic approach* [3] give nice overviews of the field for the interested reader. Cartograms [7, 13] have been used to compensate for the discrepancy between dense and sparse areas w.r.t. the visualized geo-referenced data using map distortions. Furthermore, there exist a number of pixel-based spatial visualization techniques for demographic data (e.g., [10, 2]) that aim at showing every single data point by distorting the original map.

Election results have been visualized in a number of ways, for example, in Polaris [12] using a drill-down geographic interface, in the work of Heilmann et al. [6] using rectangular cartograms, and in the work of Long et. al. [8] using a polygon visualization technique similar to ours. The authors of the latter article name their technique *Drill Down Map*, which overlays smaller versions of the constituency polygon above each other. The size of each polygon is used to express the constituency's election results relative to the other parties and color represents the respective party. In contrast to the authors' manual graphics editing approach, we propose a fully automatic visualization technique, which uses gradient fill for the inside polygons. As a result, the constituencies appear more homogeneous in our visualizations due to the smooth transitions rather than having many sharp boundaries even within the individual constituencies. Note that in contrast to visualizing all parties of each constituency, we limit our approach to the two most prominent parties of each constituency since we want our approach to scale to a larger number of constituencies than Drill Down Maps, which has been shown on 24 constituencies in the article. Healey's work [5] compares the results of four different elections by subdividing each constituency into four quadrants and colouring each of the quadrants in the winning party's color. Saturation is then used to express the winning percentage. In addition, incumbent losses are highlighted using a texture whereas the state's total election results are visually summarized in a small overlaid disc in the center. Finally, height of each state in the 3D representations expresses the number of electoral votes it represents. In contrast to this work, our proposed visualization does not interfere with straight polygon borders, which are common for many constituencies in the United States. However, our approach is limited to showing the proportion of two winning parties of one constituency, whereas Healey's work focuses on a comparison of the respective winning party during several elections. Another approach for visualizing election data based on a bipolar colormap is proposed by Roth et al. in [11]. The authors use transparency to indicate the difference between first and second party. With more than two parties it stays unclear, which party is the second-ranked. The same approach is followed in the work of Gastner et al. [4] using a bipolar colormap together with cartograms. Again there is the restriction to two parties.

## 3. TECHNIQUE

As motivated above, we propose a novel visualization technique representing the proportions of a categorical variable with geographic reference. The data basis for our method is a phenomenon with geospatial extent, like the election results per constituency. In this special case the data consists of aggregated frequencies of votes per party for each constituency. Visualizing such a spatial extensive phenomenon including the geographical distribution of votes consequently leads to a map-based technique. The following section describes and explain our method and the design decisions made.

Dealing with a map makes the choice of visual variables more challenging, as the most important variable, namely position, is already occupied representing the geographic location. Additionally, shape and position are the most important features of a map when visualizing constituencies. When showing values of a categorical data set, it stands to reason using color hue representing the different categories, i.e. parties. We therefore assigned each party their commonly used color and filled in a first step the polygons with the color of the winner. This corresponds to traditional visualization of election results. Our next step is to express the distance to the second ranked party or category and show also which party occupied the second rank. We are therefore reusing the important visual variable shape by placing a shrunk polygon of the specific constituency on top of the original polygon. The down-scaling of the polygon is determined by the numerical distance between the first two parties. If the distance is very large – the winner is far ahead of the second one –, the inner polygon will be very small, and vice versa. While the outer polygon is filled in the color of the winning party, we apply a gradient fill from the color of the second party (inner) to the color of the winner (outer). We follow the idea of cushion treemaps [14] to allow a better distinction of adjacent polygons.

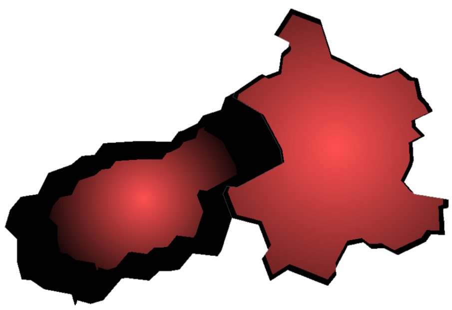


**Figure 1: Result of our technique for two neighbouring constituencies. The difference between first and second ranked is much higher in the left polygon than in the right one.**

The strongest party is placed at the outside of each constituency as the area of the polygon is increasing in quadratic manner with the diameter. Consequently the visibility will be better for the winner. Figure 1 shows an example result of our technique for two adjacent constituency polygons. The difference between first and second ranked is much higher in the left polygon than in the right one. In both cases the black coloured category had a higher count than the red coloured one.

In cases where the distance between the first and the second category is very small, leading to small differences between original and inner polygon, the area occupied by the inner polygon can produce visual artifact. In these cases the second party may be dominating the visualization, as shown in figure 2(c). Especially the north and northwest areas of Germany are dominated by the red color of the second party in the visualization.

This visual artifact is caused by the relatively large area of the inner polygon in relation to the outer one. To prevent this effect, the color of the second party used in the gradient fill is reduced in brightness. If the color of the strongest party is brighter than the color of the second one, the brightness is decreased and vice versa. In figure 2(d), the proposed enhancement is applied; red is no more the dominating color in the north and northwest areas.

# 4. APPLICATION

To validate our concept presented in the section above, we implemented a prototype visualizing election results of the United States and Germany. We enhanced the visual analysis capabilities of our tool by providing a zoomable map and detailed election results using mouse hovering. Note that our technique is not limited to political elections but can rather be applied to any categorical data with a reference to map polygons. We rather used election data as an example showing the capabilities of our proposed method as these datasets are well-known and easy understandable.

Official party colors were used to fill the polygons to generate visualizations being as familiar as possible to the broad range of people dealing with election results. Furthermore, our technique can thus be directly compared to other techniques displaying election results as shown in figure 2.

## 4.1 U.S. Presidential Elections 2008

We applied our technique to the results of the United States Presidential election in 2008. Blue color represents the Democratic Party and red color is used for the Republican Party. The resulting visualization shown in figure 3 reveals the distance between the votes for Democrats and Republicans. Our visualization can point out some interesting patterns and counties sticking out of their surroundings. In traditional visualizations of election results, only the winner of a region (in our case the U.S. counties) can be identified, whereas our technique enables the analyst to get an impression of the proximity of the two parties with most votes for each displayed region.

In addition to detailed analysis of outliers our technique is also capable of showing the overall voting structure. It is, for example, clearly visible that especially in the middle and western areas the Republican Party got the majority of the votes as the dominating color is red. In most of these counties, there are large differences between the winner and the second party, only a very small fraction of the inner polygon is visible.

Along both coast lines, one can see a large number of counties won by the Democratic Party. These are often counties with a high population, whereas the low populated Midwest voted mainly for the Republican Party. Around the Great Lakes in the north and in large areas of Colorado, New Mexico, and Arizona in the south are many counties clearly won by the Democrats.

Analysing those areas more in detail, you can notice a transition in terms of votes for the second party. Especially, going from the Great Lakes down to the south west of the United States (see figure 3), the inner red polygons are getting bigger until the dominating color changes from blue to red. Our technique not only enables us to see this transition, but it also visualizes the actual changes in the votes for the winning and the second party. This additional insight can lead to interesting areas and findings, which cannot be seen otherwise. Furthermore, our technique revealed for example outlier counties in South Dakota shown enlarged in the bottom right corner of figure 3. There are two counties visible where the Democratic Party won, namely Shannon County and Todd County, surrounded by counties typically won by Republicans. Our technique shows furthermore that the Republican Party did not get many votes in these outlier counties. In Shannon County the difference between the Democratic and the Republican Party is around 78 percentage points and in Todd county about 60 percentage points. Our visualization technique clearly reveals those large differences and may trigger further analyses.

Both counties in South Dakota are amongst the poorest in the U.S. in terms of the income per capita (United States Census Bureau Factfinder, data from the year 2000). In 2008, the Democrats had the plan to expand the public health insurance system and to decrease the taxes significantly for the non-upper-class people and companies. This could be a possible explanation for the outstanding results in those two counties. Our conclusion is supported by the result in the neighbouring Sheridan County, which has been won by the Republican Party and has almost twice as much income per capita as Shannon or Todd County.

## 4.2 German Elections in 2005 and 2009

In addition to the U.S. American Presidential election, we also analysed the elections of the German Bundestag (Lower House of the German Parliament) in the years 2005 and 2009. Germany has five important parties, which are CDU/CSU (conservative), SPD (social), FDP (liberal), Die Linke (socialist oriented), and the Grüne (ecological). The following analyses focuses only on the second votes being a proportional vote. In the essence, the second vote is more important since it, with the exception of the five percent clause, always counts in a proportional representation, whereas the first vote counts in a winner takes all manner for a particular candidate. Note that for one voter both votes may not necessarily be consistent. He could for example vote with his first vote for a candidate of the SPD and with the second one for the party FDP. Table 1 shows the overall results for the second vote of both elections. Both major parties (CDU/CSU and SPD) lost a considerable amount of voters to the smaller parties.

| Party | 2005 | 2009 |
|---|---|---|
| CDU/CSU | 35.2 | 27.3 |
| SPD | 34.2 | 23.0 |
| FDP | 9.8 | 14.6 |
| Die Linke | 8.7 | 11.9 |
| Grüne | 8.1 | 10.7 |

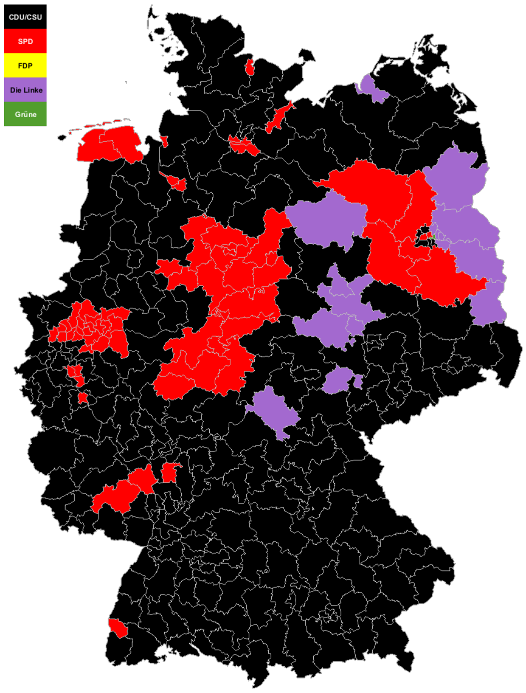
**Table 1: Results of the German elections 2005 and 2009 (second votes in percent).**

### *4.2.1 Elections in 2005*

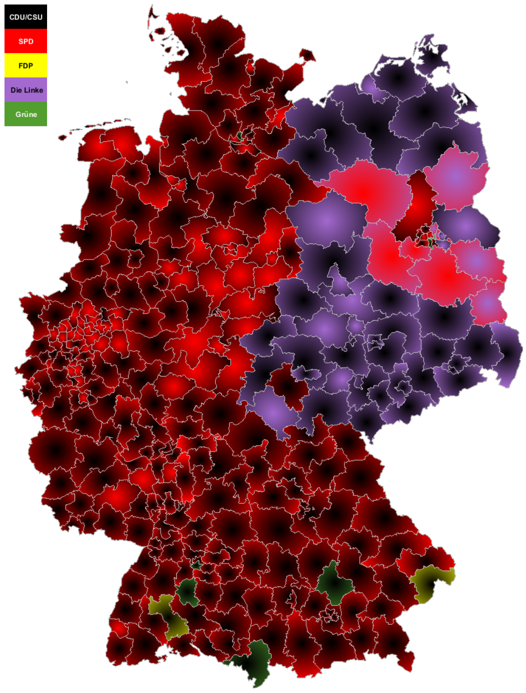
The visualization of the election results in 2005 (figure 4 on the left) shows the two clearly dominating political powers in Germany, the CDU/CSU (black) and the SPD (red). In figure 4 it is obvious that there exists a geographical partition of the main political direction. In the south the conservative party CDU/CSU is typically very strong, whereas the SPD won many constituencies in the north, east and some parts of western Germany. This is not amazing as the north of Germany was influenced by the steel industry, coal mining and trade unions.

There are also areas, where you can see large amounts of votes for Die Linke (violet color, socialist oriented), for example in the middle of Germany and areas in the eastern parts (former German Democratic Republic (GDR)).

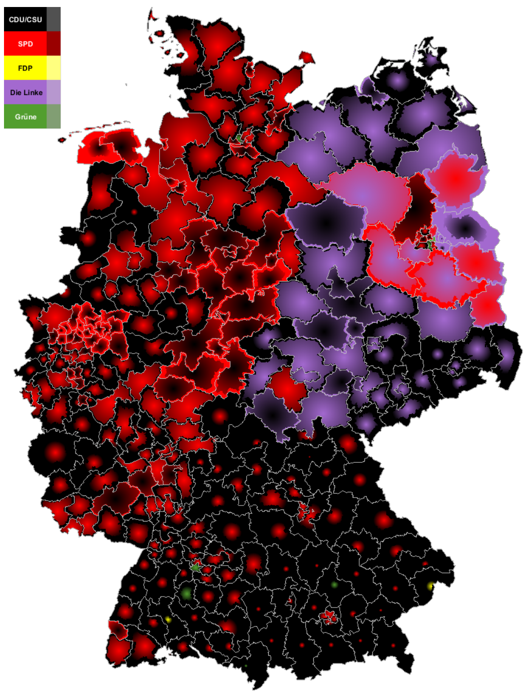
The analysis of our visualization leads to the conclusion that in



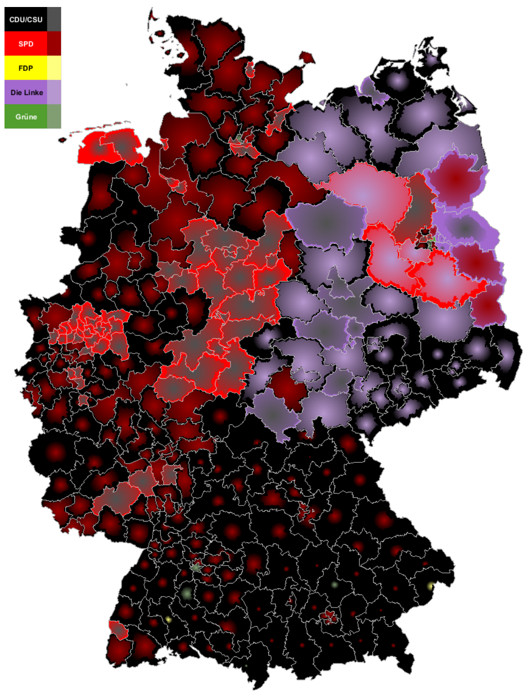

(a) Traditional technique




(b) Gradient coloring




(c) Without color correction




(d) With color correction

**Figure 2: The design steps of the proposed technique shown by visualizing the results of the German elections of the "Bundestag" in 2009: In 2(a), the standard election visualization is shown. One can recognize the winning party, but the majority situation in the districts cannot be seen. In 2(b), the majority situation is shown with a gradient for each displayed constituency, which is quite different from 2(a) and allows some insights in the result, but is very unclear in general. The polygon rescaling is applied in 2(c), without colour correction. Especially in the north and north western areas the overall impression of the election result is dominated by the colors of the second party. This effect is reduced in 2(d), where the color correction is applied.**

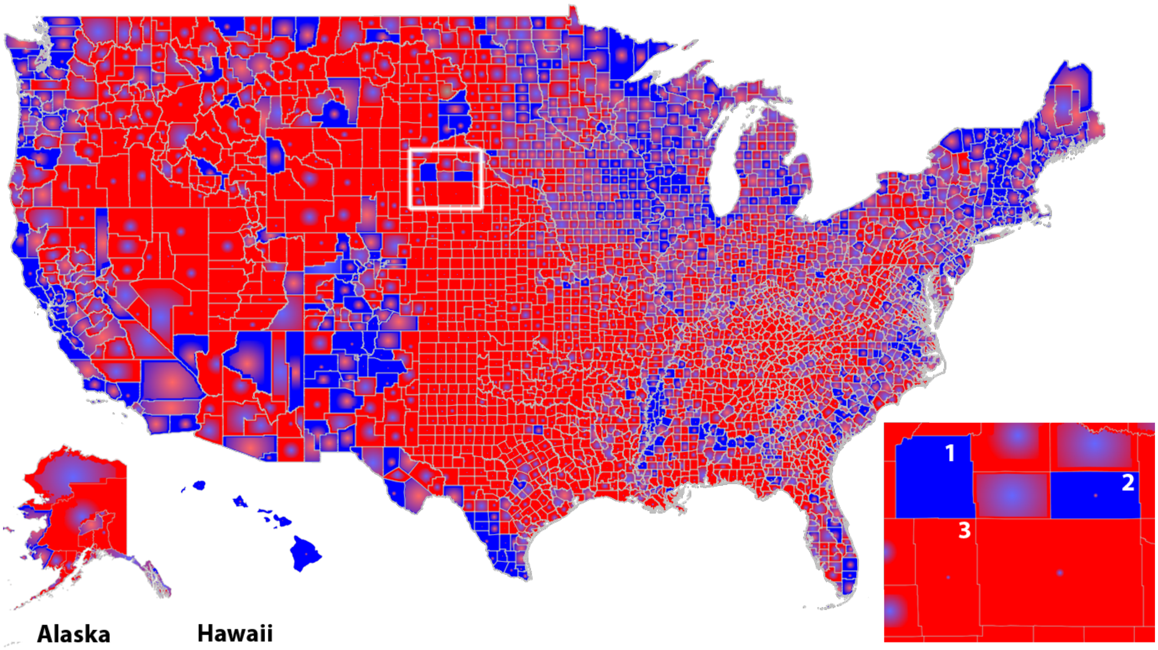



**Figure 3: 2008 US election results plotted at county level. In 2009, the Democratic Party (blue) got 52.9% of the popular votes and the Republican Party (red) 45.7%. At the bottom right: 1: Shannon County (SD), 2: Todd County (SD), 3: Sheridan County (NE)**

the elections in 2005 the CDU/CSU or the SPD won almost all constituencies, or, if it has not been won, the party got the second most votes. Except for a few areas, the socialist party Die Linke did not play a major role and was only seldom the second power in a constituency. The end result of this election was a grand coalition between CDU/CSU and SPD being perfectly reflected in our visualization.

### *4.2.2 Elections in 2009*

Compared to the election of 2005 described in the section before, the resulting visualization of 2009 shows a significant different view. In figure 4 we present the result of our method for the elections in 2009 on the left.

In the south the CDU/CSU was again clearly the dominating party. They won almost every constituency, except for Freiburg in the lower south west being a university city and thus not that conservative. All other constituencies in southern Germany were won by CDU/CSU with a large margin to the party with the second most votes, which happened to be mostly the SPD.

Taking a deeper look to the north west of Germany, the SPD started to gain votes and finally was the strongest political power in some areas. Especially around the Ruhr Metropolitan Region and in parts of Hessen and Niedersachsen the SPD in many constituencies, sometimes even with a large margin to the CDU/CSU. For example in Gelsenkirchen, the distance from the winning SPD to the CDU/CSU was around 30 percentage points.

In very large parts of north eastern Germany, Die Linke was either the winner or got the second most votes. In all of those cases, the distance to the party with the second most votes is very small. In some constituencies in the east near Berlin Die Linke got the clear majority of votes in 2009 (right in figure 5).

When comparing the visualizations of 2005 and 2009 (figure 4), we made some interesting observations. The most obvious point is that the visualization of 2009 shows significantly less red than the one of 2005. This is mainly caused by the loss of votes of the SPD

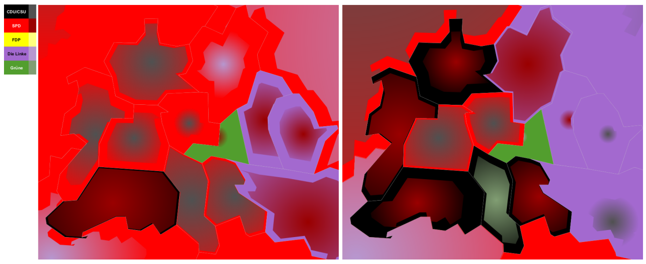



**Figure 5: Comparison of the election results from 2005 (left) and 2009 (right) in Berlin (second votes).**

in the north western parts of Germany. Inspecting the inner polygons of the different constituencies, we can see that almost every area where the SPD had won the election in 2005 is won by the CDU/CSU in 2009. The SPD is very strong in some districts, but they are obviously not able to establish large differences in terms of votes to their competitors.

In 2009, many constituencies, which had previously been won by the SPD are now black coloured, and therefore were won by the CDU/CSU. The main loss of the SPD is visible in the eastern part of Germany, where most of those areas previously won by the SPD have been lost to Die Linke and CDU/CSU. In these cases the SPD dropped steeply being the third ranked party. This finding cannot be made with traditional visualizations of the election results.

In southern Germany the CDU/CSU is even gaining power, since the inner polygons are mostly getting smaller and therefore indicating a bigger difference to the party with the second most votes.

In the previously mentioned area around Berlin shown in figure 5 the differences between the parties are very tight. A political change is clearly visible in the election of 2009. Interestingly, the change does not reflect the same structural change as in the rest of eastern Germany, where the SPD has been almost completely

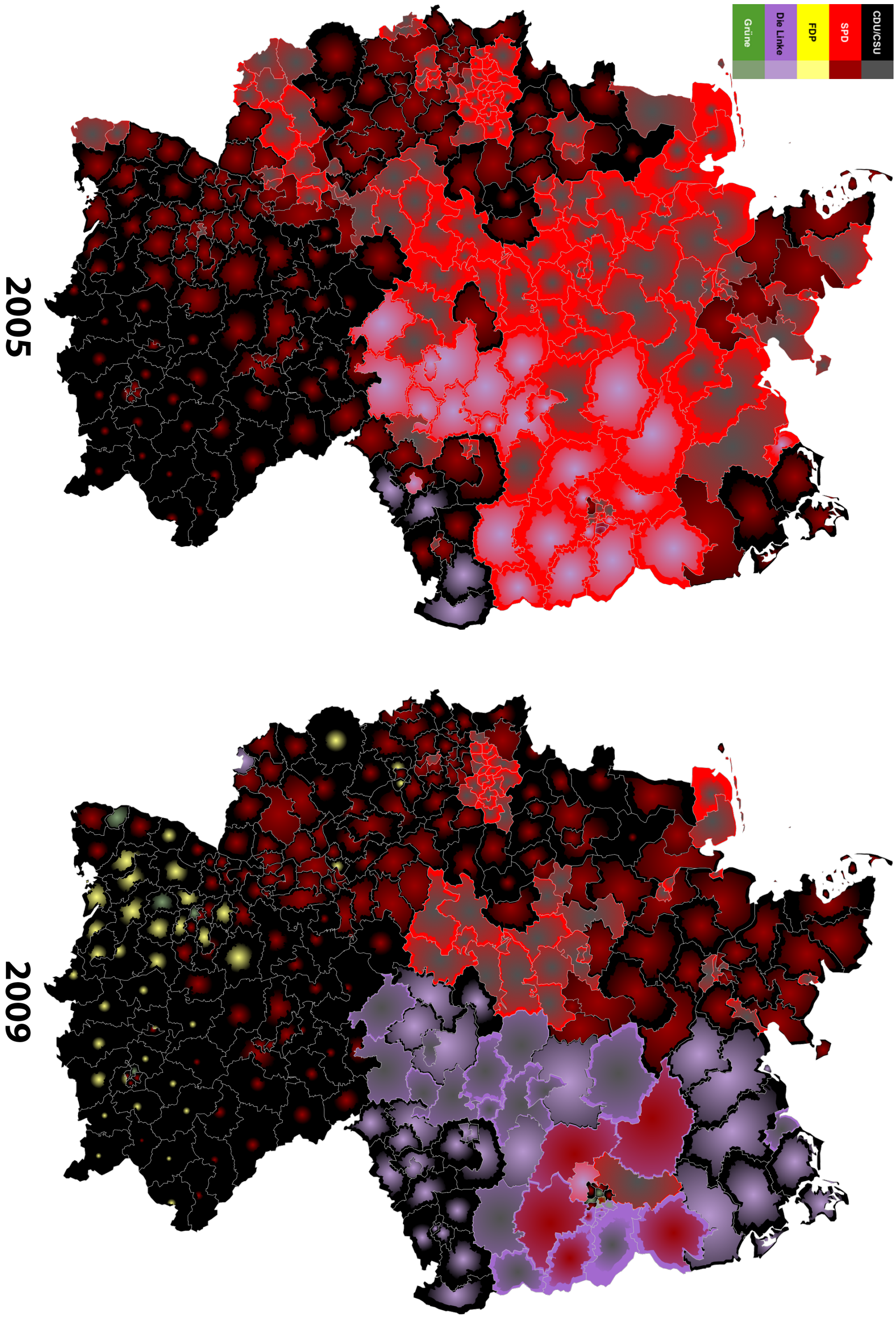



**Figure 4: German Election Results. On the left, the results from 2005 are plotted, on the right, the results from 2009 (second votes). For detailed results see table 1.**

replaced as the second political power by the party Die Linke.

# 5. DISCUSSION

We presented a technique that is capable to visualize the geographical distribution of categorical values focusing on the first and second ranked category. Our method shows for each polygon tight results as well as clear majorities. Designed for phenomena with a geospatial extent our technique cannot be applied per se to point phenomena. To visualize these point data, a spatial aggregation has to be applied as a preprocessing step, e.g. spatial clustering or binning. Using distinct colors to represent the different categories restricts us to a maximal number of 8-10 different categories for our visualization.

The proposed visualization technique can reveal interesting patterns previously hidden in the data set. We presented in the application examples in section 4 some of the geographic distribution patterns found in election data of both, the United States and Germany. The comparison of the first and second ranked category is visually more salient using our method than having two visualizations placed side by side showing the first or second category respectively. This results from the fact that the comparison has to be made in the one case in the human mind and in the other case can be directly seen in the visualization.

There is one issue that has to be addressed here, namely the visibility of the first ranked category in cases of a very tight result. In this case the outer polygon would diminish and could not be visible at all. But we still can determine these cases visually as these are the only polygons fully filled with a gradient colouring. Additionally, as we use the colors of the first and second category to determine the gradient fill, we can still visually express the order of categories in these polygons and show them being hard-fought.

We furthermore enhance the visual salience of the winner in tight results by adapting the brightness of the second party color in the gradient towards the color of the first party. Applying such a correction prevents a visual dominance of the second party's color and helps to reduce these artifacts for the whole visualization. Figure 2(c) and 2(d) show our color brightness correction and the default coloring. There are areas in figure 2(c), which are visually dominated by the color red, thus indicating that the SPD has won those areas. But in fact, the CDU/CSU, which is shown by the underlying black polygon, received most votes in those areas. Our color correction as shown in figure 2(d) reduces this effect significantly.

Furthermore, our method cannot handle different sized polygons very well as the visual salience of large polygons will always exceed the salience of small polygons. But this problem is inherent to many geospatial applications, as the visual variable position is already taken and there is not much we can do to resolve this issue. The only alternative is using distortion methods, like cartograms [7, 13] or density equalizing distortions [2], consequently destroying some of the geographic properties of the underlying topology. Our current implementation is restricted to a geometric zoom with only one focus region.

Of course, rescaling the polygons of the second party to preserve the shape and foster the recognition of the respective constituency is not the only thinkable way of visualizing such a dataset. For instance, we could instead use only a gradient fill repositioning the middle of the color gradient according to the difference. But color is not the best visual variable representing numerical values (cf. [9]). By scaling the polygons, we can utilize the length difference between both polygons, as we scale the polygons not by area but by extent (like a radius).

A further option is to use different bi-polar colormaps and expressing the ratio between winner and second vote using the interpolated color on the respective scale. Having 5 parties as, for example, in Germany this would theoretically result in 10 color scales to be used in one single map. Besides this confusingly large number of color scales, we discarded this option due to the fact that the transition points in such scales representing an equal number of votes for both parties are not always clearly defined and subtle variations in color perception can lead to different interpretations.

Yet another possible solution is to use small glyphs, i.e. histograms, representing the election result of each spatial unit. The severe drawback of this method is the induced overplotting combined with the fact that not all polygons are necessarily of the same size. In the U.S. for instance, the counties are very different in terms of the covered area. Such a glyph-based visualization would either suffer from glyphs of different sizes, with small ones not readable at all, or from high overplotting. In figure 6(a) we show such a glyph-based approach visualizing only the first and the second ranked for the U.S. presidential elections in 2008. Regions with many small counties suffer from a high degree of overplotting of glyphs. In overview zoom levels, like figure 6(a), the induced overplotting will hinder an effective and efficient visual analysis of the results. Only zooming into dense regions (see figure 6(c)) will reveal the hidden information with the disadvantage of losing the overall context. Therefore, we designed our visualization in a way that no overplotting will be introduced (c.f. figure 6(b)), while small constituencies and their winners are still recognizable. The zoomed view of our technique shown in figure 6(d) is thus not necessary, but it is shown here to illustrate the visual impression of our technique in comparison to the glyph approach. Note that due to the fact that we keep the true geography, details of small constituencies are hard to interpret both in glyph visualizations as well as in our technique. Distortion techniques might resolve these issues at the cost of destroying the original map topology.

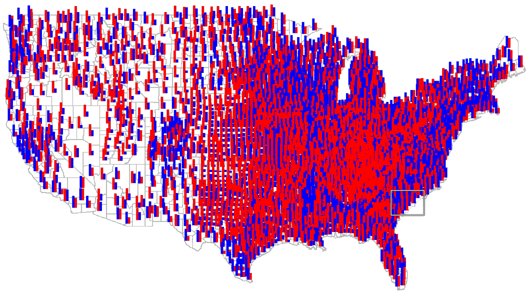
Note that our technique can be combined with cartogram approaches. In this case we would re-draw shrunken distorted polygons instead of the original polygons. Following this idea we could express a further variable that had an influence on to the total election result, for example by scaling the constituencies according to the number of votes they contain.

# 6. CONCLUSIONS

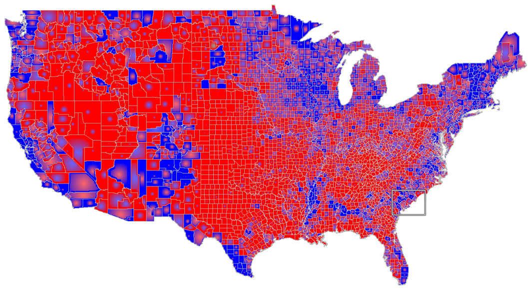
In this paper we presented a novel visualization technique for analysing proportions of geo-referenced categorical data. The technique is based on duplicating and proportionally shrinking individual polygons, which are then coloured according to the two represented categories using a gradient. The main advantages of our approach are the capability to represent proportions of more than one categorical variable in an easily interpretable way and the method's scalability to a large number of polygons.

Besides describing the technique in detail, we have shown its applicability to election results of the U.S. Presidential election in 2008 and the German federal elections in 2005 and 2009. Several visually salient findings document the technique's applicability and usefulness. To justify the strengths and weaknesses of this new technique, we discussed several alternatives and compared our approach against them. It was thereby demonstrated that in contrast to the alternatives overplotting is not an issue and consistent color usage leads to clear interpretations.

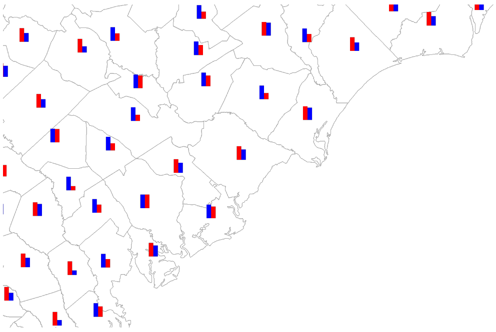
In the future, we plan to conduct a user study to prove the usefulness of the proposed visualization method. It is also planned to extend the displayed categories and to apply our technique to other visualizations such as treemaps or cartograms. Furthermore, we want to assess the influence of campaign travels of the presidential candidates on the election results.



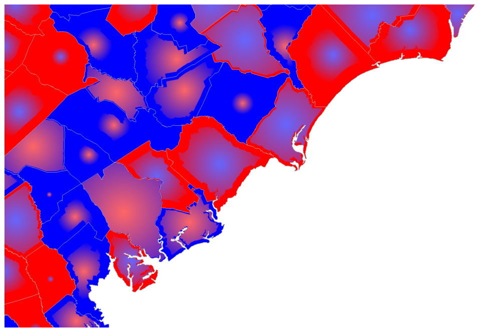
(a) Overplotting of glyphs at overview zoom level



(b) No overplotting at overview zoom level with our technique



(c) No overplotting of glyphs at higher zoom level



(d) No overplotting at higher zoom level with our technique

**Figure 6: Comparison of the U.S. presidential election results 2008, on the left with a glyph based method, on the right with our proposed technique at an overview and a higher zoom level. The glyph based approach suffers from massive overplotting at overview zoom level, especially in the eastern and south eastern regions, whereas our technique shows the data properly. The zoomed section covers the region around Charleston, South Carolina, indicated with the boxes on the figures 6(a) and 6(b).**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