Dialectometry

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1. Introduction

We discuss quantitative work on Dutch dialectology, a line of work that is often referred to as 'dialectometry'. It is worth emphasizing that a great deal of both the Dutch dialectometric work and also work on other languages and dialects has been inspired by the wish to overcome problems in the traditional methodology of dialectology, which has focused on the geographic distributions of single linguistic features (Nerbonne 2009). Examples are two isogloss maps of Weijnen which were published in 1941 (based on 45 isoglosses) and 1958 (based on another set of 18 isoglosses) and the isogloss map of Goossens which appeared in 1970. The three maps suggest different classifications since the choice of the isoglosses differs per map. Isogloss maps are verifiable, but the motivation for the selection of the isoglosses remains unclear. Goossens (1977) mentioned that the isogloss method cannot be applied without making subjective choices. The dialectometric strategy has been to seek more satisfying characterizations by aggregating over large number of linguistic features. The aggregating step is inevitably quantitative, which has allowed the introduction of powerful quantitative techniques into dialectology.

2. Literature survey

2.1. Categorical measurements: Background

Séguy
The first to develop a method of measuring dialect distances was Jean Séguy, assisted and inspired by Henri Guiter. Jean Séguy was director of the *Atlas linguistique de la Gascogne*. He and his associates published six atlas volumes containing maps in which single responses were plotted for 154 dialect locations. Séguy's major survey used five types of linguistic variables: 67 features from diachronic phonetics, 76 from phonology, 68 from morphosyntax, 44 from verb morphology and 170 lexical items, 425 variables in total. Séguy sought a way to analyse the maps in a more satisfying way than was possible with traditional analytic methods, and came up with the idea of counting "the number of items on which neighbors disagreed." (Chambers and Trudgill 1998: 138). At the back of the sixth volume of the atlas, a map is provided for each of the linguistic levels in which the number of items on which two neighboring dialect locations disagree is printed between the two dialect locations. After these six maps, there are two additional maps in which the six maps are aggregated. On the second map, the total number of disagreements between two neighbors was expressed as a percentage: the number of agreements divided by 425 times 100. The percentage "was treated as an index score indicating the linguistic distance between any two places" (Chambers and Trudgill 1998: 138, see also Séguy 1973a, 1973b, 1973c).

Goebl
Hans Goebl continued and elaborated on Séguy's work, striking out independently in several respects. We base our sketch on Goebl (1982a, 1984, 1993). Goebl most extensively analysed *l'Atlas Linguistique de l'Italie et de la Suisse Méridionale* (AIS), compiled by Karl Jaberg and Jakob Jud in the first quarter of the twentieth century. He selected 251 varieties and 696 working maps from the AIS. Each working map represents a dialect feature and requires assigning a value at each of the 251 sites. 569 maps represent lexical variation, and 127 maps represent morphosyntactic variation. While Séguy calculated distances, Goebl calculated similarities. The similarity between two varieties is calculated as the percentage of items on which the two varieties agree. Goebl refers to this measure as 'relative similarity' (originally in German: *relativer Identitätswert*, RIW). He also introduced a second measure: weighted similarity (originally: *gewichteter Identitätswert*,

GIW). The GIW method weights infrequent feature overlap among pairs of dialect varieties in a dialect area more heavily than frequent feature similarities, opposing the tendency in several areas of quantitative linguistics that very infrequent words should be treated as noise, unreliable evidence of linguistic structure (Nerbonne and Kleiweg 2007). Features which are common to few dialects, but which are found only infrequently overall, characterize the dialects' similarity more strongly than features which are also found in many dialects. For this reason similarity between dialects depends more on infrequently shared features than on frequently occurring features.

Goebl also introduced THIESSEN tiling to dialectology, a technique which draws tiles around points on a map so that maps are divided into regions around sampling sites as evenly as possible. This technique produces the basis of CHLOROPLETH maps, in which each of the tiles is assigned a linguistic value based on (similarity) calculations with respect to a reference point, e.g. a single village. Goebl's work examines a large range of descriptive statistics derived from the distribution of linguistic similarity, and he examines each of these, e.g. similarity with respect to the entire range of reference sites. It is quite characteristic of Goebl's work that he insists on examining variation from each of a large range of locations, e.g. Paris, Lyon, etc. when the AIS is analyzed. Goebl (1993) also uses INTERPOINT maps which depict distances between neighboring dialects as "walls" which grow in darkness as the linguistic dissimilarity increases. This visualization is also called the HONEYCOMB method (Inoue 1996). A complementary visualization technique is the BEAM MAP, also used by Séguy. Linguistically similar dialects are connected by dark beams, and more dissimilar ones by lighter beams (see Figure 1a). On the basis of distances among dialect varieties Goebl performs cluster analysis (Goebl 1982b, 1983), thus finding the main dialect groups which are geographically shown as differently colored dialect areas in a map.

2.2. Application to Frisian and Dutch

Séguy and Goebl's methodology has also been applied to Frisian and Dutch varieties at the lexical, phonological, morphological and syntactic level. The variables used in this methodology are usually nominal.[1] On the basis of these variables, the number (or percentage) of agreements (similarity) or disagreements (distance) are measured, and these measurements are numerical.[2] In the studies we mention below in this section, the measurements are numerical.

Lexicon

Kruijssen (1990,1992) presented a study aimed at determining whether the dialect of Lommel, regarded as a Brabant dialect, actually belonged to the Limburg group. He measured the lexical similarities between Lommel and a set of 12 Limburg varieties à la Séguy and Goebl using data from the *Woordenboek of Limburgse Dialecten* ('Dictionary of Limburg Dialects', Weijnen and Goossens (1983-2008)). Kruijsen found that the distance between Lommel and the closest Limburg dialect was nearly as large as the largest distance within the Limburg group. It is therefore not likely that Lommel is a Limburg variety.

Heeringa and Nerbonne (2006) measured lexical distances among 360 varieties in the Dutch dialect area. This area comprises the Netherlands, the northern part of Belgium and French Flanders. The measurements are based on 125 items taken from the *Reeks Nederlandse Dialectatlassen* (RND, Blancquaert and Pée (1925-1982)). Lexical distances were measured using Goebl's GIW. They found that the varieties are lexically divided into Frisian varieties (including Frisian mixed varieties), Low Saxon varieties, Holland varieties (including Zeeland, Utrecht and the Veluwe), and southern Dutch varieties (Flemish, Brabant, Limburg). The latter group is a geographically large area, but in the same paper the authors show that this area is divided into even smaller groups at the level of the sound components.

Giesbers (2008) measured lexical distances between 10 locations in the Kleverlands area,

[1] That is, the values which a nominal variable may have are like names. When comparing values of a nominal variable, they are either equal or different, and we cannot measure the degree to which values differ.

[2] Or: ratio measurements, i.e. measurements are numbers on a scale which has an absolute zero.

along the Dutch-German national border. She selected five bi-national pairs of sites and measured distances among the pairs of varieties and with respect to standard Dutch and German. Since Giesbers also measures pronunciation distances, we return to this study in Section 2.3.3.

Pronunciation
Klaas van der Veen, following the work of Séguy and Goebl (van der Veen 1986; van der Veen 1994), measured similarity among West Lauwers Frisian varieties on the basis of word isoglosses. For example, the Frisian word forms of *niet* 'not' are *net* and *nit*, dividing the Frisian varieties into two groups. The Frisian forms of *recht* 'straight' are *rjocht*, *rjucht* and *rucht*, dividing the Frisian varieties into three groups. In van der Veen (1986), 87 word isoglosses are listed, and in van der Veen (1994) we count 96 word isoglosses. The words chosen are the most highly frequent words in written West Lauwers Frisian, and the pronunciations are gathered from different sources (e.g. the RND). In contrast to Séguy and Goebl, van der Veen weights isoglosses directly by the relative frequencies of the words in which they occur. Like Goebl, he uses cluster analysis to identify groups among the varieties.

Morphology
Heeringa et al. (2009) focus on morphological distances as measured among Low Saxon varieties. Séguy's overlap measure is applied to data from the *Morphological Atlas of Dutch Dialects* (De Schutter et al. 2005, Goeman et al. 2009). The following feature domains are considered: plural substantives (43 features), diminutives (39 features), possessive pronouns (11 features), verbs (present tense and past tense, 24 features), participle prefix GE- (4 features) and verb stem alternations (past tense, 16 features). The distance measurements corresponding with the domains are weighted equally and aggregated. They determine four groups: 1) Groningen, 2) the northern part of Drenthe, 3) Stellingwerven, Kop van Overijssel and Salland, 4) Achterhoek and Twente.

Syntax
Spruit (2008) measured syntactic distances among 267 varieties in the Dutch dialect area. He used data from the *Syntactic Atlas of Dutch Dialects* (Barbiers, Bennis and De Vogelaer 2004) and applied Goebl's RIW and GIW. GIW resulted in more sharply distinguished groups than RIW (see also Spruit, Heeringa and Nerbonne 2009). Spruit shows a dominant split between a northern group (including Frisian, Holland and Low Saxon varieties) and a southern group. Within the southern group the West Flemish varieties and the Limburg varieties are clearly distinguished.

2.3. Frequency-based methods

2.3.1. Profile-based linguistic uniformity

Profile-based linguistic uniformity compares language varieties on a range of heterogeneous linguistic variables in corpora created for this purpose and was introduced by Geeraerts, Grondelaers and Speelman (1999), who used it to study register variation and regional variation in Dutch. Their aim was to see whether Belgian and Netherlandic Dutch converged from 1950 to 1990 and whether the convergence was due to Belgian changes. Focusing on the lexicon, they assume *formal onomasiological variation* occurs when different terms are used to refer to the same entity. They define a *formal onomasiological profile*, or *profile*: "a profile for a particular concept […] is the set of alternative linguistic means used to designate that concept or linguistic function in that variety, together with their frequencies (expressed as relative frequencies, absolute frequencies or both)."

For example the concept *jeans* appears in their Netherlands sample 81 times (70%) as *jeans* and 34 times (30%) as *spijkerbroek*. In Belgium, the frequencies are 64 (97%) and 2 (3%) respectively. The distance between the two profiles is the sum of the absolute differences between the corresponding relative frequencies:[3] (|70-97]) + (|30-2|) =55%. The distance between two varieties is usually based on several concepts and is calculated as the sum of the corresponding profile distances. The concepts need not be lexical, but may be morphological or syntactic as well. Once distances are calculated, statistics can be applied to classify the varieties. Speelman, Grondelaers and Geeraerts (2003) apply multidimensional scaling, which we discuss below in Section 3.2.

2.3.2. Phone and feature frequency methods

Hoppenbrouwers and Hoppenbrouwers developed the phone frequency method (PFM) and the feature frequency method (FFM) to measure dialect distances on the basis of pronunciation. The methods were introduced in 1988 and also described by Hoppenbrouwers and Hoppenbrouwers (2001). An extended analysis of their work is given by Heeringa (2002).

Phone frequency method
Hoppenbrouwers and Hoppenbrouwers (2001: 1) suggest comparing varieties based on samples of speech in phonetic transcription. They count the frequencies of phones (segments) in each sample. Since samples differ in size, relative frequencies are used. The distance between varieties is the sum of the absolute values of the differences between their (relative) phone frequencies. We illustrate this in an small example. Let us assume for two dialects A and B the following relative frequencies in their samples:

	[i]	[e]	[a]	[o]
Dialect A	10%	25%	40%	25%
Dialect B	20%	40%	20%	20%
difference	10%	15%	20%	5%

The distance between A and B is the sum of the percentage differences which are shown in the last row: 10% + 15% + 20% + 5% = 50%.

Feature frequency method
The phone frequency method (above) does not take into account the fact that some segments are rather more similar than others, e.g. [i] and [e] are more similar than [i] and [a]. To accommodate the insight that phonetic similarity is gradual, Hoppenbrouwers and Hoppenbrouwers (1988) also developed a feature frequency method.

Speech sounds can be described by way of DISTINCTIVE FEATURES. Vowels are pronounced in the front or in the back of the oral cavity (described by the features FRONT and/or BACK); they are pronounced with a low, mid or high tongue position (described by HEIGHT); and they are pronounced with spread or rounded lips (described by ROUND). To determine feature frequencies, all sounds which might appear in the transcriptions must be defined in terms of features. The authors used the features from *The Sound Pattern of English* (SPE) (Chomsky and Halle 1968), an articulation-based system, as starting point. In working with the RND material, the SPE system was modified and extended to represent the distinctions in the atlas material as well as possible.

Hoppenbrouwers and Hoppenbrouwers then count the number of sounds in the sample as [ADVANCEMENT FRONT, [HEIGHT LOW], etc. to obtain feature frequencies. From a speech sample, we obtain a histogram of the relative frequencies of different feature values. Hoppenbrouwers and Hoppenbrouwers (1988, 2001) calculated histogram similarity using the Pearson's correlation coefficient (a measure of how well two variable properties agree, e.g. the height and weight of adults). If we repeat this procedure for each pair of samples, we obtain a similarity matrix where

[3] A second, more complex way of calculating profile distances is described by Speelman, Grondelaers and Geeraerts (2003). This study is outside of the scope of the present chapter.

each variety is defined as a vector (row) of similarity values with respect to all other varieties (and to itself). Cluster analysis was applied to the similarity matrix to find groups (areas).

2.3.3. Application to Dutch

Hoppenbrouwers and Hoppenbrouwers (2001) is the most extensive application of the feature frequency method. The authors work with full RND texts, each containing 139 sentences transcribed phonetically. Using 156 varieties, they find a main division into Low Saxon, Limburg and other varieties. The other varieties consist of three subgroups: 1) Frisian (including Town Frisian, Het Bildt and Stellingwerf varieties), 2) Holland and North-Brabant, 3) Zeeland, Flemish and Belgian Brabant.

They also measured distances between dialect varieties and standard Dutch, finding the Limburg and Groningen varieties most distant, and those in North-Holland, South-Holland and Utrecht closest. Surprisingly, the Frisian varieties were measured to be relatively close to standard Dutch. We will return to this in Section 3.2. See Heeringa, Nerbonne and Osenova (2010) for an application of Hoppenbrouwers' techniques in contact linguistics which exploit the advantage of these techniques in that they do not require the same words to be sampled in different sites.

3. Recent work: Techniques using edit distance

A disadvantage of the frequency-based methods is that they are not sensitive to the order of phonetic segments in a word. For example, the word *konijn* 'rabbit' is pronounced as [kniːnə] in the dialect of Deelen and as [kəniːn] in the dialect of De Lutte. The two pronunciations will erroneously be considered as identical in frequency-based techniques. Séguy and Goebl would examine each corresponding sound pair separately. The Dutch word *hart* 'heart', for instance, is pronounced as [hɑrt] in Vianen (Netherlands) as well as in the standard variety and as [ærtə] in Nazareth (Belgium). When the two pronunciations are properly aligned, we may compare five segment positions:[4]

1	2	3	4	5
h	ɑ	r	t	
	æ	r	t	ə
1	1			1

We find that the two dialect varieties differ in the segment positions 1, 2 and 5. It would be interesting to compare hundreds of dialects based on a large sample of words this way. However, if we work with 200 collection localities, there will be ((200 x 200)-200)/2 = 19,900 pairs of sites, for which we need to align say 100 word pairs to derive the variables from the alignments. This task can be fully automated with Levenshtein distance, as Kessler (1995) first showed, applied to Irish Gaelic. The Levenshtein distance is a numerical value defined as the cost of the least expensive set of insertions, deletions and substitutions needed to transform one string into another (Kruskal 1999). In our example, the [h] is deleted, the [ɑ] is replaced by [æ], and [ə] is deleted. In this example each of these operations has a cost of 1, so the total distance is 1+1+1 = 3.

3.1. Variants

Phone string comparison versus feature string comparison
The simplest technique is *phone string comparison*. In this approach all operations bear a 'cost', of for instance 1. In our example the substitution of the [ɑ] by [æ] has a cost of 1, and the substitution

[4] Actually, each segment position is a categorical variable (in the simple version under discussion here).

of the [ɑ] by [y] would cost the same, since the phonetic affinity between phones is ignored. A more sensitive technique might use gradual distances between segments as operation weights, perhaps calculating the weights on the basis of segmental features. When for example vowels are described by three features (height, backness and roundness), distances between vowels can be calculated in three-dimensional space and then used as operation weights in the Levenshtein distance, so that the substitution of [ɑ] by [æ] will cost less than the substitution of [ɑ] by [y]. Kessler calls this metric *feature string comparison*. Heeringa (2004) measures segment distances on the basis of several feature systems, including the system implied by the IPA table organizing sounds by place and manner of articulation and voicing (see also Heeringa and Braun 2003, who provide details). He also measures distances between segments on the basis of their spectrograms. Since a spectrogram is the curve plotting intensity against time and frequency, the curve distances between the spectrograms reflect acoustic differences. The samples which the spectrograms are based on were pronounced by John Wells and Jill House and are found in the recording *The Sounds of the International Phonetic Alphabet* (1995).[5] Heeringa (2004) focuses especially on the more perceptually oriented models, which emphasize the differences that a speaker can hear in someone else's speech.

The choice of operation weights depends on one's research goal. If the goal is to approximate how differences are perceived by dialect speakers, then the use of binary costs (0/1) outperforms that of gradual costs (Heeringa 2004), which suggests that the fact that segments differ is more important than the degree to which they differ, perhaps reflecting the categorical basis of speech distinction. All segmental weighting schemes to-date have led to only small differences in measurements at the aggregate varietal level (Heeringa 2004: 186), giving only slightly different correlations to distances as perceived by the dialect speakers themselves in a perception experiment. It is probably necessary to validate measurements on individual words if we are to make progress in this area.

Free alignment versus forced alignment

To deal with syllabicity, the Levenshtein algorithm may be adapted so that only vowels may match with vowels, and consonants with consonants, with several exceptions: [j] and [w] may match with both consonants and vowels, [i] and [u] with both vowels and consonants, and central vowels (which in our research boils down to schwa) with both vowels and sonorant consonants. So the [i], [u], [j] and [w] align with anything, the [ə] with syllabic (sonorant) consonants, but otherwise vowels align with vowels and consonants with consonants. In this way unlikely matches (e.g., a [p] with an [a]) are prevented. This approach was first applied to Sardinian dialects (Bolognesi and Heeringa 2002), and then to Dutch (Heeringa and Braun, 2003). In a validation study, Heeringa et al. (2006) found that forced alignments perform better than free alignments, i.e. they approach dialect perception more closely.

Relative distances versus absolute distances

Nerbonne et al. (1996) normalized Levenshtein distances by dividing the absolute distance by the length of the longer word, calling this *relative edit distance*. The idea behind this is to emphasize the perception of words as crucial linguistic units. In the example with the two variants of the word for 'heart', where we found a Levenshtein distance of 3, the relative distance would be 3/4= 0.75. If a dialect variant consisting of five segments were included, the denominator value would be 5. One may also choose to normalize using the sum of the lengths of the two variants (in our example: 4+4=8) or using the length of the cost alignment (in our example: 5). The different ways of normalizing are discussed by Heeringa (2004: 130-132).

Again the choice between relative distances and absolute distances may depend on one's scientific goal. Heeringa et al. (2006) showed that absolute Levenshtein distances approximate dialect differences as perceived by the dialect speakers better than results based on relative Levenshtein distances, i.e. normalized by alignment length. This suggests that the weight of the

[5] See http://www.phon.ucl.ac.uk/home/wells/cassette.htm.

substitution of e.g. the [u] in a word variant of dialect A by the [y] in the variant of the same word in dialect B is independent of the length of the variant in the perception of the speakers. On the other hand Beijering, Gooskens and Heeringa (2008) found that intelligibility correlates better with relative distances than with absolute distances. In both cases the differences were not large.

All-word comparison vs. same-word comparison
Kessler calculated edit distances not only for words that are phonetic variants of each other, but also for lexical variants, calling this the *all-word* approach. We can alternatively restrict our comparison to words that are phonetic or phonological variants of each other, i.e. cognates, adopting Kessler's *same-word* approach. Both approaches have been applied to the same set of 360 Dutch dialects (see also Section 3.2). The all-word approach is found in Heeringa (2004), and the same-word approach is found in Heeringa and Nerbonne (2006). Although we did not publish the correlation between both measures, it was in fact extremely high (r=0.99). The maps in the papers naturally coincide. The classification map obtained on the basis of all-word distances shows 13 groups, and the classification map obtained on the basis of same-word distances shows 11 groups. The maps are not identical, but all borders in the same-word map are also found in the all-word map. The maps thus do not contradict each other. This leads us to conjecture that non-cognate comparisons just act as noise, but details may naturally differ in other data collections.

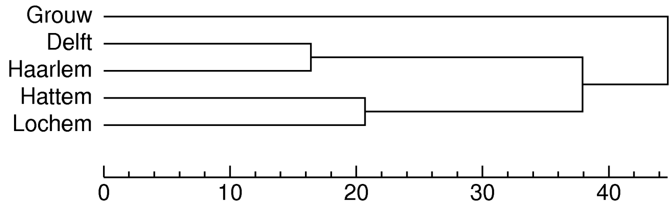
3.2. Application of Edit Distance to Frisian and Dutch

Measuring mutual relationships
Levenshtein distance was first applied to the comparison of Dutch dialect varieties by Nerbonne et al. (1996). It was applied to 20 Dutch varieties, taken from the RND, where 100 word pronunciations were digitized for each variety. All-word distances were calculated, and on the basis of these distances the varieties were classified using cluster analysis. Cluster analysis had also been used in the earlier Dutch dialectometric studies of van der Veen (1986, 1994). The goal is to identify the main groups, or *clusters*. In hierarchical clustering, clusters may consist of subclusters, and subclusters may in turn consist of subsubclusters, etc. The result is a hierarchically structured tree in which the dialects are the leaves. Jain and Dubes (1988) mentioned seven alternative clustering techniques. Nerbonne et al. (1996) used the *Ward's method*, which gives a well-balanced tree. Heeringa (2004: 150-153) found that Ward's method yielded counterintuitive results and found the *Unweighted Pair Group Method using Arithmetic averages* (UPGMA) superior. Dendrograms naturally give rise to a "derived distance" between varieties, namely the distance over the branches of the dendrogram. Heeringa and Nerbonne (2006) suggest that UPGMA derived distances correlate most strongly with the original measurements, i.e. the measurements the cluster technique was applied to. Nerbonne et al. (2008) investigate means of ensuring stability in clustering as well. By 'stability' we mean the extent to which the clustering remains the same when elements are modified in small ways.

We illustrate cluster analysis by a small example. Assume linguistic distances among five Dutch dialects are measured, where the distances represent the average percentage to which dialect pairs disagree at the level of the sound components, measured with Levenshtein distance. The distances are arranged in the following table:

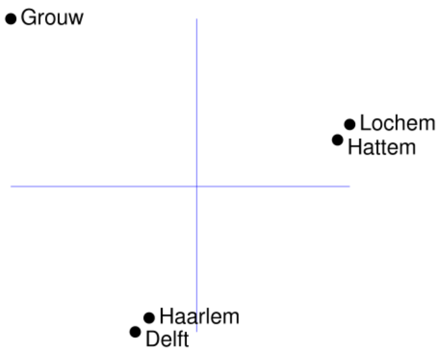
	Grouw	Haarlem	Delft	Hattem	Lochem
Grouw		42	44	46	47
Haarlem			16	36	38
Delft				38	40
Hattem					21
Lochem					

When we apply UPGMA cluster analysis to this table, we will obtain the following dendrogram:



Nerbonne and Heeringa (1998) published a study in which 104 varieties are involved and 100 word pronunciations for each variety. The data was taken from the RND, and all-word pronunciation distances were measured. The distances are geographically shown in a beam map. This type of map was introduced by Séguy (1973) and used by Goebl (1993) (see Section 2.1.1 above). Linguistically close varieties are connected by darker lines, and distant varieties are connected by lighter ones.

In addition to the analysis using clustering (Ward's method, see above), the results were analyzed using multidimensional scaling (MDS). Embleton (1993) appears to have been the first to use MDS in dialectology. MDS analyses a set of distances between elements, placing them in a two- or three-dimensional space so that the (Euclidean) distances among them in the low-dimensional space reflect the original distances, i.e. the distance the MDS procedure was applied to, as closely as possible. Just as for cluster analysis, MDS exists in several variants. Togerson (1952) proposed the first metric method, Classical MDS. Kruskal extended this to Non-metric MDS, which uses the ranks of the distances (Kruskal and Wish 1978). Heeringa (2004) found that MDS results obtained with the latter method in dialectology resemble the original distances most closely. When we apply Kruskal's Non-metric MDS to our small distance matrix of five dialect varieties, we obtain the following MDS-plot:



Nerbonne and Heeringa (1998) show a two dimensional plot in which all 104 varieties are found, where the linguistically close varieties are shown near each other in the MDS plot, and varieties which strongly differ are found farther away from each other. The plot in fact resembles the geographical map with Frisian varieties in the northwest (upper left), West-Flemish varieties in the southwest and Ripuarian varieties in the southeast. Subsequently, the authors scaled the distances to three dimensions, associating each dimension with a color (red, green or blue) and each dialect point with a mix of colors depending on its coordinates in the three-dimensional MDS solution. If we use these colors with the choropleth map (see Section 2.1.1), we see a discrete dialect landscape where most borders do not separate tiles of very different color, but are still sharp. Alternatively, we can color the space between sampling sites by interpolation. For example, if point *a* is yellow and point *b* is blue, then, if no other points intervene, we gradually shade intermediate points from yellow into green and then into blue. Nerbonne and Heeringa (1998) used the latter approach, known as inverse distance weighting.[6] The map they show was the first in the history of dialectology to show dialect variation as a *continuum* in an analytically well-founded way.[7]

[6] Examples of such maps obtained on the basis of the same data can be found in Heeringa (2004), p. 272 and 273.
[7] Software for measuring both categorical dialect distances and string edit distance-based dialect distances, and for

The most extensive Dutch study based on material of the RND was performed by Heeringa (2004). All-word pronunciation distances among 360 different dialect varieties were involved, and 125 word pronunciations per variety were used. Cluster analysis was also applied. From the dendrogram, a binary hierarchically structured tree, the main 13 clusters were examined, each of them discussed in detail.[8] A beam map, showing the 13 main groups found with cluster analysis, and MDS continuum maps are included. Heeringa and Nerbonne (2006) use the same data set, but measure same-word distances. A beam map and a choropleth MDS map obtained on the basis of the measurements in this study are shown in Figures 1a and 1b. As noted in Section 3.1, results of the all-word vs. same-word approaches are quite similar. The more global classification of the second study shows a division into Frisian, Low Saxon, a large central group (Holland, Utrecht, North-Brabant), West-Flemish (including Zeeland), East-Flemish, Flemish Brabant (including Antwerp), and Limburg, which is divided into eastern and western groups and a small northern part of the province of Liege. This classification partly agrees and partly disagrees with the classification shown in the map of Daan and Blok (1969), which is the most recent Dutch dialect map. Differences may be explained by the fact that the dialectometric map is obtained exclusively on the basis of pronunciation while the map of Daan and Blok is obtained on the basis of the perception of the speakers (Netherlandic part) and on the opinions of dialect speaking linguists (Belgian part).

In 2007 a study was published in which Wieling, Heeringa and Nerbonne measured same-word pronunciation distances among 613 Dutch varieties, using data from the Goeman-Taeldeman-van Reenen Project (GTRP)[9] which was collected in the period 1980-1995. Since the Netherlandic transcriptions are narrower than the Belgium ones, results are analyzed per country. Beam maps and MDS continuum maps are shown. The maps suggest a classification which is quite similar to the classification obtained on the basis of the RND measurements. The RND data set used in the studies mentioned above and the GTRP data set have 224 localities and 59 words in common. The RND and GTRP distances correlate strongly (r =0.83 in Netherlands, and r = 0.82 in Flanders).

Measuring with respect to a reference point

Besides measuring relationships among dialect varieties, it is useful to measure distances with respect to a single reference point. For Dutch we find three examples: distance measurements compared to Proto-Germanic, standard Dutch and Afrikaans.

Heeringa and Joseph (2007) measured same-word pronunciation distances between 360 Dutch dialect varieties and proto-Germanic. The same RND data set was used as in earlier studies, and the proto-Germanic forms were taken from a proto-Germanic dictionary (Köbler, 2003). The authors found that present-day Frisian varieties and the varieties in the eastern part of North-Brabant are closest to proto-Germanic, while the Ripuarian varieties are most distant from proto-Germanic.

Heeringa (2004) measured all-word distances between the set of 360 RND varieties and standard Dutch. Each dialect variety is compared to standard Dutch by comparing 125 word realizations to the corresponding standard Dutch pronunciations. The results were projected on a map using colors according to the “rainbow” scheme: the closest varieties are red, while the most distant varieties are blue. Intermediate points were colored using interpolation, just as in Nerbonne and Heeringa’s (1998) MDS continuum map. The map is shown in Figure 1c. Frisian and Ripuarian are most distant groups from standard Dutch, andthe dialect of Schiermonnikoog is the variety least like standard Dutch. Closest are the *Randstad* varieties, where Haarlem is maximally close to standard Dutch. Recall that Hoppenbrouwers and Hoppenbrouwers (2001) found that Groningen

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creating all the types of maps mentioned in this contribution is included in *Gabmap*, a web application for dialectometry developed at the University of Groningen and made freely available at: http://www.gabmap.nl/ (Nerbonne et al. 2011).

[8] However, one group, the former island of Urk, contains only one variety and therefore does not branch.

[9] For practical reasons Dutch dialectometrists used RND data for a long time. This does not mean that they judge the RND data superior to the GTRP data. The GTRP data is collected in a much smaller time span and transcriber differences may be smaller. Therefore, more recent analyses are based on the GTRP data.

and Limburg varieties were most distant and Frisian was relatively close to standard Dutch (see Section 2.2.3). As explained in Section 2.3.1, frequency-based methods do not consider the sequential structure of word pronunciations, while Levenshtein distance (used by Heeringa 2004) does. The effect of this difference is reflected in the different outcomes. In the map by Daan and Blok (1969), colors also reflect distances to standard Dutch. Dialects which are closest to standard Dutch are found in the *Randstad* and are white, while distant dialects are found in Friesland (blue), Groningen and Twente (darker green) and Limburg (red). Although the colors are chosen intuitively, they agree largely with the colors in the map of Heeringa (2004). The main difference is the coloring of West and French Flanders, which looks relatively close to standard Dutch in Daan's map and relatively distant to standard Dutch in Heeringa's (2004) map.

Dialectometry may help us to detect the origin of a colonial variety. Heeringa and De Wet (2008) compared Afrikaans to Standard Dutch, Standard Frisian and Standard German. Same-word pronunciation distances were measured by means of Levenshtein distance, and Afrikaans was found to be closest to Standard Dutch. Afrikaans pronunciation was also compared to 361 RND varieties.[10] Afrikaans was found closest to the variety of Zoetermeer (South Holland), which largely agrees with Kloeke's findings (1950, *Herkomst en Groei van het Afrikaans*). According to Kloeke "the old dialects of South Holland on the one hand and the 'High' Dutch on the other" (pp. 262-263) are the two chief sources of Afrikaans.

Measuring dialect convergence and dialect divergence

Dialects are usually not static, but are constantly changing under pressure of several factors, such as the influence of the standard language, and contact among localities as the result of increased mobility (see e.g. Auer and Hinskens (1996)). Hinskens, Auer and Kerswill (2005) write:

> "Dialect change can have several different manifestations. Among these, dialect convergence […] and dialect divergence […] noticeably affect relationships between related dialects."

In relation to this Hinskens, Kallen and Taeldeman (2000) observe:

> "Linguistic convergence can be defined as a process of language change leading to languages or language varieties becoming more similar to one another, whereas linguistic divergence can be defined as change in which languages or language varieties become more dissimilar. We define dialect convergence and divergence as the becoming more similar and dissimilar, respectively, of related dialects."

Below we present two dialectometric studies which focus on Dutch dialect convergence and divergence.

The *Algemeen Nederduitsch en Friesch dialecticon* (Winkler 1874) contains 186 translations of the parable of the prodigal son into dialects of the Netherlands, northern Belgium and western Germany. In 1996 Harrie Scholtmeijer repeated Winkler's field work for the dialects in the Netherlands. Heeringa and Nerbonne (2000) used Winkler's and Scholtmeijer's data, selecting 41 varieties found in both sources, and converting the texts to phonetic transcriptions, where Winkler's comments about the pronunciation were also taken into account, so that they could measure all-word pronunciation distances to standard Dutch on the basis of both the 1874 and the 1996 data. They subtracted the 1874 distances from the 1996 distances, so that the negative values indicate convergence and the positive ones divergence. Most varieties (23) have converged toward standard Dutch, which suggests that standard Dutch is encroaching on the territory of the dialects. This study might be regarded as a preliminary exercise in the use of dialectometry in the investigation of dialect change, but one should be aware of the fact that transcriptions derived from orthographic

[10] The same set of 360 RND varieties was used, but the dialect of Amsterdam was added.

transcriptions are not very reliable.

Wieling, Heeringa and Nerbonne (2007) approach convergence and divergence from another perspective. Since the GTRP data they analyze is not the same as the RND data, they performed a regression analysis using RND distances as an independent variable to predict GTRP distances. The regression analysis identifies an overall tendency between the RND and GTRP, against which relative convergence/divergence may be identified: particularly divergent local dialects are those for which the actual difference between the RND and GTRP distances exceeds the general tendency, and particularly convergent local dialects are those with distances smaller than the tendency. In our analysis of the results, we have to be aware of the fact that both the RND and the GTRP have been affected by transcriber borders, and that these borders probably do not always coincide. In this study a variant of the beam map is shown to illustrate convergence and divergence. In Figure 1d we show the same map. Dialects which diverge are connected by red lines, and dialects that converge are connected by blue lines.[11]

Measuring the influence of the state border

Hinskens (1997) points out that the Dutch/German state border which crosscuts a fan of old dialect continua from north to south, is increasingly becoming an important isogloss bundle. He distinguishes vertical convergence under pressure of the standard languages and, as the result of this, horizontal divergence between dialects at each side of the border, which were originally closely related (p. 7-8, see also Hinskens, Kallen and Taeldeman (2000: 19-21)). Woolhiser (2005) gives an extensive overview of previous research on border effects in Europe (p. 241-245). Below we discuss two Dutch/German studies which show that dialectometric methods may help to investigate the influence of the state border on dialects at both sides of that state border.

Heeringa et al. (2000) studied eight varieties in or close to the German county of Bentheim, and nine Dutch varieties nearby, using RND data, gathered in 1974-1975, and new data collected in 1999. The same set of 100 words is used in the two sets. The 17 varieties were compared to standard Dutch and standard German. All Dutch dialects were found to converge toward standard Dutch, while all the German dialects appeared to converge toward standard German. The results suggest that the national border is becoming a linguistic border. The authors noted, however, that six of the nine Dutch varieties had also become more like standard German (as well as more like standard Dutch)!

The Kleverland dialect continuum extends from Duisburg in Germany to Nijmegen in the Netherlands. The Dutch-German national border was drawn through this dialect continuum, but not until early in the nineteenth century. Giesbers (2008) studied this area in order to see whether the national border has triggered a rift in the dialect continuum. She selected five dialect location pairs, where each pair consisted of a Dutch and a German village. She gathered transcriptions of 100 nouns for each site from both young and old speakers. She applied dialectometric techniques (among others) to gauge the effect of the state border, measuring lexical and phonetic-phonological distances among the varieties and with respect to the standard languages.[12] Pronunciations which differ in two or more segments are considered as lexically different (p. 143). Pronunciation distances are measured as relative same-word distances. Two-dimensional MDS plots were made for the lexical and phonetic distances, and for each age group. Giesbers found that both the lexical and the phonetic distances between German and Dutch dialects are larger than the distances within the respective national groups. Secondly, she found that Dutch varieties have converged more strongly toward standard Dutch than German varieties have converged toward standard German. Particularly on the lexical level, the German speakers preserve more old dialect forms than the Dutch.

[11] Compare molecules which diverge at high temperatures (represented by red in weather charts) and converge at low temperatures (represented by blue). One may also argue the other way round: red is the color of love and attraction (convergence) and blue is the color of neutrality and distance (divergence).

[12] The software package *RuG/L04* was used, http://www.let.rug.nl/~kleiweg/L04/.

De Vriend et al. (2008) looked for a way to visualize the gap between the Dutch and German varieties in Giesbers's (2008) study. They measured geographical distances as the shortest travel distances by car (GEO). The linguistic distances (old/young, lexical/phonetic, i.e. four distance matrices) were scaled to the same range as the geographical distances, and then projected onto the geographic map. When the (scaled) linguistic distance between two locations is larger than the geographic distance, a ridge between the locations is projected. The authors expected to find peaks especially between localities on opposite sides of the state border. The landscape, however, showed only limited support for the hypothesis that the Dutch-German state border has become a linguistic border, since peaks were also found elsewhere.

3.3. Explanatory factors

Geography and population sizes

It is a fundamental postulate of dialectology that language variation is structured geographically. Hinskens, Auer and Kerswill (2005) argue that dialects are primarily geographically defined, but "geography as such does not influence language varieties, but does so through its social effects" (p. 28). Besides geographical proximity, large settlement sizes also increase the chance of social contact and the chance that dialects influence each other. Trudgill (1974) combined 'prior-existing linguistic similarity', geography and population sizes in his "gravity model" in which settlement size plays the role of mass in physics. The model predicts that proximity and population size should correlate with linguistic similarity. Hinskens (1993) applied this formula in order to calculate the linguistic influence of Heerlen and Kerkrade – two urban centers in the southeast of the Dutch province of Limburg – on the dialect of Rimburg, a small village northeast of the two cities, close to the Dutch/German border before the rise (in 1900) and after closing (in 1988) of the coal mines. Nerbonne and Heeringa (2007) studied the factors of geography and population size in a sample of 52 Low Saxon varieties, using RND data, with 125 word pronunciations per variety. They found a significant correlation between their all-word distances and geographic distances, but the addition of population information did not add any explanatory power to the model. Heeringa et al. (2007) applied the same model to a set of 27 varieties in the Netherlands and north Flanders. The data had been collected by Renée van Bezooijen in 2001, and consisted of pronunciations of 100 nouns per variety. The findings were similar: again, geography correlated significantly with the all-word pronunciation distances, but population size information - although statistically significant - had only a minor effect. This minor effect may be partly explained by the fact that present-day population sizes are used, while the dialect relationships originated several centuries earlier. On the other hand, there appears to be a strong correlation between present-day population sizes and historical population sizes. Nerbonne and Heeringa (2007) show a high correlation between population sizes between 1815 and 1930 ($r=0.86$). If the effects date from much earlier, other population data might have to be examined.

Surname variation

Local migrations and cultural diffusion may be reflected in genetic diversity. When exploring these connections, we do not assume a direct influence of genetic variation on dialect variation, but one could imagine that the family influences the language variation of children just as it influences many other cultural differences, and that this influence is reflected genetically. In order to pursue this idea, Manni, Heeringa and Nerbonne (2006) and Manni et al. (2008) compare the geographical pattern of surname variation to the geographical pattern of dialect pronunciation variation. Surnames can be safely used as a proxy to Y-chromosome genetic variation. Surname distances and dialect pronunciation distances among 226 Netherlandic varieties are compared. The pronunciation distances are the same as used by Heeringa (2004). The authors found a significant correlation between isonymy and dialect distance ($r = 0.417$, $p < 0.001$), but once the collinear effect of geography on both surname distances and linguistic distances was taken into account by partial correlation, there was in fact *no* statistically significant association between the two. This may reflect the fact that pronunciation and related areas of phonetics and phonology are more deeply embedded in a language system than family names, but it also indicates that language variation is not transmitted through the family (at least not via the paternal line).

4. Problems, lacunas, prospects, desiderata

4.1. Data

Although Dutch dialects are undoubtedly among the most well-documented in the world, quantitative analyses are nonetheless often frustrated by the scarcity of data which documents not only linguistic variation, but also the many potential extralinguistic correlates of variation, including not only geography, but also education, social standing, occupation, and sex. As we move from work emphasizing the description of the dialect landscape to work exploring its explanation, we need systematic data collections of these types. Naturally any effort aimed at filling this gap would need very careful design, in order to arrive at a reasonable compromise between a broad sampling of the factors and their potential interactions and a feasible size for the entire project.

4.2. Method

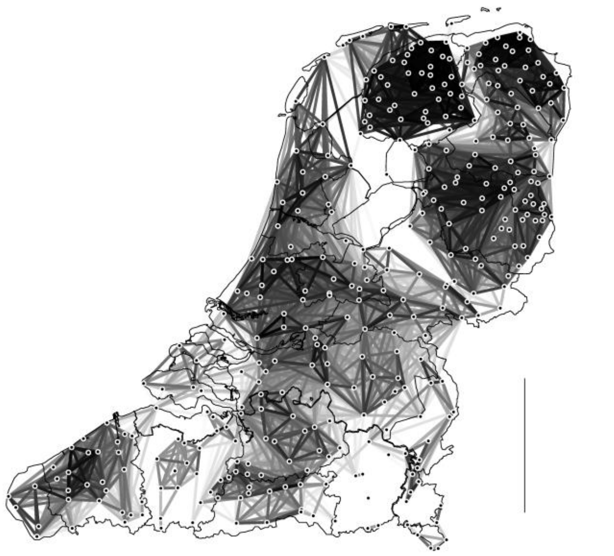
The edit-distance inspired work is capable of automatic application to large collections, and has been successful in rapidly analyzing new and large data sets (Wieling, Heeringa and Nerbonne 2007). It has also opened new avenues of investigation into dialect convergence and divergence (Heeringa et al. 2000), on the exact relation of linguistic variation to geography and to the role of social contact (Nerbonne and Heeringa, 2007) and on the relation between linguistic variation and family relatedness (Manni et al. 2008). There are nonetheless two (related) points where improvement would be most welcome.

First, this concerns the linguistic basis of aggregates. Nowadays a great deal of the interest in language variation is what one might regard as “purely” linguistic, and it has focused on the degree to which linguistic structure, e.g., phonemic structure, co-articulation, or natural processes such as strengthening and lenition, is instantiated in linguistic variation. Edit distance approaches have so far not contributed to this part of dialectology, and it would be useful to develop techniques aimed at identifying the recurrent differences found in a given data collection.

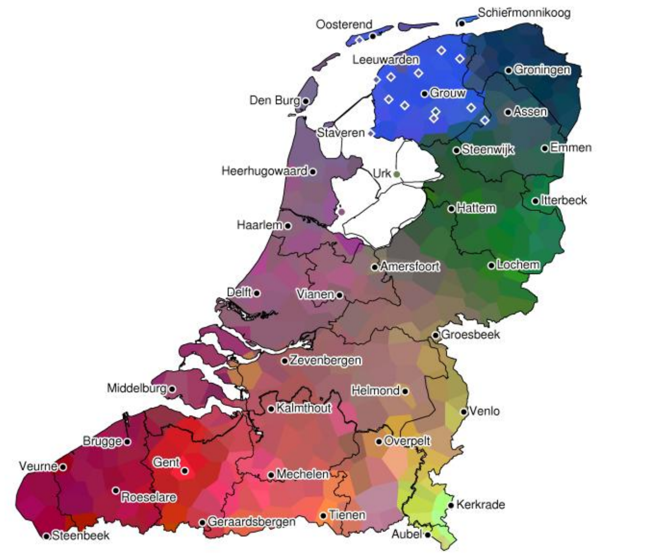
In relation to this, linguists wish to know the linguistic basis of classifications which are obtained on the basis of aggregated distances. In Section 3.2, we discussed multidimensional scaling as a technique to put dialect varieties in a two- or three-dimensional space according to the linguistic distances among them. Heeringa (2004) correlated the distances per dimension with the dialect distances obtained on the basis of individual words. Each dimension is associated with the highest correlating word, being the main explanatory factor of that dimension.

It would be enlightening to analyse the results of cluster analysis (Section 3.2) in a similar fashion, in order to determine what feature differences are represented by borders and by which features dialect groups are characterized. A breakthrough in linking aggregate analysis to a linguistic basis has been achieved by Wieling and Nerbonne (2010), who use bipartite spectral graph partitioning to simultaneously cluster dialect varieties and identify their most distinctive linguistic features in Dutch dialect data. Bipartite spectral graph clustering simultaneously seeks groups of individual features which are strongly associated, even while seeking groups of sites which share subsets of these same features. The term ‘spectral’ refers to the representation of a graph as a matrix in which each cell value reflects the strength of a connection from one node to another. The matrix may then be analyzed using techniques from linear algebra. In Wieling and Nerbonne’s work, sound correspondence nodes are linked to nodes representing geographical sites (towns and villages). This graph is analyzed to obtain a spectrum finding the clusters of sites and sound correspondences.

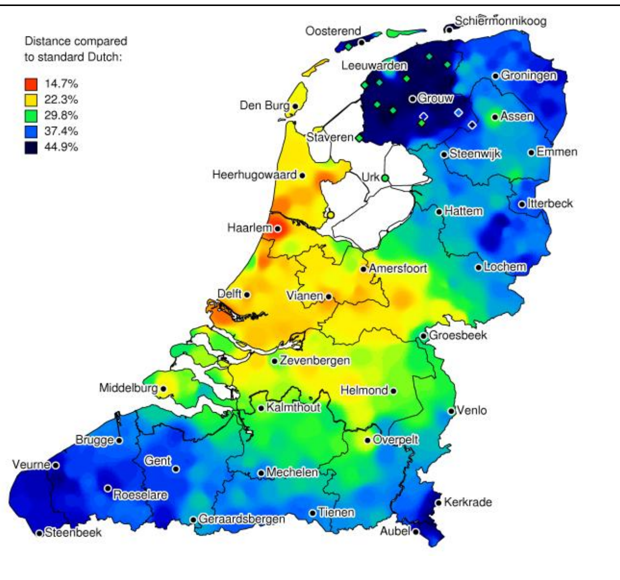
Second, it is clear that efforts aimed at refining edit-distance have been stymied by their validation methodology, which has been fixed on examining the degree to which aggregate measurements coincide with dialect speakers' judgments of how alien an entire speech pattern is (perceived to be). In retrospect perhaps it should not be surprising that comparisons at this aggregate level have been frustratingly inconclusive. Although promising new technical avenues are opening up as we compare alignment quality (Wieling, Prokic and Nerbonne 2009), we suspect that we should also turn to psycholinguistic (psychophonetic) techniques in an effort to validate the edit distance measurements more sensitively, i.e., at the level of individual words.



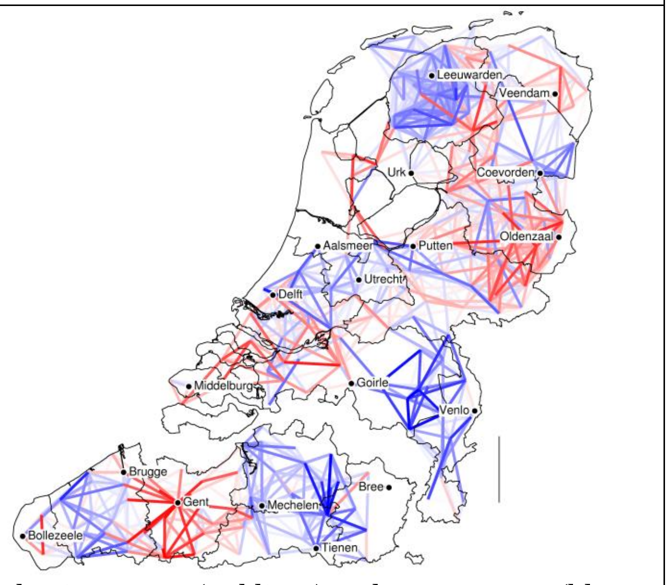
a. Beam map, 360 varieties, RND data.



b. Choropleth MDS map, 360 varieties, RND data.



c. Rainbow continuum map, distances to standard Dutch, 360 varieties, RND data.



d. Divergence (red lines) and convergence (blue lines), 224 varieties, RND vs. GTRP.

Figure 1. Visualization techniques in dialectometry. All of the maps show pronunciation distances measured with Levenshtein distance. In the map on the upper left (a), dark lines join sites that are linguistically similar. In the map on the upper right MDS coordinates in three dimensions are interpreted as red, green and blue intensities. The diamonds note dialect islands. The map on the lower left shows similarity to the standard language, and the map on the lower right shows relative convergence and divergence during the twentieth centrury. In the lower right corner of both Figures a and d a black vertical line is shown. Lines in the map longer than this line are not shown.

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