Reconstructing Language History by Using a Phonological Ontology. An Analysis of German Surnames

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Abstract

This paper applies the ontology-based dialectometric technique of Engsterhold (2020) to surnames. The method was originally developed for phonetic analyses. However, as will be shown, it is also suited for the study of graphemic representations. Based on data from the *German Surname Atlas* (DFA), the method is optimized for graphemic analysis and illustrated with an example case.

1 Introduction

Engsterhold (2020) introduced an ontology-based dialectometric method aiming at the investigation of the phonological structure of dialects on the basis of phonetic features.[1] The author exemplifies his technique based on the phonetic maps of the *Linguistic Atlas of the Middle Rhine Area* (MRhSA), which are available in IPA notation. The so-called *phonOntology* is a classification of the sounds of the MRhSA data according to their phonetic features, which are automatically matched by means of an inference procedure. At the same time, they are related to a historical reference system, which means that, in addition to the phonetic assignment, a phonological classification is implemented. For example, the long vowel [uː] in Moselle Franconian *gruß* ('big') is assigned the phonetic features [+close, +back, +long, +round] and relates to MHG *ô*.

On this basis, a vector of sound characteristics is created for each location in the study area. Comparing the vectors of all locations in the dataset, data classifications can then be performed that provide information about which locations are maximally similar or distant with respect to the phonetic characteristics of the data. Since the procedure systematically accounts for historical phonological classes (*gruß*, *groß* < MHG. *ô*), the analysis can be restricted to selected subsets, for example, to a single historical reference sound or the combination of historical sound classes.

For historical data, however, phonetic assignment cannot be reliably implemented. Even a phonological classification bears its difficulties since in historical writing, we find a broad variation of graphemes referring to the same sound. What is required is a rough assignment of graphemes to all possible phonemes which leaves room for both, allophonic and allographic variation. In this paper, we present such a modification based on German surname data. Our aim is to show how the ontology-based procedure can be applied to identify regional phonological patterns, even in data that is part of written language.

2 Method

In order to process large amounts of data and, at the same time, apply the inferences based on the ontology, *phonOntology* makes use of semantic web technologies. The data is organized in a TripleStore graph database (*GraphDB*)[2] using the *Resource Description Framework* (RDF) and the *Web Ontology Language* (OWL) as a language for describing the rules that are implemented in the phonetic ontology.

The classification of the data is based on cluster analyses. This needs the transformation of data, which is performed via one-hot encoding into a data set that generates a multidimensional feature vector for all locations and for all sounds. Subsequently, the data are standardized using *z*-transformation. In order to optimize classification results, principal component analysis (PCA) is performed so that the resulting data set has fewer dimensions but still explains most of the variance in the data set.

[1] https://doi.org/10.17192/z2020.0213

[2] https://ontotext.com

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The clustering algorithms used are *k*-means, Ward's agglomerative clustering (Ward), and the Gaussian mixture model (GMM). In our study we added *k*-medoids and spectral clustering (*k*-nearest neighbor, SC-*k*NN). Since no ground truth or verification dataset is available, the evaluation of the cluster analysis is limited to intrinsic metrics. Thus, primarily cluster stability is evaluated. For this purpose, the silhouette coefficient (SC) and the Calinski-Harabasz index (CH) are used. In addition, bootstrapping and *k*-fold methods are used to generate pseudo-ground truths, which can then be used to evaluate classification results (cf. Engsterhold 2020).

In this way, cluster analysis based on the *phonOntology* allows the semi-automated investigation of sound properties across all tokens and phenomena of a given corpus. This provides a deeper insight into the sound-related structure of a study area under discussion.

The method is free of interpretative assumptions and designed for large data sets. It offers the possibility to highlight and evaluate structures in a chaotic-looking data set. The architecture is similar to the built-up of the PHOIBLE database (Moran et al., 2014). The classification methodology is similar to the methods described in Nerbonne et al. (2011).

3 Material

3.1 Background

We chose German surnames as an example of applying the ontology-based dialectometric technique to a data set of graphic representations. Surnames preserve linguistic material which is up to 900 years old. They developed from bynames in the medieval period and became finally fixed in the course of the 16th century. Investigating the current distribution of surnames allows conclusions to be drawn about historical dialects and writing traditions.

Several studies focus on the areal distribution of specific phonological or graphic variants in German surnames (e.g., Kunze and Kunze, 2003; Dammel and Schmuck, 2009). They face the difficulty that most of the surnames are restricted to limited regions. Usually, several surname types are compared in order to be able to investigate the areal distribution of linguistic features in the surnames.

Quantitative approaches as e.g., the isonomy analyses by Cheshire et al. (2011) or Flores Flores and Gilles (2020) are able to determine spatial structures by using big datasets, but they do not inform about the linguistic characteristics of the identified isonymy structures.

In contrast, our technique not only allows to determine spatial structures but also makes it possible to investigate the linguistic features that are crucial for the classification. It is the characteristic of ontologies that they allow a multidimensional access to the data and thus provide the user with different perspectives of analysis.

3.2 Data

The data comes from the *German Surname Atlas* database (cf. DFA), which is an extract from the database of the *Deutsche Telekom AG* as of June 30, 2005. The database comprises > 28 million private telephone connections (= surname tokens) with > 850,000 different names (= surname types). The data set matches the number of tokens of a surname type with the postal code districts comprising five digits each, e.g., *Hausmann* (surname type) | *27628* (postal code) | *5* (number of tokens).

3.3 Preparation

In preparation for the analysis, the historical reference sounds for each surname type were determined via the map commentaries of the DFA volumes as well as via historical and etymological dictionaries. The map commentaries inform about the etymology of the presented surnames, and they collect the relevant variants of a surname group (e.g., the surname types *Groth*, *Grote*, *Grott*, *Groß*, *Gros*, and *Gross* [see Table 1] that can be traced back to the same etymon WG **grauta*-). For vowels the Middle High German (MHG) and for consonants the West Germanic (WG) reference sounds were identified. By aligning the surname types with historical reference sounds we encountered a central problem that comes across when researching the spatial distribution of surnames: Except for a limited number of high frequent surname types, the occurrence of most surnames is restricted to small-scale regions. Applying the historical reference system, these types become aggregated via the annotation.

As surnames are writing-induced data with considerable historical depth, a phonetic classification of the data is hardly possible. Hence the annotation was oriented towards the grapheme-phoneme system of Early New High German (cf. Anderson et al., 1981) which enables to align the graphemes of the surnames with phonological sound types. In this way, we allow for allophonic and allographic variance. Applying the *phonOntology*, we created feature vectors for each postal code district. The feature vectors to be derived here are thus rougher and more strongly typed than in the original use case of *phonOntology*.

Table 1 provides an extract from the annotation table dealing with the variance of the consonant (sound types *t* vs. *s*) in the coda of names which are related to the standard German adjective *groß* 'big' (cf. DFA 2: 448–449). The sound types, as does

Grapheme	Types	Sound	Historical reference
<t>	*Grote*	t	WG *t*
<th>	*Groth*	t	WG *t*
<tt>	*Grott*	t	WG *t*
<ß>	*Groß*	s	WG *t*
<s>	*Gros*	s	WG *t*
<ss>	*Gross*	s	WG *t*

Table 1: Example of the grapheme-phoneme alignment of the surname types.

their graphemic representation, differ with respect to the plosive vs. fricative realization thus referring to the historical process of the High German consonant shift.

In this specific case, the different graphemes <ß>, <s> and <ss> refer to the same idealized sound type *s* whereas <t>, <th> and <tt> refer to the sound type *t*. When the alignment to several sound types is possible, the annotation allows for multiple references. Especially, concerning the length and quality of vowels, multiple reference is the normal case. In the present case, an idealized phonological feature vector as in (1) would be applied to the sound types. This feature vector is the basis of the intended linguistic classification over several family names. The feature vectors consist of the place (postal code district), the corresponding linguistic features and the number of tokens that account for the features.

$$s = [+cont,\ -nas,\ -lab, \ldots] \quad (1)$$

$$t = [-cont,\ -nas,\ -lab, \ldots]$$

Following the choice of linguistic phenomena that are presented in the DFA 1 and 2, the annotated data set comprises 8,197 surname types with more than 2.3 million tokens (= approx. 8 % of the whole dataset). The sounds and graphemes that show oppositions in the surnames were traced back to 36 historical reference sounds. In Table 1, the historical reference sound is West Germanic *t* (= WG *t*).

4 Analysis of a Defined Range of Sound Classes

4.1 Quantitative Analysis

The following analysis focuses on the linguistic structure of surnames that are linked to long vowels in Middle High German. Therefore, the data set is filtered for the historical reference sounds MHG *â, æ, ê, î, ô, œ, û, iu*. This reveals a subsample of 1034 different surname types with a total of 278,689 surname tokens.

Table 2 shows the results of the evaluation of cluster stability performed by *phonOntology* for both a 2-cluster and a 3-cluster solution. Comparing the silhouette coefficients (SC) and the Calinski-Harabasz indexes (CH), we see that for both clusterings – following the silhouette

	2		3	
Clustering	**SC**	**CH**	**SC**	**CH**
GMM	0.20	186.97	0.13	133.60
k-*means*	0.27	251.24	0.23	210.14
k-*medoids*	0.24	235.63	0.23	209.03
SC-kNN	0.28	217.73	0.25	198.12
Ward	0.23	207.96	0.23	190.38

Table 2: Evaluation of the clustering algorithms.

coefficients – the SC-*k*NN algorithm shows the best results. Regarding the Calinski-Harabasz index *k*-means leads to the best results. It should be noted that *k*-means still performs well on the SC, while SC-*k*NN only achieves average performance on the CH. In the following, we present the findings of both cluster analyses.

The results of the cluster analyses consist of two parts, a map and an assessment of the individual linguistic features. As regards the maps, the clustering is plotted against the dialect classification introduced by Wiesinger (1983). The clustering is strictly based on the properties of the feature vectors and neither influenced by the geographical proximity of the postal code districts nor by the linguistic information provided by Wiesinger's map. The colors and numbers of the clusters are allotted by chance and have no meaning.

The assessment of linguistic features is no longer binary, as indicated by (1), but metrical according to their impact on the particular clusters found by the classification algorithm under discussion.

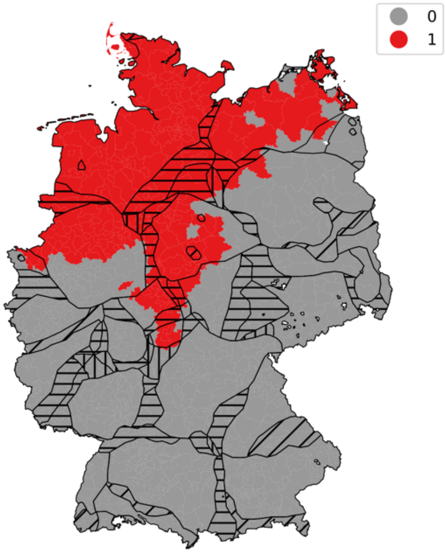

Figure 1: SC-*k*NN clustering (2 clusters) for MHG long vowels.

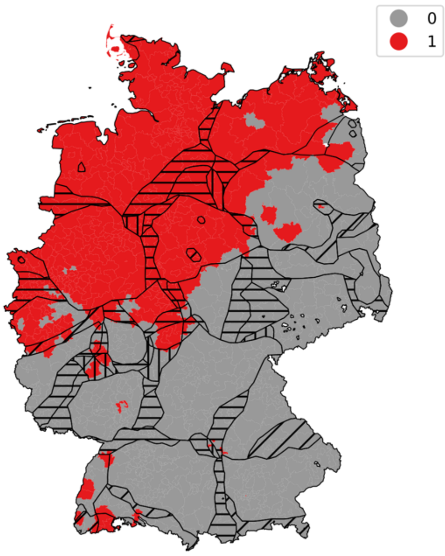

Figure 2: *K*-means clustering (2 clusters) for MHG long vowels.

Comparing the maps in Figure 1 and 2 reveals that both clustering techniques, *k*-means and SC-*k*NN, lead to overall contingent and coherent clusters. In both maps there is a clear north-south divide. However, the northern cluster in Figure 2 (*k*-means) is more widespread than the comparable cluster in Figure 1 (SC-*k*NN). On the other hand, in contrast to Figure 1, there are some regions in the Southwest that are part of the northern cluster in Figure 2.

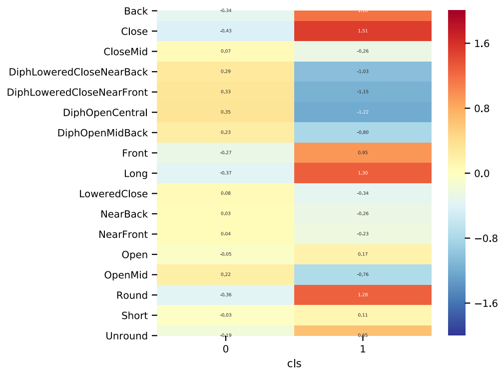

Figure 3: Linguistic features of the SC-*k*NN clustering (2 clusters) for MHG long vowels.

In addition, Figure 3 shows the linguistic features that are relevant for the clusters in Figure 1. In this analysis, the data set is filtered for MHG long vowels. Therefore, Figure 3 shows only the linguistic features of the sounds (in the surnames) that are related to MHG long vowels as reference sounds. The values are presented in contrast for each feature (we have kept Engsterhold's feature names for now out of simplicity). Above-average values are colored in red, low values in blue. Compared to (1), it becomes obvious that, in order to ensure comparability, the phonologically induced binary classification has been resolved. Each category of a binary differentiation is now defined as a separate feature. The same holds for the categorical classification of the vowel space. Figure 3 lists all of the resulting characteristics for all features set for the vocalism.

Since the values per cluster are related and scaled at the relations of all features per cluster, the values across clusters cannot be directly related to each other. Nevertheless, they indicate an inverse relationship in the two-part cluster. Not reported are features with zero realizations as is the case, for example, for [central], [nil], [mid]. These features typically refer to schwa, which seems to be not relevant for the sound class under discussion.

The logic of this procedure can be best explained by focusing on the northern red cluster 1 in Figure 1. The first result from Figure 3 is that this cluster prefers monophthongs over diphthongs, which becomes clear by the fact that features connected to diphthongs are the less frequent ones in cluster 1 (e.g., [DiphLoweredClose-NearBack] refers to *au*).

Second, the most characteristic features of cluster 1 are [close], [long], [round]. Translating these features into sounds, the most frequent features of cluster 1 stand for sounds like *u* and *i*, but also *ü* if assuming that the features do not necessarily have to be linked. Other features of higher impact are [back], but also [front] and [unround] thus referring to the remaining monophthongs.

In this way, for the sound class in focus, not only a spatially definable dominance of monophthongs over diphthongs becomes apparent through cluster 1. In addition, a gradation in the relevance of individual features within the group of monophthongs becomes clear, which characterizes the quantitatively identified cluster. These features, in turn, make it possible to predict which sounds to expect in this cluster.

Examining the characteristic features of the clusters in Figures 4 (*k*-means), a similar picture becomes visible, however, the values are more balanced than in the SC-*k*NN clustering.

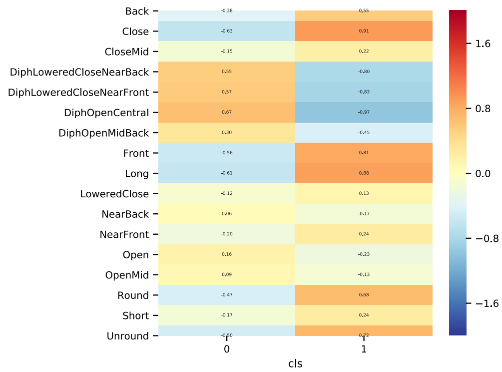

Figure 4: Linguistic features of the *k*-means clustering (2 clusters) for MHG long vowels.

4.2 Linguistic Interpretation

The specific characteristics of the clusters can be interpreted by looking at the historical sound changes that affected the Middle High German long vowels and their Low German equivalents. Here, we recognize the New High German diphthongization that affected the German dialect regions in different extent and in temporal succession (cf. Reichmann and Wegera, 1993: 64–67).

While the diphthongization captured most of the High German area, the Low German and the Alemannic dialects preserved the historical monophthongs. However, the areal distribution of the surname clusters differs from the distribution of the NHG diphthongization in the dialects: the surnames show phonological features of the NHG diphthongization even in areas where the dialects preserve the old monophthongs, for example, in Eastern Low German and in Alemannic (with some exceptions, see e.g., the scattered red postal code districts in Figure 2). This refers to the graphematic basis of surnames. Surnames were part of the regional writing traditions that were severely influenced by the arising NHG written language. In the Low German regions, the strong influence even led to a change from the former Low German writing language of the Hanse to the NHG written language, starting in the Brandenburgish area in the 16th century (cf. Peters, 2015). Thus, the surnames as part of the writing traditions mirror an advanced and medially different development of the NHG diphthongization compared to the dialects; they show "verhochdeutschte" forms.

The influence of the NHG written language was especially high when the source lexemes of the surnames were transparent and could be transferred into High German forms by applying simple transformation rules (e.g., LG/ALEM *u* > HG *au* in LG/ALEM *Husmann* > HG *Hausmann*).

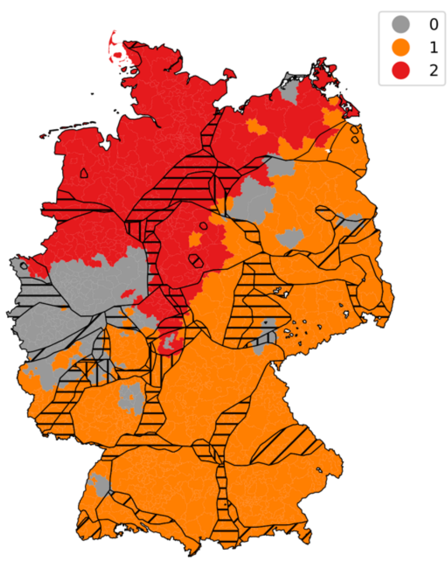

Figure 5: SC-*k*NN clustering (3 clusters) for MHG long vowels.

Looking at the higher clustering in Figure 5, we see that the areas that change their classification between Figures 1 and 2 now create own clusters, together with the adjacent areas.

It thus becomes apparent that the third cluster structure in Figure 5 indicates transition zones (grey cluster, 0). It shows intermediate values for diphthongs and long monophthongs (cf. Figure 6). On the other hand, cluster 0 is characterized by high values for specific features which sets it apart from the two main clusters. The most prominent features are [NearFront] and [OpenMid], pointing at high occurrences of different monophthong sound features and their underlying phonological processes, for example, shortening of long vowels (e.g., *Siffert* < MHG *Sîvrit* 'Siegfried') or umlaut (e.g., *Krämmer* < MHG *krâmære* 'grocer').

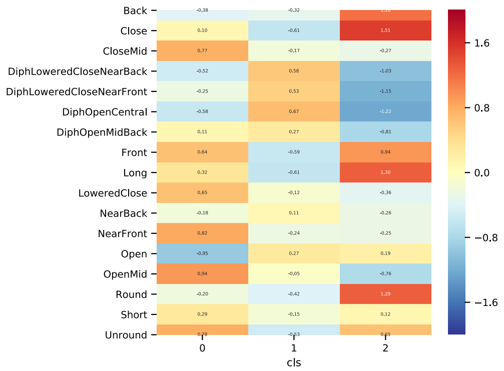

Figure 6: Linguistic features of the SC-*k*NN clustering (3 clusters) for MHG long vowels.

As a result, this example analysis has shown that the cluster structure of the surnames that relate to MHG long vowels depict both, the development of historical sound changes like the diphthongization, and region-specific phonological characteristics. In this way, the spatial structures revealed by our ontology also reflect fundamental cultural events and processes like the change of the writing tradition in the Low German area.

5 Analysis of an Individual Sound Class

5.1 Quantitative Analysis

Focusing on only one sound class, we are able to investigate the outcome of regional specific developments in more detail. As an example, we restricted our data set to surnames that were assigned to MHG û (e.g., *Kruse, Kruss, Krause* < MHG *krûs*). We expect that the spatial structure mirrors the realization of the NHG diphthongization and its regionally different outcomes. In contrast to the analysis of all MHG long vowels we should see more clearly how the historically long monophthong *û* developed depending on the dialect regions. Except from our interest for the diphthongization, we aim at identifying regions with a tendency towards umlaut.
The subsample of our analysis comprises 199 types with 58,708 tokens. We present the cluster solution for four clusters. As Table 3 indicates, *k*-means shows the best results.

	4	
Clustering	**SC**	**CH**
GMM	0.02	167.48
k-*means*	0.47	599.98
k-*medoids*	0.34	418.14
SC-kNN	0.44	586.25
Ward	0.42	553.89

Table 3: Evaluation of the clustering algorithms.

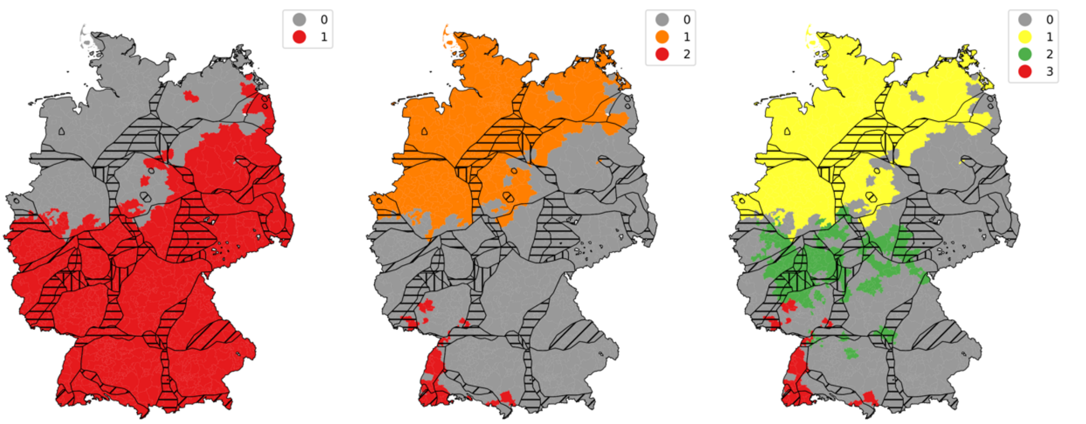

Figure 7: Comparing the *k*-means clusterings (2, 3, and 4 clusters) for MHG *û*.

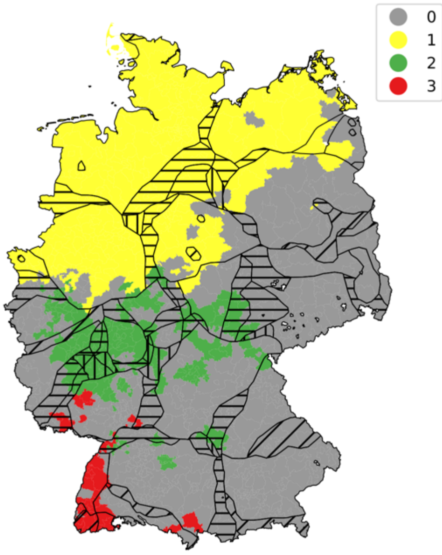

Figure 8: *K*-means clustering (4 clusters) for MHG *û*.

The map in Figure 8 presents the results for the 4-cluster solution for *k*-means. Again, the cluster structures are mostly coherent and consistent. Comparing this map with the 2-cluster solution in Figure 7, it becomes evident that the northern cluster (yellow, 1) is already separated from the other clusters. The 3-cluster analysis then segregates the red cluster (3) in the southwest. Only in the 4-cluster map, the green cluster (2) appears as a substructure of the grey one (0).

Comparing the clusters from Figure 8 with their linguistic features in Figure 9, we see that the clusters are defined by the different outcomes and developments of the historical reference sound MHG *û*.

The main divide in Figure 8 results from the opposition of monophthongs vs. diphthongs. For example, the grey cluster 0 is mainly characterized by the features [DiphLoweredCloseNearBack] and [DiphOpen-Central] which indicate the diphthongized vowel *au*. Similar holds for the green cluster 2, which refers, e.g., to the well-known preference for diphthongs in Hesse (see Birkenes and Fleischer, 2019).

Furthermore, in the Baden area of southeast Germany, it is the short lowered-closed, near-back vowel *u*, that influences the clustering (red, 3).

Finally, the green cluster 2 is characterized not only by diphthong features but mainly by features that indicate the umlaut diphthong *äu/eu* [DiphOpenMidLoweredClose-NearFront].

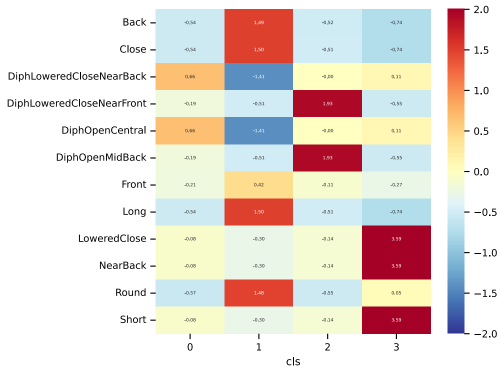

Figure 9: Linguistic features of the SC-*k*NN clustering (3 clusters) for MHG *û*.

5.2 Linguistic Interpretation

Evaluating the spatial structure from a historical point of view, the main north-south divide shows where the NHG diphthongs were adopted in the regional writing traditions. It is remarkable that the diphthongs in the surnames (e.g., *Krause* vs *Kruse*) prevail not only in the regions where the diphthongs occur in the dialects, but also in Baden and Brandenburg where the Alemannic and Low German dialects preserved monophthongs. Here, the surnames are influenced by the regional writing traditions that are more progressive in adopting NHG forms than the dialects.

On the other hand, the higher clusterings show that in cases where the lexical basis is not transparent, the dialectal realizations prevail: In Baden, an example is the surname *Sutter(er)* vs *Sauter* which shows characteristic shortening (*uː* > *u*) in the closed syllable. The profession name *Sutter/Sauter* derives from MHG *sûter* 'tailor, shoemaker'. Other than the competing lexemes *Näher*, *Schneider* and *Schuster*, the lexeme *Sutter/Sauter* was not adopted into the NHG written language. Today, it is only known as a dialect word (cf. *Schweizerisches Idiotikon*[3]) or as a surname.

Thirdly, the analysis shows that there are well-defined areas in which, additionally to diphthongization, umlaut modification took place. Those areas (green cluster 2) are restricted to western and central dialects, and do not appear in

[3] https://www.idiotikon.ch/Register/faksimile.php?band=7&spalte=1477

the Upper German regions, that, significantly, are known for their non-affinity towards umlaut.

In summary, the example demonstrates that the spatial analysis of surnames provides information about regionally specific developments in the graphic and phonological representations of surnames.

6 Conclusion

The paper has shown that the ontology-based analysis technique provides a tool which allows to investigate the regional distribution of phonological characteristics in the German surnames. At the same time, it is possible to detect the spatial extension of historical sound changes that are mirrored in the surnames. We assume that the surnames not only represent fossils of historical spoken language but also developments in regional and transregional writing traditions.

A characteristic of our approach is the multidimensional processing of the surname data, which provides a variety of starting points for further research. Depending on how the data set is filtered, different perspectives are possible. Either the diachronic and diatopic developments of a single historical reference sound are investigated, or the analysis is broadened to describe the major graphemic and phonological features of the surname landscapes of Germany.

Limitations

The presented study was limited by the selection of the surname types for annotation. Following the choice of topics that are presented in the DFA 1 and 2 the historical reference sounds are not represented in a balanced way. Also, our annotation categories cover, at present, neither the phonological nor the morphological contexts of the analyzed sounds.

The greatest challenge was the alignment of graphemes and phonemes. While we managed to cope with multiple references between graphemes and phonemes, we did not yet implement a technique that identifies regionally diverse phonological realizations of the same grapheme (e.g., the grapheme <ue> corresponds to either /y/ or /u:/ depending on the dialect area). We plan to implement this in the future.

Ethics Statement

We declare that our research complies with the ACL Ethics Policy. As surnames are part of personal data, we ensured that data protection was not violated at any time.

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