Patterns of language variation and underlying linguistic features: a new dialectometric approach

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1. INTRODUCTION

For almost forty years quantitative methods have been applied to the analysis of dialect variation: these methods focused mostly on identifying the most important dialectal groups using an aggregate analysis of the linguistic data (Séguy 1973; Goebl 1984; Nerbonne *et al.* 1999). While viewing dialect differences at an aggregate level certainly gives a more comprehensive view than the analysis of subjectively selected features, the aggregate approach has never fully convinced linguists of its use as it fails to identify the linguistic distinctions among the identified groups. Michele Loporcaro (2009) criticizes that dialectometry measures the structural distances among dialectal varieties without passing through a rationalization of the linguistic structure.

Recently, Wieling and Nerbonne (2010, 2011) proposed a promising graph-theoretic method, the spectral partitioning of bipartite graphs, to cluster varieties and simultaneously determine the underlying linguistic basis. Their results for Dutch are promising, and this method can be taken as an answer to Loporcaro's criticism, since it permits one to reconstruct which features underlie the aggregate patterns of dialectal variation and the role played by each of them. In this way, the gap between models of linguistic variation based on quantitative analyses and more traditional analyses based on specific linguistic features is significantly reduced. This paper illustrates the application of this technique on the dialectal corpus of the *Atlante Lessicale Toscano* (ALT)[1] and discusses the results. The atlas material contains phonetic transcriptions even though the published atlas documents lexical variation. Our analysis focuses on the level of phonetic variation. As documented

[1] ALT (Giacomelli *et al.* 2000) is available as an on-line resource, ALT-Web, http://serverdbt.ilc.cnr.it/ALTWEB/.

in Montemagni (2008), this is the level for which an aggregate analysis of the ALT dialectal corpus differs from the analyses by Giannelli (2000) and Pellegrini (1977). Phonetic variation in Tuscany thus provides a challenging case study to test this new technique.

Two additional contributions of this paper are technical: first, we weight sound correspondences by their frequency in order to emphasize more common correspondences, and second, we introduce a means of tracking correspondences in their phonetic context. As sound changes are recognized to be conditioned by phonetic context, this modification should result in detection that is not only more sensitive, but also linguistically better founded.

2. THE DATA SOURCE

2.1. The *Atlante Lessicale Toscano*

The ALT is a regional linguistic atlas focusing on dialectal variation throughout Tuscany, a region where both Tuscan and non-Tuscan[2] dialects are spoken. ALT interviews were carried out in 224 localities of Tuscany, with 2193 informants selected with respect to socio-demographic parameters, on the basis of a questionnaire of 745 items designed to elicit mainly lexico-semantic variation.

In ALT, each dialectal item is assigned a multi-level representation: for this study, we focused on the phonetic transcription and normalized representation levels where the latter is meant to abstract away from phonetic variation within Tuscany. At this level, neutralization is only concerned with phonetic variants resulting from productive phonetic processes (e.g. variants involving spirantization or voicing of plosives like /t/, as in [skjaˈtʃaː**θ**a] and [skjaˈtʃaː**d**a]), while it does not deal with morphological variation nor unproductive phonetic processes. The alignment of the different representation levels was exploited to automatically extract all attested phonetic variants (PV) sharing the same normalized form (NF). Due to the features of the normalized

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[2] This is the case for dialects in the north, namely Lunigiana and small areas of the Apennines, which belong to the group of Gallo-Italian dialects.

representation level, we can be sure that patterns of variation emerging from the analysis of PVs of the same NF document only genuine phonetic processes.

2.2. Building the experimental dataset

In this study, ALT dialectal data were used in a quite peculiar way, namely as a corpus: i.e. we did not start from a predefined set of questionnaire items specifically designed to investigate the geographic distribution of phonetic features, but rather from the set of the attested ALT lexical items, which were elicited from informants for quite different (mainly, lexico-semantic) purposes. By using atlas data as a corpus, the problem of inherently subjective feature selection is significantly reduced, thus providing a more "realistic" linguistic signal (Szmrecsanyi, to appear). On the other hand, by using atlas data as a corpus one of the main advantages usually ascribed to atlas-based studies, namely the areal coverage of dialectal items, can no longer be taken for granted. To overcome this potential problem, we enforced a minimal areal coverage threshold when selecting NFs (see below).

In particular, we focused on the phonetic variants of NFs selected from the ALT dialectal corpus based on both linguistic and geographical criteria. With respect to syntax only nouns and adjectives were selected,[3] both as single words and multi-word expressions.[4] Phonetic variability represented the other linguistic criterion: NFs were selected where the number of PVs ranged from 5 to 34 (the maximum number of PVs attested for one NF). Geographical criteria included: i) the areal coverage of selected NFs, which we required to be ≥ 100 (out of 224) locations; ii) the locations investigated which included 213 (out of the 224) locations where Tuscan dialects are spoken. The resulting dataset included 444 NFs (4.64% of all diatopically varying NFs), for a total of 502,799 phonetically variant tokens.

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[3] As in ALT verbal answers are represented by different inflected forms not always explicitly marked, verbs were excluded from the experimental dataset to prevent potential noise deriving from verbal morphology.

[4] Note that selected multi-word expressions were represented by "frozen" word combinations.

In order to test the representativeness of the selected sample of 444 NFs with respect to the whole set of NFs having at least two PVs attested in at least two locations (used in Montemagni 2008), we measured the correlation between overall phonetic distances and phonetic distances focusing on the selected sample which turned out to be very high (r = 0.994). We can thus conclude that the selected sample can be usefully exploited to reliably study the patterns of phonetic variation in Tuscany.

Since in the proposed analysis method PVs recorded in each location are compared with those attested in a reference variety, the experimental dataset also included the phonetic realization of the selected NFs in standard Italian.

3. METHODS

3.1. Extracting sound correspondences

Every variety attested in a given location is described in terms of the realizations of a given phonetic segment with respect to a reference variety (i.e. standard Italian). Attested phonetic realizations are encoded in terms of sound correspondences (SCs) linking the dialectal allophone with its realization in the reference variety.

SCs are obtained by aligning the PVs of a NF in a variety with its reference realization (standard Italian) on the basis of an adapted Levenshtein algorithm (Levenshtein 1965). The regular Levenshtein algorithm aligns two strings by minimizing the number of insertions, deletions and substitutions necessary to transform one string into the other. For example, the Levenshtein distance between the standard and dialectal realizations of *birignoccolo* ‘swelling’ is 3, since we need three operations (one deletion, one substitution and one insertion) as shown below.

Standard Italian	b	i	r	i	ɲː	ɔ	kː		o	l	o
Valle Dame	b	i	r		ɲ	ɔ	kː	w	o	l	o
				D	S			I			

Instead of the simple Levenshtein algorithm, we used a more sensitive version which uses automatically determined phonetic distances to increase the quality of the alignments (for more details see Wieling *et al.* 2009; Wieling and Nerbonne, accepted).

Since for each location investigated there was a socio-demographically differentiated group of informants potentially giving rise to multiple responses, we represented the variety with the most frequent phonetic variant of each selected normalized form.

The PV alignments exemplified above are used to identify SCs. We focus on phonetic correspondences involving non-identical segments and insertions and deletions, as these are most interesting. We also ignore SCs occurring infrequently (in fewer than 25 varieties) in a single word only.[5] Due to the fact that in the ALT dataset the same SC could originate from different phonetic processes, we decided to enrich their representation with contextual information, i.e. for each SC we also identify the left and right (single segment) context. As context, we only distinguish consonants, vowels, semi-vowels, a gap (in the case of an insertion or a deletion) and the word boundary (for the initial and final segment of a word). For instance, the SC [ɲː]#[ɲ] in the example above is recorded as V[ɲː]V#G[ɲ]V indicating that there are vowels to the left and right of [ɲː] and that there is a vowel to the right and a gap to the left of [ɲ].

As the next step, we count how frequently each contextualized SC occurs in every variety. We normalize these frequencies by dividing by the number of words, as not all words are attested in every variety. The normalized frequencies are stored in a matrix, exemplified below, where the rows represent the varieties and the columns represent the distinct SCs.

	V[tʃ]V#V[ʃ]V	_[b]V#_[bː]V	V[tʃ]V#V[ʒ]V
Anghiari	0.0845	0.0000	0.0000

[5] This follows from the fact that we wanted to avoid using noisy SCs originating from lexically driven processes, e.g. assimilation.

Antignano	0.1671	0.0112	0.0000
Arni	0.0049	0.0000	0.0191

This matrix is used as input for the spectral partitioning method to obtain the clustering of varieties together with their characteristic SCs.

3.2. Clustering SCs and varieties simultaneously

The method we use to *simultaneously* identify the geographical clusters in the dataset as well as their characteristic phonetic features is called the hierarchical spectral partitioning of bipartite graphs (Wieling and Nerbonne, 2010). A bipartite graph is a graph which has two sets of vertices (representing varieties and SCs) and a set of edges connecting vertices from one set to the other set (each edge represents the occurrence of a SC in a variety). Hierarchical spectral partitioning refers to the hierarchical clustering method, which is based on calculating the singular value decomposition of the input matrix.

Wieling and Nerbonne (2010) used a binary variety × SC matrix where only the presence or absence (of the correspondence in the variety) was stored (based on a frequency threshold to reduce the effect of noise). The disadvantage of this approach is that there is no distinction possible between high and low frequency phonetic correspondences. In this study, we opted instead to keep the normalized frequency values. To ensure that every SC is equally important, we scaled all individual columns between 0 and 1. After applying the hierarchical spectral partitioning method to the scaled input matrix, a hierarchical clustering is obtained where varieties are clustered together with SCs.

3.3. Determining the most important phonetic features for every cluster

As every cluster will contain many varieties and SCs, and we are interested only in the most important phonetic features for every geographical cluster, we need a method to distinguish the most important SCs. Following Wieling and Nerbonne (2011), we define the importance of a SC in a cluster as a linear combination of two measures, distinctiveness and representativeness.

The representativeness of a SC measures how frequently the SC occurs within the cluster. E.g., if there are ten varieties in the cluster and the sum of the normalized frequencies equals 4, the representativeness equals 0.4 (4/10).

The distinctiveness of a SC measures how frequently the SC occurs within a cluster as opposed to outside of the cluster, taking the relative size of the cluster into account. E.g., if the SC does not occur outside of the cluster, the distinctiveness is 1 (the phonetic correspondence perfectly distinguishes the cluster from the rest), no matter how large the cluster. Alternatively, if a cluster contains 50% of the varieties and 50% (or less) of the total sum of the normalized frequencies, the distinctiveness is 0 (the phonetic correspondence does not distinguish the cluster at all).

The values of distinctiveness and representativeness range between 0 and 1. Normally representativeness and distinctiveness are averaged to obtain the importance score for every SC (higher is better). In this study we decided to weight representativeness twice as heavily as distinctiveness since our matrix contained many infrequent (non-informative) SCs, whose distinctiveness was very high.

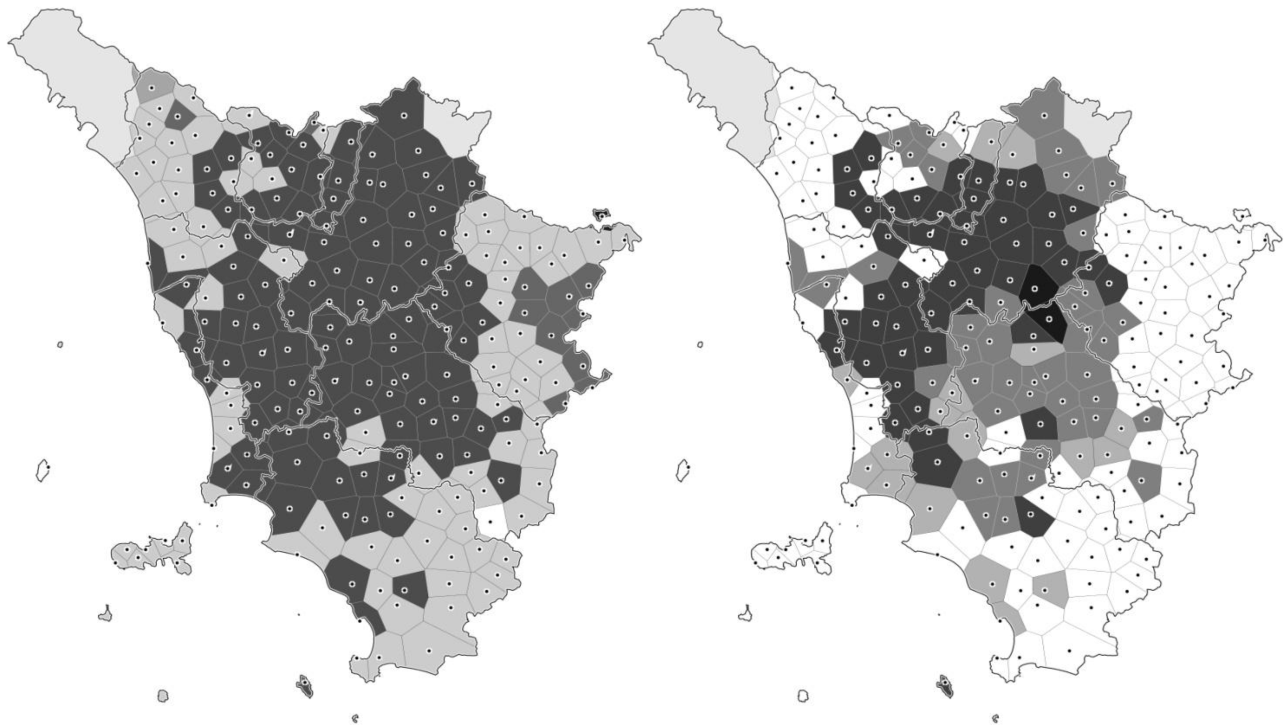
4. Results

The results obtained are based on 208 SCs extracted from the analysis of the PVs of 444 NFs. By classifying the SCs extracted according to the type of phonetic segments involved, it turns out that Tuscan phonetic variation is mainly concerned with consonants: i.e. 70% are consonantal SCs against 25% which are vocalic and 5% which involve semi-vowels.

4.1. Geographical results

In Figure 1, the map on the left shows the geographic visualization of the clustering of Tuscan varieties into six groups, whereas the map on the right provides a more detailed view of the core cluster showing its further subdivisions[6].

Figure 1



The map on the left shows a macro-picture of Tuscan dialects where the phonetic areas identified are arranged in an onion-like shape built around a big central area covering the province of Florence and propagating in different directions, towards south (in the province of Siena), east (in the province of Arezzo) and west (covering the provinces of Prato, Pistoia, Lucca up to most part of Pisa and Livorno). Around this central area, there is an external layer within which smaller distinct areas can be clearly detected.[7] If we turn to the map on the right, it can be seen that the core area has been further subdivided following the onion-like pattern depicted above (the outer area is

[6] We also identified a further subdivision of the other largest cluster of the map on the left; this is not shown here, due to the difficulty of visualizing it adequately within the same map.

[7] In spite of the fact that in this study we are focusing on Tuscan dialects only, these smaller varieties can be seen as transition zones strongly influenced by either northern or central dialects.

ignored, and colored white), i.e. a new intermediate layer has appeared between the external layer and the core: a new core covers a more restricted area revolving around Florence and expanding in all directions, in particular west and south.

The phonetic areas identified follow the pattern reported in Montemagni (2007, 2008), but they differ from the analyses by Pellegrini (1977) and Giannelli (2000), where the former is based on the distribution of phonetic phenomena and the latter results from the simultaneous consideration of phonetic, phonemic, morpho-syntactic and lexical features. In both cases, it is interesting to note that the proposed dialects from a) the Florentine area, b) the Siena area and c) the western areas (Pisano-Livornese) cannot be clearly identified in Figure 1.

4.2. Linguistic results

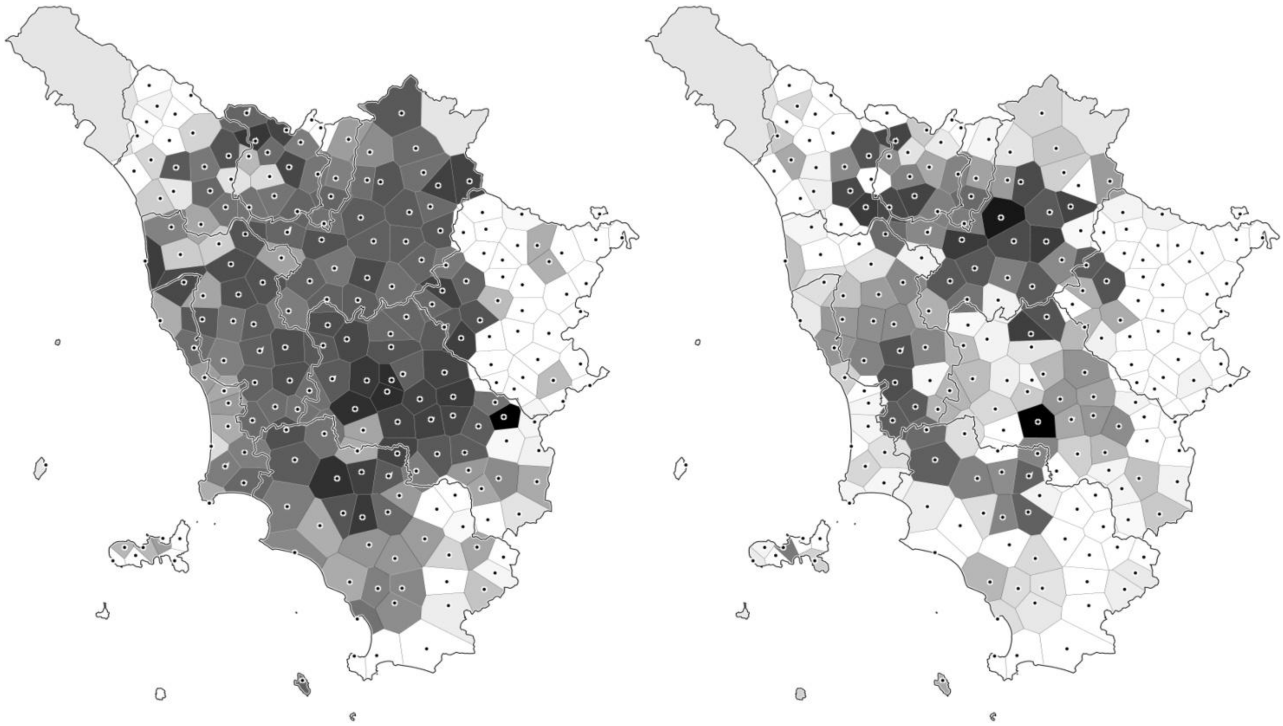
For what concerns the underlying linguistic features, let us first focus on the dialectal clusters in the left map. The SCs underlying the core area in the left map cover different phonetic phenomena: more than half of the segment pairs correspond to spirantization phenomena involving both voiceless and voiced stops /p t k b d g/ as well as /v/ in different contexts and with different outcomes, e.g.: the SC [d]#[ð] occurring in the contexts V[_]V#V[_]V, V[_]C#V[_]C and _[_]V#_[_]V as in [ˈprɔ**d**a] vs [ˈprɔ**ð**a], [paˈ**d**rino] vs [paˈ**ð**rino], [faˈrina ˈ**d**oltʃe] vs [faˈrina ˈ**ð**oltʃe] respectively; or the SCs V[t]V#V[θ]V, V[t]V#V[h]V and V[t]V#V[-]V as in [imbraˈna**t**o] vs [imbraˈna**θ**o] or [imbraˈna**h**o] or [imbraˈnao]. Other highly ranked features are represented by the rhoticism of preconsonantal /l/ (as in [a**l**biˈkɔkːa] vs [a**r**biˈkɔkːa]) and phonotactic lengthening in word initial position (as in [a ˈ**k**azo] vs [a ˈ**kː**azo]). In the external layer, the list of underlying phonetic features is much longer and more heterogeneous. Among the top features we note SCs corresponding to: spirantization phenomena involving the voiceless velar stop /k/ (characterized by a stronger but still spirant realization, as in [albiˈ**k**ɔkːa] vs [albiˈ**x**ɔkːa]) and the affricates /tʃ/ and

/dʒ/ (e.g. [ˈa**tʃ**ino] vs [ˈa**ʃ**ino]); affrication of postconsonantal /s/ > /ts/ in both word internal and word initial positions (e.g. [al ˈ**s**ole] vs [al ˈ**ts**ole]); lengthening/shortening phenomena involving consonants (e.g. [aˈ**b**eto] vs [aˈ**bː**etu]); and voicing of intervocalic stops (e.g. [ˈa**p**e] vs [ˈa**b**e]). The minor clusters appear to correspond to transition varieties, characterized by quite peculiar features, involving both vowels and consonants (this was not the case for the major clusters where most of the features were consonantal): e.g. [aˈbet**o**] vs [aˈbːet**u**], [diˈt**a**le] vs [diˈt**ɛ**le].

Let us turn now to the clusters of the map on the right subdividing the core area of the map on the left. The set of SCs characterizing the new and more restricted core has to do with the spirantization of both voiceless and voiced stops with a main difference with respect to the features underlying the core in the map on the left: SCs involving the voiced stops /b d ɡ/ are all assigned a much higher rank, whereas SCs including voiceless stops play a minor role and are restricted to /p t/ only. Around the new core, there is a cluster characterized by the spirantization of the voiceless stops /p t/ and the affricate /tʃ/; close to it, there is a smaller cluster also characterized by the spirantization of /p t/. A further cluster identified, covering marginal areas of the just described clusters, is mainly characterized by the spirantization of the voiceless stop /k/ (with the /h/ outcome).

The overall picture can be summarized as follows: in the map on the right, the core area is characterized by the spirantization of both voiced and voiceless plosives with a higher salience assigned to the former. In the other layers, spirantization phenomena are progressively restricted to voiceless plosives, with only /k/ being involved in the external layer: by gradually moving away from the core, we first observe clusters characterised by SCs involving /p t/, then by /k/ with progressively less spirant outcomes (i.e. [h] and then [x]).

Figure 2



In order to assess the reliability of the features identified, consider now the geographic distribution of SCs instantiating spirantization phenomena, i.e. including /p t k b d g/ in the reference and their spirant counterpart on the dialectal side. In Figure 2, the frequency of occurrence of each SC class is represented in terms of increasing darkness: areas characterized by a higher frequency are coloured with dark grays, whereas the reverse holds for less frequent features. The left and right maps report the distribution of voiceless and voiced spirantization respectively. Achieved results with the whole dataset are in line with the maps in Figure 2: the core area is characterised by the spirantization of both voiceless and voiced plosives, the further layers by voiceless spirantization only.

From this global analysis of the phonetic features underlying the identified dialectal clusters, we can claim that on the basis of the selected dataset patterns of phonetic variation in Tuscan dialects appear to be mainly due to spirantization phenomena, which originally arose in Florence and spread rapidly in different respects: geographically, by spreading from Florence in all directions, especially southward and westward; and phonologically, by originally involving the velar stop /k/, then /p t/ up to the voiced stops /b d g/.

5. CONCLUSION

In this paper we illustrated the application of the hierarchical spectral partitioning of bipartite graphs technique on the ALT dialectal corpus and discussed the results. The contribution of this study is twofold. From the point of view of Tuscan dialectology, it helps gain insight into the nature of phonetic variation in Tuscany, by simultaneously providing a classification of dialectal varieties and their underlying linguistic basis. Obviously, these results need further investigation in different directions. First, it would be interesting to enlarge the dataset to check whether identified variation patterns and underlying features change and to what extent; achieved results for what concerns spirantization phenomena should be analyzed in the light of the primary texts on the topic of Gorgia Toscana (Giannelli and Savoia, 1978, 1980). Second, due to the simultaneous diatopic and diastratic characterisation of the ALT data, it would be interesting to extend this study by considering socio-economical factors playing a role in the phonetic variation process as well. Experiments are currently being carried out by using Latin as a reference language, instead of standard Italian. On the technical side, this study gave us the opportunity to design a contextualised representation of SCs resulting in a better founded analysis of underlying phonetic features and to explore the role of frequency of phonetic features in the study of dialectal variation.

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