ShakerVis: Visual Analysis of Segment Variation of German Translations of Shakespeare's *Othello*

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Abstract: William Shakespeare is one of the world's greatest writers. His plays have been translated into every major living language. In some languages, his plays have been re-translated many times. These translations and re-translations have evolved for about 250 years. Studying variations in translations of world cultural heritage texts is of cross-cultural interest for arts and humanities researchers. The variations between re-translations are due to numerous factors including the differing purposes of translations, genetic relations, cultural and inter-cultural influences, rivalry between translators, and their varying competence. A team of Digital Humanities researchers has collected an experimental corpus of fifty-five different German re-translations of Shakespeare's play, *Othello*. The re-translations date from between 1766 and 2010. A sub-corpus of 32 re-translations has been prepared as a digital parallel corpus. We would like to develop methods of exploring patterns in variation between different translations. In this paper, we develope an interactive focus+context visualization system to present, analyze and explore variation at the level of user-defined segments. From our visualization, we are able to obtain an overview of the relationships of similarity between parallel segments in different versions. We can uncover clusters and outliers at various scales, and a linked focus view allows us to further explore the textual details behind these findings. The domain experts who are studying this topic evaluate our visualizations and we report their feedback. Our system helps them better understand the relationships between different German re-translations of *Othello* and derive some insight.

1 INTRODUCTION

William Shakespeare's plays have been translated into every major living language. In some languages, his plays have been re-translated many times. These translations and re-translations have been produced for about 250 years, in varying formats: some as books, including reading editions and study editions; some as scripts for performances (theatre, film, radio and television scripts). Multiple heritage text translations have remained, until now, an untapped resource for Digital Humanities. Divergence of multiple kinds caused by various factors is normal among multiple translations, due to differing translation purposes, genetic relations (translators 'borrowing' from one another), context-specific ideological and cultural influences, inter-translator rivalry, and translator competence and style. Studying variations in re-translations of world cultural heritage texts is of cross-cultural interest for humanities researchers. This does not just apply to Shakespeare. Variations among re-translations reveal histories of language and culture, intercultural dynamics, and changing interpretations of every translated work.

Digital Humanities researchers working on a project called 'Translation Arrays: Version Variation Visualization', have collected an experimental corpus of fifty-five different German re-translations of Shakespeare's play *Othello* (1604). The translations date from between 1766 and 2010. Most texts were acquired in non-digital formats. A representative sample of 32 of the re-translations has been digitized. The 32 texts of one scene of the play have been cleaned, formatting normalized, all texts segmented, speech by speech, and all segments semi-automatically aligned with a so-called 'base text' (Shakespeare in English), to create a parallel corpus. The selected scene is Act 1, Scene 3: in Shakespeare's original text. This scene is c. 10% of the play's length; it has c.3,000 words from the play's total of c.28,000 words; and the scene has 88 speeches. This parallel corpus can be accessed at the Translation Arrays project website: *www.delightedbeauty.org/vvv*. Based on this corpus, the team want to explore variations between different translations at the segment level, in order to uncover patterns relating to different types of translation, historical periods, genetic relations, and patterns relating to different sub-sets of segments. Sub-sets include speeches by certain characters (with the hypothesis that translators interpret characters in the play in distinctive ways, and therefore translate their speeches in different ways), and segments with certain linguistic and poetic features, such as metaphors, puns, rhyme, interpretative challenges, and so on. The team's general long-term aim is to develop analytic tools which will work for any corpus of re-translations. In this paper, the domain experts have selected a subset of their collected translations which are of great interest and they would like to analyze and explore the variations between them. The detailed information of these selected documents is discussed in Section 3.

Based on this collection, we attempt to devise a statistical metric to compute the similarity coefficients between pairs of documents, i.e. translations or versions of each segment, on the basis of lexical concordances. The original textual information is converted to a term-document matrix and further projected onto a lower-dimensional space. These document vectors with reduced dimensionality can be presented, analyzed and explored by our novel, application-specific interactive focus+context visualization system. From our visualization, we are able to obtain an overview of the distributions and relationships between documents of various segments. By the means of interaction support, the user is able to explore the underlying clusters, outliers and trends in the document collection. A focus view enables in-depth comparison between documents in order to identify the textual details behind these patterns. In the end, we can identify which segments from the original play provoke very different translations and which are characterized by similar translations, i.e stable content. Our tool is evaluated by the domain experts who are studying this topic. The findings help them better understand how different German translations of *Othello* relate to one another and to the base text.

In this paper, we contribute the following:

- We develop an interactive visualization system, abbreviated as ShakerVis, for presenting, analyzing and exploring segment variations between German translations of *Othello*.
- We derive statistical metrics, such as Eddy and Viv values to measure the stability of segment translations of *Othello*.
- Our system is evaluated by the domain experts. Some interesting patterns and findings are discovered.

The rest of the paper is organized as follows: Section 2 discusses previous work related to our approach and the problem domain. Section 3 describes the specific group of *Othello* translations we are using in this paper. Section 4 demonstrates the key ideas in preprocessing the textual data, projecting the data onto lower dimensional space and computing a similarity value for each segment translation. Section 5 presents our visualization and interactions to explore and analyze the derived document statistics. Section 6 reports the feedback from the domain experts who are studying this problem. Section 7 wraps up with the conclusion.

2 Related Work

In this section, we will briefly discuss the previous work on document visualization.

2.1 Single Document Visualization

Since 2005, from the major visualization conferences, we can observe a rapid increase in the number of text visualization prototypes being developed. A large number of visualizations have been developed for presenting the global patterns of individual document or overviews of multiple documents. These visualizations are able to depict word or sentence frequencies, such as Tag Clouds (B.Scott. et al., 2008), Semantic-preserving Word Clouds (Wu et al., 2011), Wordle (Viegas et al., 2009), Rolled-out Wordle (Strobelt et al., 2012), WordTree (Wattenberg and B.Viegas, 2008), or relationships between different terms in a text, such as PhraseNet (van Ham et al., 2009), TextArc (Paley, 2002) and DocBurst (Collins et al., 2009b). The standard Tag Clouds (B.Scott. et al., 2008) is a popular text visualization for depicting term frequencies. Tags are usually listed alphabetically and the importance of each tag is shown with font size or color. Wordle (Viegas et al., 2009) is a more artistically arranged version of a text which can give a more personal feel to a document. ManiWordle (Koh et al., 2010) provides flexible control such that the user can directly manipulate the original Wordle to change the layout and color of the visualization. Word Tree (Wattenberg and B.Viegas, 2008) is a visualization of the traditional keyword-in-context method. It is a visual search tool for unstructured text. Phrase Nets (van Ham et al., 2009) illustrates the relationships between different words used in a text. It uses a

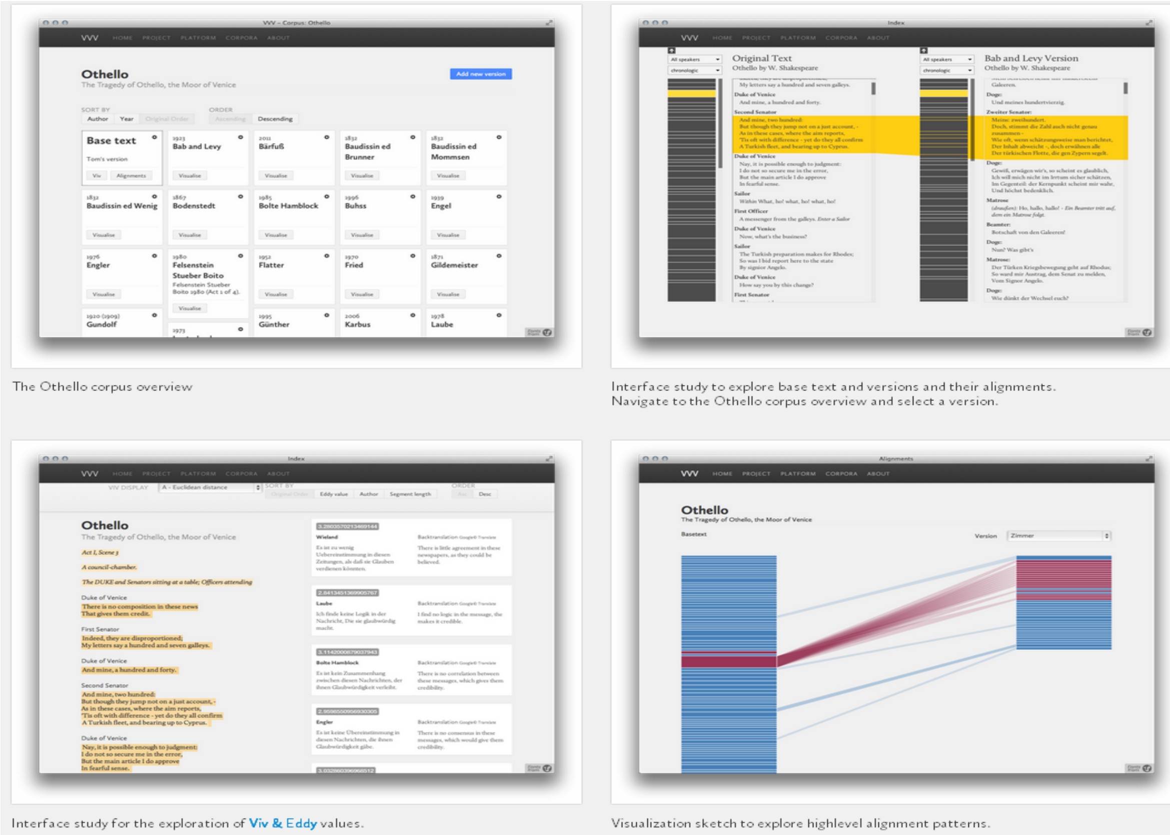

Figure 1: This image shows an overview of four interfaces of the Translation Arrays tool suite (Cheesman et al., 2 13).

simple form of pattern matching to provide multiple views of the concepts contained in a book, speech, or poem. A TextArc (Paley, 2002) is a visual representation of an entire text on a single page. It provides animation to keep track of variations in the relationship between different words, phrases and sentences. DocuBurst (Collins et al., 2009b) uses a radial, space-filling layout to depict the document content by visualizing the structured text. The structured text in this visualization refers to the is-kind-of or is-type-of relationship. These visualizations offer an effective overview of the individual document features, but they cannot provide a comparative analysis for multiple documents. In our analysis, we need to develop tools which can compare multiple documents at the same time. However, we still need single document visualization to depict the term frequencies for every document being compared. This will offer a context view for the user to understand the distribution of the word usage by different authors. In our work, we utilize a heatmap to present such information.

2.2 Multiple Document Visualization

In contrast to single document visualizations, there are relatively few attempts to differentiate features among multiple documents. Noticeable exceptions include TagLine Generator (Mehta, 2006), Parallel Tag Clouds (Collins et al., 2009a), ThemeRiver (Havre et al., 2002) and SparkClouds (Lee et al., 2010). Tagline Generator (Mehta, 2006) generates chronological tag clouds from multiple documents without manual tagging of data entries. Because the TagLine Generator can only display one document at a time, it is unable to reveal the relationships among multiple documents. A much better visualization for this purpose is Parallel Tag Clouds (Collins et al., 2009a). This visualization combines parallel coordinates and tag clouds to provide a rich overview of a document collection. Each vertical axis represents a document. The words in each document are summarized in the form of tag clouds along the vertical axis. When clicking on a word, the same word appearing in other vertical axes is connected. Several filters can be defined to reduce the amount of text displayed in each document. One disadvantage of this visualization is its incapability to display groups of words which are missing in one document but frequently appear in the others. This information often reveals the style of different translators with respect to the uniques words they have used. Also, when handling a large document corpus, the parallel tag clouds might suffer from visual clutter due to the limited screen space. In order to address this, in our previous approach (Geng et al., 2011), we have developed a structure-aware Treemap for metadata analysis and document selection. Once a subset of documents are selected, they can be further analyzed by our Focus + Context parallel coordinates view. Our previous approach tries to visualize how each unique term changes in each translation, whereas in this paper we would like to work on a more abstract document level, namely segment or speech of German translations of *Othello*. Understanding which segments remain stable and which exhibit high variability sheds new light on the local culture with respect to both the time period and region. Therefore, our major goal for this project is to develop an interactive visualization system to present and explore the parallel segment variations between multiple translations.

In addition to generic visualization techniques, we also notice a number of emerging visualizations developed specific to particular applications. (Jankun-Kelly et al., 2011) present a visual analytics framework for exploring the textual relationships in computer forensics. The visualizations presented in Michael Correll and et. al (Correll et al., 2011)'s work is similar to ours, which provide modern literary scholars an access to vast collections of text with the traditional close analysis of their field. The difference is that we focus on the untagged multilingual translations. The visualization named PaperVis provide a user-friendly interface to help users quickly grasp the intrinsic complex citation-reference structures among a specic group of papers (J.-K. Chou, 2011). The world's language explorer presents a novel visual analytics approach that helps linguistic researchers to explore the worlds languages with respect to several important tasks, such as the comparison of manually and automatically extracted language features across languages and within the context of language genealogy (Rohrdantz et al., 2012).

2.3 Previous work on Multiple Shakespeare Translations

Stephan Thiel's work presents all the plays of Shakespeare, using the deeply tagged WordHoard digital texts, filtered through analytic algorithms (Thiel, 2006). DocuScope is a text analysis environment with a suite of interactive visualization tools for corpus-based rhetorical analysis (Carnegie Mellon University, 1998). Michael Witmore, Director of the Shakespeare Folger Library, and Jonathan Hope have used DocuScope for years to analyze Shakespeare and other early modern texts (Hope and Witmore, 2004). These work effectively present the original Shakespeare's work, but not translations. The previous work which is more related to this paper is presented in Translation Arrays tool suite (Cheesman et al., 2 13). The Translation Arrays project is creating tools for exploring and analyzing corpora of re-translations, i.e. multiple translations into the same language. Such corpora can be mined for data on the past and present development of translating languages and cultures, on inter-cultural dynamics, and on the interpretability of translated works and parts of works. Recently the project team created a corpus store, a segmentation and alignment tool, and web-based visual interfaces. These offer alignment structure overviews, navigation through parallel texts, and a comparison of two versions of a segment alongside a full base text view (with back-translations from German to English). An overview interface of these interfaces is shown in Figure 1. In the last mentioned view, all the translations of a selected segment are retrieved and can be sorted in several ways, e.g. author name, date, or length, or by relative lexical distinctiveness, or distance from other versions. We call this relative distance value 'Eddy', from the metaphor 'eddy' (turbulence) and because it can be calculated from concordances in many ways, all involving the sum of values associated with individual documents (Cheesman and the Version Variation Visualization Project Team, 2011). Thus, all versions of a segment can be ranked in this view, in order of distinctiveness. In a further step, the set of Eddy values for versions of a segment can be reduced to a single value and compared with sets of Eddy values for other segments. This value is termed 'Viv' (vivacity). The base text is annotated with Viv in the website, so as to identify 'hotspots', where translations are most different. The work presented in this paper develops a new metric for 'Eddy' and demonstrates visualizations which enable users to identify clusters and outliers in re-scalable text and segment corpora. Future work integrates these visualizations into the project's web-based tool suite, and devises a metric for aggregating these 'Eddy' results into a 'Viv' annotation.

3 Background Data Description

In this paper, we concentrate on the visual analysis of parallel segment variation. A segment refers to a section within a document, of arbitrary size. Segments might be lexical terms, phrases, or sentences, in any text; or acts, scenes, and speeches in playtexts; or chapters, paragraphs, and spoken dialogue in works of prose fiction; or chapters and verses in works of scripture; and so on. In our current work, each speech in the play is regarded as a segment. Equivalent speeches in the German translations have been aligned with the English base text. Alignments can be problematic and complex, because some retranslations re-order and omit material from the base text and add new material with no base text equivalent. The experiment reported here uses a selected sub-corpus: ten re-translation texts of known interest, and seven parallel segments from each. The segments were selected for non-problematic alignments and for comparable, relatively high segment lengths (42 to 95 words in the base text). They consist of the seven consecutive longer speeches which begin in the base text with Desdemona's speech 'My noble father' (excluding three very short speeches beginning with the Duke's speech 'If you please'). The ten re-translations investigated include: (a) two different editions of the standard verse translation for performance and reading (Baudissin 1832, as edited in 2000 for Project Gutenberg, and as edited by Brunner in 1947) (Baudissin, 1832; Brunner, 1947); (b) two didactic prose translations for students (Engler 1976, Bolte 1985) (Engler, 1976; Bolte, 1985); (c) one recent prose translation for performance (Zaimoglu 2003), known to be an outlier because the text is very idiosyncratic (Zaimoglu, 2003); and (d) five verse translations for performance, or for performance and reading, dating from the 1950s-1970s (Flatter 1952, Schröder 1962, Fried 1970, Lauterbach 1972, Laube 1977) (Flatter, 2009; Rudolf Alexander Schröder, 1963; Fried, 1999; Lauterbach, 1996; Laube, 1978). The genetic and stylistic inter-relations of these five versions have not yet been studied, but all are considered 'complete' and 'faithful'.

4 FUNDAMENTALS

In this section, we utilize statistics to measure the relative distinctiveness of a segment or document, in relation to other German translations. In order to achieve this, several steps are implemented, such as, converting the original text into vector space, reducing the document dimensionality and computing

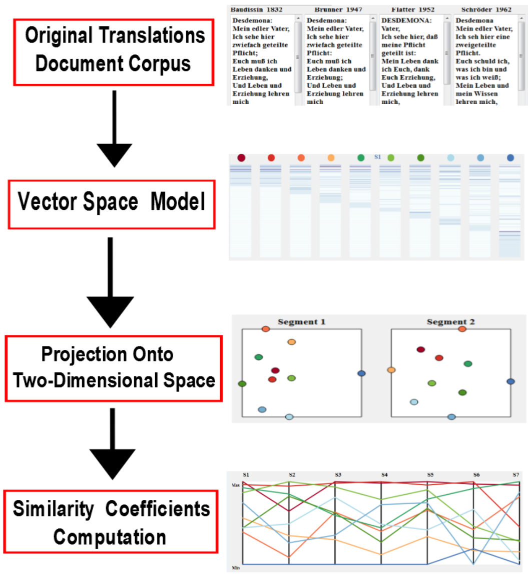

Figure 2: This diagram demonstrates how our statistical coefficients are derived and the way they can be visualized.

the average similarity value, as depicted in Figure 2. We initially pre-process the original document corpus which contains ten different German translations of *Othello*. Each translation contains seven speeches, namely segments. A segment in one translation is semi-automatically aligned to the same segment in the other translations. The text preprocessing transforms the original document into a term-document matrix. A document can then be regarded as a vector with each dimension representing a unique term, as discussed in Section 4.1. Because the derived document vector suffers from high dimensionality, it is noisy due to the existence of uninteresting instances of terms. Also visualizing and analyzing documents in such a high-dimensional space can be challenging. Therefore we utilize the multi-dimensional scaling technique to project original document vectors onto a lower dimensional space (Davison, 1992). With reduced dimensionality the document can be presented by conventional visualization techniques, such as scatterplots. This helps the domain expert visually identify and recognize the clusters, outliers and trends between documents, as discussed in Section 4.2. Finally, we compute similarity coefficients for documents in different segments. In addition, a global similarity value for each document can be obtained by calculating the diameter of each segment, as discussed in Section 4.3.

4.1 TEXT PRE-PROCESSING

During the text preprocessing, we process our original texts in six steps, namely document standardization, segmentation, alignment, exclusion of non-relevant text elements, and tokenization. Since the *Othello* translations are collected from various sources (some PDF, some archival typescripts, mostly books), we firstly transform and integrate them into a standard XML format. Next, we define contiguous segments for each document and align the segments with the English-language base text, using machine-supported manual methods. In this process we also define and exclude some components of the original text which we do not want to process: such as stage directions, editorial notes, and etc. However the names of speakers for each speech are provided in the output display. This leaves the text which is relevant for similarity calculation: the speeches. Then, tokenization breaks the stream of text into a list of individual words or tokens. During this process, we can also experiment with selecting certain words for inclusion or exclusion from the token list, such as common 'function words' or 'stop words' carrying little meaning; also with stemming, to remove suffixes, prefixes, and grammatical inflections; and with lemmatization, to reduce all tokens to their root forms. These techniques will be carried out in the future work. Based on this cleaned and standardized token list, we are able to generate a concordance table for each segment by deriving the frequencies of every unique token in every translation segment.

4.2 DIMENSION REDUCTION

After the original document has been cleaned and preprocessed, we are able to construct a weighted term-document matrix where the list of terms associated with their weight is treated as document vectors. The weight of each term indicates its importance in a document. Empirical studies report that the Log Entropy weighting functions work well, in practice, with many data sets (Landauer et al., 2007). We use Tf (Term frequency) to refer to the number of times a term occurs in a given document, which measures the importance of a word in a given document. We use Gf to refer to the total number of times a term i occurs in the whole collection. Thus the weight of a term i in document j can be defined as:

$$\omega_{i,j} = (1 + \sum_{j} \frac{\frac{tf_{i,j}}{gf_i} \log \frac{tf_{i,j}}{gf_i}}{\log n}) \log(tf_{i,j} + 1) \quad (1)$$

where n is the total number of documents in the corpus. The term gf_i is the total number of times a term i occurs in the whole collection. Large values of $\omega_{i,j}$ imply term i is an important word in document j but not common in all documents n.

Then a document j can be represented as a vector with each dimension replaced by the term weight:

$$\vec{D}_j = (\omega_{0,j}, \omega_{1,j}, ..., \omega_{n,j})^T \quad (2)$$

In order to reduce the dimensionality of the original document vector, we utilize the Classical Multi-Dimensional Scaling technique to project document vectors onto a two-dimensional subspace (Davison, 1992). Given n items in a p-dimensional space and an $n \times n$ matrix of proximity measures among the items, multidimensional scaling (MDS) produces a k-dimensional representation of p items such that the distances among the points in the new space are preserved and reflect the proximities in the data (Fodor, 2002). In our data sample, the input data of MDS is a square matrix containing dissimilarities between pairs of document vectors. The output data is a lower-rank coordinate matrix whose configuration minimizes a loss function called stress:

$$\underset{d_1,...,d_I}{\operatorname{argmin}} \sum_{i<j} (\|d_i - d_j\| - \delta_{i,j})^2 \quad (3)$$

where $(d_1, ..., d_I)$ is a list of document vectors in lower dimensional space. $\|d_i - d_j\|$ is the Euclidean distance between documents d_i and d_j. $\delta_{i,j}$ is the dissimilarity value, i.e Euclidean distance, between documents i and j in their original dimensional space.

Given a list of document vectors, using MDS will project the high-dimensional vector on a two-dimensional map such that documents that are perceived to be very similar are placed closed to each other on the map, and documents that are perceived to be very different are placed far away from each other.

4.3 SIMILARITY MEASURE

The similarity coefficients between every two document vectors in a reduced dimensional space can be defined as the Euclidean distance between them. Once we have obtained a similarity value for every pair of translations of the same segment, then a weight value for each translation can be computed by averaging the sum of similarity values between the given translation and all other neighbouring translations. As introduced in Section 2, we name this value as "Eddy", which can be defined as:

$$Eddy_(D_j^i) = \frac{\sum_{k=1}^{n} \|D_j^i - D_k^i\|}{n} \quad (4)$$

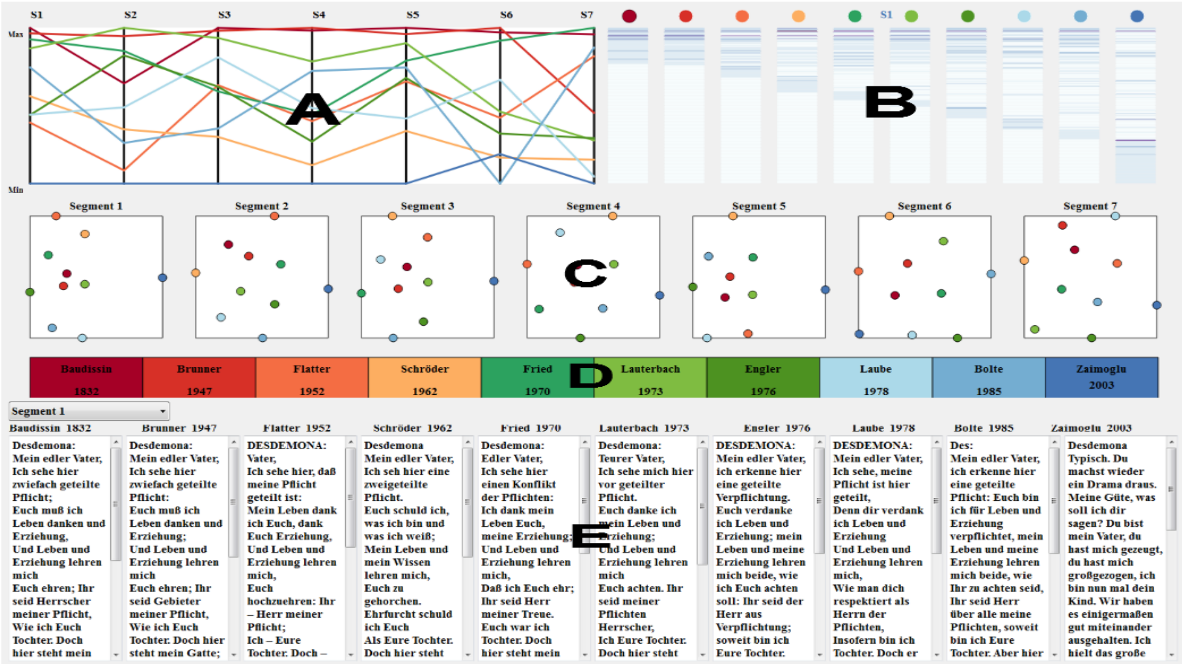

Figure 3: This figure shows an overview of our visualization system. (A) is a parallel coordinates view which shows the similarity values for each translation across multiple segments. (B) is the heat map representing the term-document frequency matrix. (C) is a scatterplot view which depicts the relationship between translations in each segment. (D) shows the document control panel where the user is able to brush and select one or many translations for comparison. (E) depicts the actual text.

where n is the number of documents in a segment i. D^i_j represents a document j in a segment i.

In a traditional clustering algorithm, a diameter refers to the average pairwise distance between every two elements within a cluster (Xu and Wunsch, 2005). If translations of the same segment are regarded as a cluster, then the stability of the segment from the original play can be measured by its diameter. A segment with low stability indicates that translations for this segment vary a lot between different authors, whereas a segment with high stability indicates translations for this segment are similar. As introduced in Section 2, we name the diameter for a segment i as "Viv" value:

$$Viv(i) = \frac{\sum_{k=1}^{n} Eddy(D^i_k)}{n} \tag{5}$$

where n is the total number of translations in a segment i. This "Viv" value can be used to rank the segments with respect to the degree of variance between its translations.

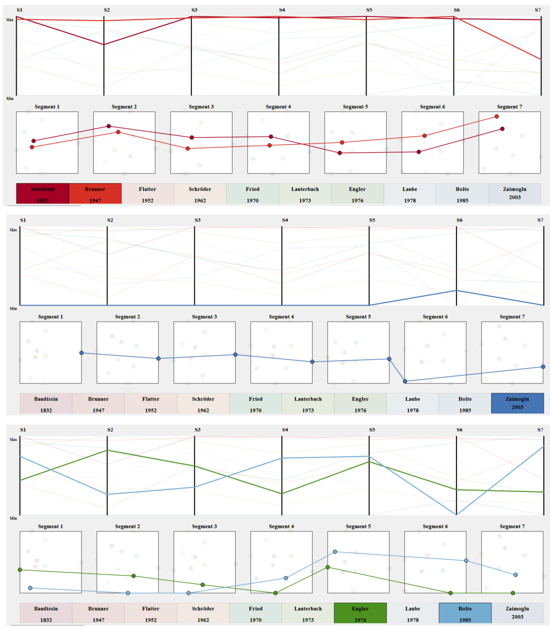

Figure 4: This figure depicts three interesting findings by the means of brushing and selection.

5 VISUALIZATION

In this section, we present our interactive visualization system to explore and analyze the extracted segment features from Section 4. Ben Shneiderman (Shneiderman, 1996) proposed the visual information seeking mantra: overview first, zoom and fil-

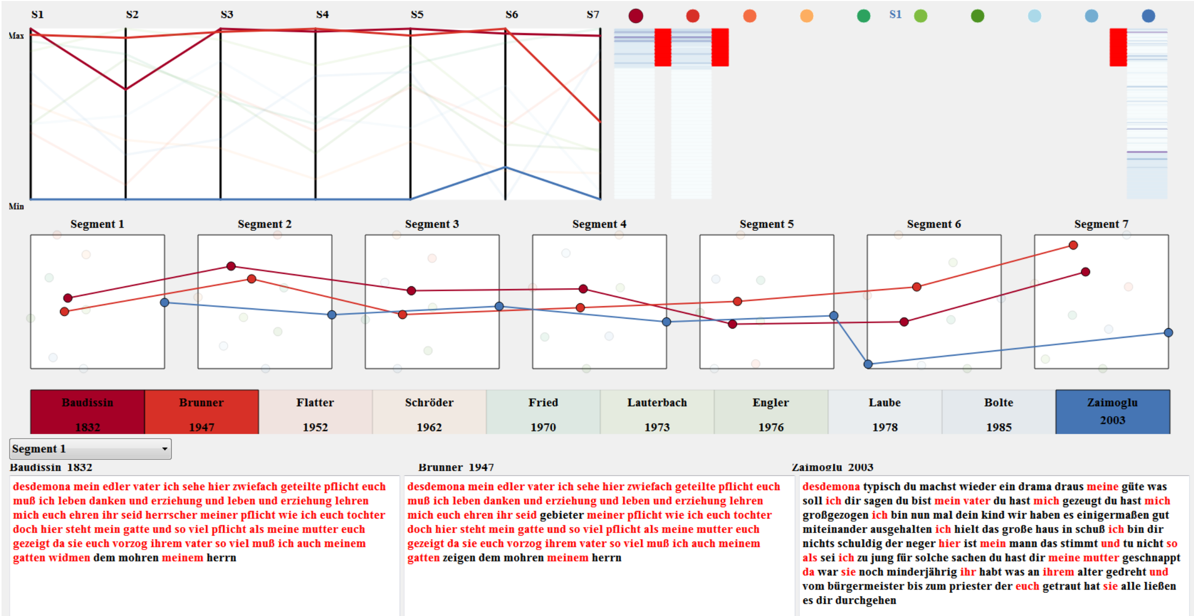

Figure 5: This figure shows a focus + context view of multiple selections of different translations. These selections include two very similar translations and one extra translation which appeared as an outlier. The user is able to obtain an overview of segment distinctiveness from the context view. Comparing the corresponding translations side by side from the text view enables in-depth analysis. Unique terms brushed from heat maps are highlighted in red in the text views.

ter and details on demand, as visual design guidelines for interactive information visualization. Following this rule, our visualization system is composed of two parts. One offers a context view which is composed of scatterplots and parallel coordinates views, which gives an overview of distributions and relationships between translations across different segments, as discussed in Section 5.3 and Section 5.2. The other part provides a detail view, which allows an in-depth analysis for one individual segment using term-document frequency heatmap. This view provides a side-by-side textual and term-document frequency comparison to uncover the underlying details which result in clusters or outliers, as discussed in Section 5.4. Shown in Figure 3 is an overview of our visualization system. The input data set is a document corpus with ten translations by different authors in different time periods. The details of these translations are introduced in Section 3. Each translation can be decomposed into seven different segments. Each segment is an individual speech translated from the original *Othello* play. Different versions of translations have different interpretations for each speech of the *Othello* play, we have therefore built a separate concordance for each segment.

5.1 Document Control Panel

Part (D) of Figure 3 shows a document control panel. Each rectangular box is assigned a unique color to depict a unique translation. Labelled on the box is the name of the author and the year the corresponding translation was published. The translations are arranged in chronological order by default. The user is able to select one or many translations for comparison. Every time they select a translation, the scatterplots and parallel coordinate views are updated. Interactions on the scatterplots and parallel coordinates make the brushed documents highlighted in the document control panel.

5.2 Parallel Coordinates View

Part (A) of Figure 3 shows parallel coordinates (Inselberg and Dimsdale, 1990). Parallel coordinates, introduced by Inselberg and Dimsdale (Inselberg, 2009; Inselberg and Dimsdale, 1990) is a widely used visualization technique for exploring large, multidimensional data sets. It is powerful in revealing a wide range of data characteristics such as different data distributions and functional dependencies (Keim, 2002). As discussed in Section 4.3, for each translation, an Eddy value is computed for each of its segment. This information can be depicted by parallel coordinates, where each dimension represents an individual seg-

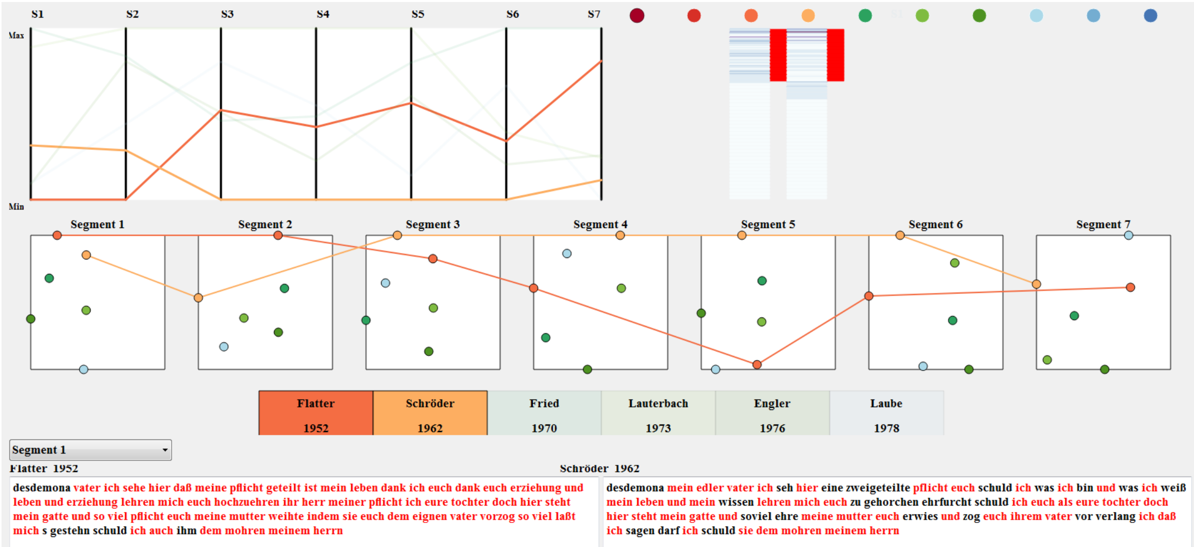

Figure 6: In this image, the domain experts have pushed aside some of the uninteresting documents and the rest of the documents are rescaled on the scatterplot and parallel coordinates. Based on this smaller subset and rescaled visualization, the domain experts find two interesting documents, as highlighted and linked in the scatterplot view. These two documents are distinct from the others, especially Schröder appears as an outlier.

ment with every Eddy value linearly interpolated on it. Then an Eddy value for a translation containing various segments can be depicted by a polyline in the parallel coordinates. The top of the axis represents the smallest Eddy value, which means on average a translation is similar to all the other translations in a given segment. The bottom of the axis represents the largest Eddy value, which means on average a translation is different to all the others. We offer various interaction support, such as an AND and OR brush, for the user to explore different multidimensional patterns.

5.3 Scatterplot View

The parallel coordinates view presents an average similarity value for each translation across multiple segments. If the user is interested in the relationship between each pair of translations for a given segment, we incorporate multiple scatterplot views to represent this information. Document vectors with reduced dimensionality can be visualized and presented by scatterplots for each segment, as shown on part C of Figure 3. Each translation is depicted by a constant unique color across all segments. The scatterplots offer a clear overview of how different translations relate to each other. The relative positions of document vectors in the scatterplot can visually reveal which set of translations are close to each other and which are further away. This could additionally uncover some interesting clusters or outliers. For example, we are able to observe an outlier as depicted in blue on the far right of segment one and on the top of segment three. In addition, from the parallel coordinates view, we are able to see that this translation written by Zaimoglu in 2003 is an outlier across most of the segments, which draws the same conclusion as our initial assumption. For some of the segments, documents are almost equally distributed and not positioned closely as a compact cluster, such as segment six and seven. These segments have a relatively larger pairwise Euclidean distance between translations compared to other segments. This indicates that authors might have distinctive interpretations for these two segments in *Othello*. If the users would like to see how a whole translation behaves across all segments, then we provide a link to connect the corresponding point in each segment scatterplots, as shown on the top of Figure 4. This provides a coherent view of how similar each translation is compared to others in each of its segments. Figure 4 depicts several interesting initial findings by the means of brushing and selecting as discovered by domain experts. The first finding is shown in the first row of Figure 4, which shows the closest similarity between Baudissin and Brunner: editions of the same text, with orthographic differences in all segments and term- and phrase-differences in some segments. The second finding is shown in the second row of Figure 4, which clearly identifies the stylistic outlier, Zaimoglu 2003, a very idiosyncratic translation or 'tradaptation'. The third finding is shown in the third row of Figure 4, which demonstrates that the two didactic prose translations for study purposes (Engler 1976, Bolte 1985) cluster together in most segments, distinct from all others. This is expected: these versions share the same time period, translation skopos (purpose: didactic), and aesthetic form (prose), all leading to similar word-choices. As the translations are selected, the corresponding document is shown to give a side-by-side textual comparison. As illustrated on the part (E) of Figure 3. Once the user has observed some interesting patterns from the context views, they can zoom into each segment for more detail from this text view.

5.4 Term-Document Frequency Heat Map

The system created here was done in close collaboration with a domain expert in German translations of Shakespeare's work. The following review is provided by him. When we checked varying distances on the scatterplots against actual textual differences, we discovered that significant differences in word-choices are not easily identified. Distances are computed from concordances which treat different word-forms as different tokens (e.g. 'Cypern'/'Zypern', 'kräftigen'/'kräft'gen'). Therefore only relying on the scatterplot and parallel coordinates view is not yet effective for identifying segments where translators (and editors) of very closely similar versions make different significant word-choices. In order to analyze differences between pairs of versions in more detail, including a measurement of character-string similarities (which also will help detect genetic relations), we have proposed a term-document frequency heat map to compare segments on term level. Part B of Figure 3 is a term-document frequency heat map for segment one. Each column of our heat map represents an individual document. For a better discrimination between different documents we decide to leave a small gap between every two columns. Each row of our heat map represents a unique keyword. Every cell inside a heat map depicts the frequency of a keyword (row) in a given document (column). The darker color in each cell reveals a higher term frequency and the lighter color reveals a lower term frequency. Our keyword list contains all the unique words occurred in all translations in this given segment. From this heat map, we are able to easily observe that the first two segments share a number of common words. This might explain why these two segments stay closer to each other from the scatterplot view described in Section 5.3. In addition, the user is able to brush these common keywords and the corresponding document text view will be updated, as shown in Figure 5. The text view shown on the bottom row of figure 5 depicts three selected document in segment one. The brushed keywords from the heat map are highlighted in red in the text view. As we can observe that the first two translations are very similar with respect to the common words and sentences they share. However the other selected documents only share a few of the brushed keywords and reveal a different style of writing. A full list of heat maps for all of the segments is shown in Figure 7.

6 DOMAIN EXPERT REVIEW

The ShakerVis tool implements a new approach in textual studies: comparison of multiple translations, which have been segmented and aligned, using metrics to analyse the relations among lexical choices in translations of individual segments. The point of doing this is that multiple translations of great works of world literature, philosophy, and religion are rich data sources for arts and humanities research, but so far under-exploited. The scriptures of all major religions, influential ancient and modern philosophical works, and important works of literature are in many cases translated over and over again into major world languages, each time differently. Such re-translations all embody variant interpretations of their source texts. They document cross-cultural relations between source and target cultures, and they document the evolution of language and ideas in target cultures. That makes them very significant sources. But even beyond this, the patterns of variation among translations can also shed new light on translated texts themselves. Literary, religious and philosophical texts are essentially polysemic or ambiguous: they can be interpreted in various ways. By studying the various ways in which they have been interpreted by translators , we can discover important aspects of their meaning-potential, which would not be obvious if we only read them in one language, or only read a few of the many existing translations. Thus, both diachronic (historically-oriented) and synchronic (trans-historical, comparative) approaches to multiple translations are appropriate. ShakerVis enables us to advance investigations of both sorts.

Until now, in print media, comparing large numbers of translations in systematic ways was a very difficult and tedious task, which took huge amounts of scholars time, and the findings could not be easily presented or verified. As a result, studies of multiple translations are few and far between, and the researchers tend to select only modest numbers of translations, and to present only small selected samples to the readers of their research publica-

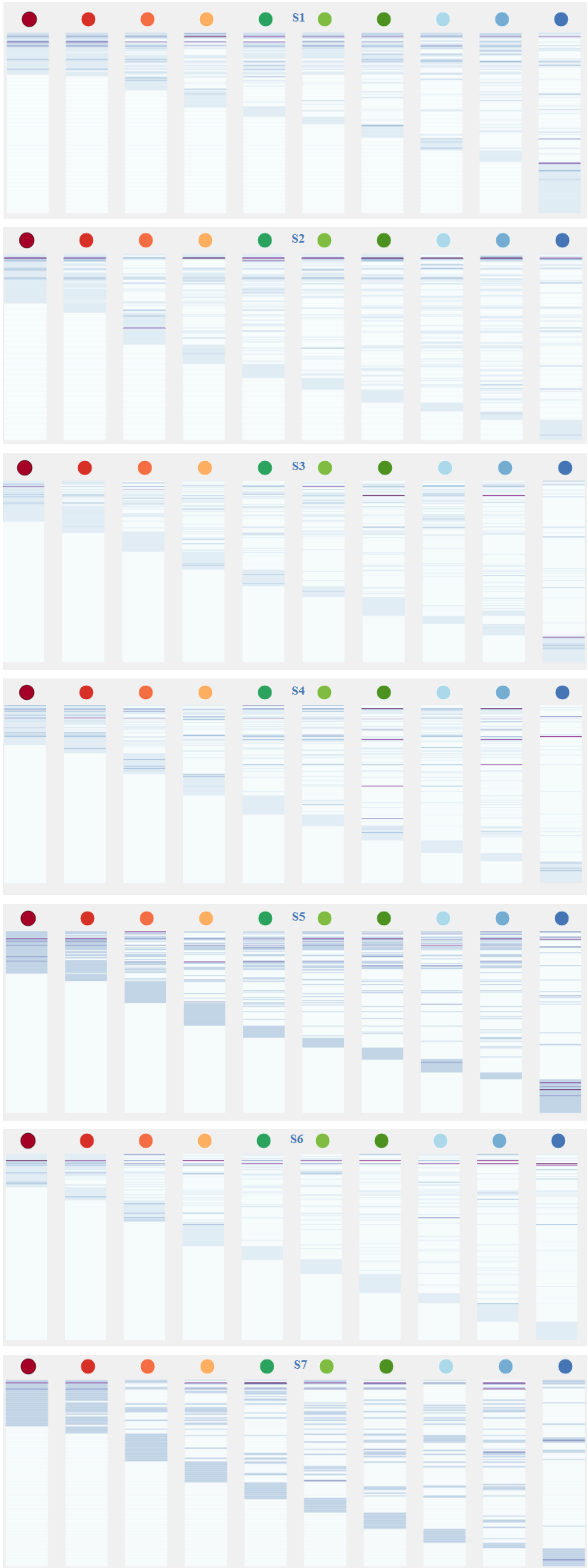

Figure 7: This image shows the term-document frequency heat maps for all of the seven segments.

tions (Sehnaz Tahir Gürcaglar, 2009). Our work is seizing the opportunities presented by digital media to create new tools which facilitate comparison of arbitrarily large sets of translations, in their entirety, and collaborative investigations of them by teams combining different disciplinary and linguistic skills. We aim to make the processes of creating versions corpora and exploring variation within them far easier, and to facilitate the formulation and investigation of hypotheses and the presentation of findings. Some prototype tools are presented online at www.delightedbeauty.org/vvv (Cheesman et al., 2 13). We intend to integrate the key features of ShakerVis with our online work.

ShakerVis is an important prototype for further development of our approach. It allows us to explore patterns in variation among multiple translations (versions) of a text, from segment to segment. The color codes associated with individual versions provide clear visual navigation between versions and the visualizations of their inter-relations: scatterplots and parallel coordinates, offering alternative representations of relations of proximity/distance between word-choices per segment. The scatterplot view of differences is more useful than the parallel coordinates view. Full text view is important so we can check analytically discovered patterns by reading actual text data. A limitation of the interface, dictated by desktop screen size, is that only 10 versions can be compared. Our current dataset includes 37 German versions of Shakespeares Othello, and even that is only about half the extant German translations/adaptations. The ShakerVis experiment only tackled 7 segments (speeches) in the play: our dataset includes over 80, and even that is only about 10% of the play. As our work develops, the problems of scale, which obstruct translation comparison in print media, also become more problematic in digital media. We eventually hope to work with translations in as many different languages as possible: in the case of a popular Shakespeare play like Othello, that would mean around 400 translations in 100 languages. (No reliable global census of Shakespeare translations even exists.)

As discussed in Section 5 above, Figures 4, 5 and 6 depict several interesting initial ndings by the means of brushing and selecting scatterplots and parallel coordinates in ShakerVis. A first set of findings confirms what we already know about the texts, and this reassures us that the patterns being discovered by the tool and the underlying metrics correspond with ground truth. Two translations (Baudissin, 1832; Brunner, 1947) are variants of Baudissins famous 19th-century translation: they are absolutely similar in wording, except for orthographic differences and some changes in wording made by Brunner as editor. Two translations (Engler, 1976; Bolte, 1985) are both generically and historically similar to one another, and distinct from all the others, in that they are didactic prose translations of the 1970s-80s, for classroom use. (The other eight are translations for stage performance and/or for general readers.) As we would expect, ShakerVis shows each of these two pairs of versions clustering, in all segments, more than any others. Where Baudissin and Brunner are concerned, ShakerVis scatterplots also show different distances from segment to segment, depending on what proportion of words in the segment differ (Brunners different word choices or different orthography). Finally, another expected finding is that the most free translation of all, Zaimoglus controversial recent tradaptation using modern slang, shows up in ShakerVis as an outlier in all segments. Zaimoglu (Zaimoglu, 2003) uses different wording from any other translation. These results are not surprising, but welcome confirmation that the tool is in principle reliable.

Further partial confirmation is provided by the result depicted in Figure 6. Previous non-digital, but quantitative-algorithmic work on over 30 German translations of a single segment in Othello (the rhyming couplet: If virtue no delighted beauty lack, Your son-in-law is far more fair than black) identied Schröders translation as the most distinctive of all (i.e. the highest Eddy value). The modified algorithm used in our online Translation Array places Schröders translation of this segment as the second most distinctive (Cheesman et al., 2 13). In ShakerVis, when we re-scale the sample of ten versions analysed to exclude the five just mentioned (the two variants of a 19th-century translation, the two didactic translations, and the 21st-century outlier), we are left with versions of the 1950s-1970s, all written to be performed, and in verse: Flatter, Schröder, Fried, Lauterbach, and Laube. These are historically and generically similar, but diverse in their wordings. Among these, ShakerVis scatterplots and also the parallel cordinates show Schröder as a clear outlier in most segments (i.e. highest Eddy value), followed by Flatter as the next most distinctive. So Schröders relative distinctiveness as a translator, found in some previous work, is confirmed in this different sample. However, it must be added that Schröder does not appear as a particularly distinctive translator when all Eddy values for all segments in our online dataset are averaged (Eddy History graphic, in (Cheesman et al., 2 13)). Of course this underlines the importance of a systematic and wide-ranging comparative study, and the limitations of sampling, where literary texts are concerned. The ShakerVis analysis must be extended to our full text existing dataset, and indeed other, larger datasets.

ShakerVis also produces more surprising discoveries, which raise new research questions: exactly what we aim to do. A first set of questions relate to translation genetics (translations depending on or borrowing from earlier ones) and translation periodisation (translations obeying cultural rules of style specific to certain historical periods). Setting aside variant texts, which are known to be close genetic relatives, and a few versions which are explicitly identified as being based on an earlier translation, most translations are presented as the translators original work; but in fact in most cases the translators knew, and probably re-used, the work of previous translators. Just how they did so is interesting to humanities researchers from several points of view. An interesting ShakerVis result is the finding that the translation by Fried (1970) (Fried, 1999) appears closest (of all others in this sample) to the two didactic prose versions, clustering with them in most segment scatterplots. The didactic versions (1976 and 1985) are later than Fried. A periodisation effect a certain style of translation from the 1970s and 1980s can be excluded here, because other translations in the ShakerVis sample, from the same decades, do not show the same proximity. Periodisation effects could be systematically investigated with a larger sample: we know that such effects exist, but we do not know exactly how they work. It is more likely in this case that the didactic versions were directly influenced by (i.e. borrowed some wording from) Frieds version. The concordance heatmaps do not particularly help us to investigate this hypothesis, as they display all words used by all versions, and do not highlight multiple specific words which are re-used by multiple versions, nor do they allow us to select multiple non-neighboring words. Signals of significant word re-use which would be expected in cases of borrowing therefore remain hard to detect amid the noise of variation. There is room for refinement here. But, alerted by scatterplot proximity, we can read and compare the versions, and we can then see that the didactic versions by Engel and Bolte do, indeed, have some wording in common with Fried which is not found in other versions. We still have some way to go in this area, but hypotheses concerning genetic relations can be investigated far more efficiently and tested far more accurately with digital tools than by means of arduous close comparative reading alone.

Frieds version is involved in two more findings. ShakerVis scatterplots show a tendency for Fried to cluster with other post-1970 versions (as well as the didactic versions), in some segments. If this can be conrmed as a trend with a larger data sample, it raises interesting questions. Frieds translations of Shakespeares plays were very prestigious in German culture in the 1970s-80s, and are still highly regarded, in print and used in theatres, today. But they were and are not the only prestigious Shakespeare translations, by any means, over these decades. Prestige can be measured in many ways, but not least in terms of influence on other translations. If we can determine patterns in borrowing between translations, we can create an algorithmically-generated time-map of translation genetics, influence and relative power: a map which shows how different translators work relates to that of their precursors and successors. This would be an important contribution to understanding the evolution of the culture concerned. To do this, we might want to filter out periodization effects, in order to isolate clusterings only explicable in terms of textual genesis. This kind of analysis and output would be interesting in many other re-translation contexts, as well as Shakespeare.

In fact, in a culture where there are very many different translations of a particular work, questions of borrowing are highly controversial, because translators intellectual property is involved. Hamburger (Hamburger, 2006) discusses this question passionately with reference to German Shakespeare translators, particularly mentioning cases of translations used in theatres in the former East Germany in the 1980s, which were based on West German translators work (such as Hamburgers), without permission or payment of royalties. So it is very interesting indeed that ShakerVis scatterplots show the work of East German translator Lauterbach (1973) (Lauterbach, 1996) clustering more than any other stage version in this sample with Fried (1970) (Fried, 1999). From simply reading the two texts side by side, it would not appear obvious at first that Lauterbach has borrowed from Fried. But after ShakerVis points us to this proximity, we read and compare these versions again. Now, certain similarities are striking. As with the didactic versions, once we have been alerted to it, we can see that Lauterbachs version has some wording in common with Frieds. Whether this might be due at least in part to a periodisation effect, or a genetic effect (i.e. borrowing, even plagiarism), is an interesting topic for further research.

Perhaps the most interesting result of the ShakerVis experiment relates to the question of differences between segments in the translated text, in terms of translators aggregated behaviour: that is, a Viv value finding. Even though the sample is small and the method experimental, ShakerVis appears to have enabled us to discover an Othello Effect in translators aggregate choices when re-translating a great work. ShakerVis allows us to investigate the hypothesis that translations in general (in any one language, at least, and possibly also across multiple languages) vary in regular ways according to specific variable features of the translated segments. This could apply to many kinds of features, including differing levels of difficulty, ambiguity, or obscurity of meaning, or ideological contentiousness. Such features of discourse are hard to define objectively or quantify, not least because they may be considered as intrinsic to a translated source text, or else as properties of the relation between the source text and the translating and interpreting culture. They may, however, become definable through refinements of the analytic approach we are developing: that is a key aspiration in our work. On the other hand, features such as speech by [character name], are simple, objective attributes of segments in a dramatic text. And it is more than likely that translators, as a group, tend to respond differently to different characters, i.e. speakers in a dramatic text, whose speaking parts are each represented by a different set of speech-segments. So speaker attributions are a suitable focus for investigating possible regularities in associations between segments with specific features (in the translated text and all translations), and regularities in the range and distribution of Eddy values calculated for all translations. We refer to the quantification of such ranges and distributions as Viv values (Cheesman et al., 2 13). They represent the amount of divergence between all the translations of a segment, or the overall stability/instability of the translations . A segment which most translators translate with similar words has a low Viv value. Where translators seem to disagree with one another a lot, Viv value is high. This is a way of pinpointing segments in a text which provoke dissent among translators: where there is greatest interpretative variation across all the translations. For humanist readers of great works, this is potentially very interesting as a way of detecting hotspots of disagreement over what a text might be said to mean. It also promises to provide new kinds of evidence of what exactly translators do when they translate differently from one another. In our online prototype work, Viv values for segments are calculated from all Eddy values by various experimental metrics (as an average of the Eddy values, or as their standard deviation) and displayed as a varying color coding, underlying the base text (i.e. the English Shakespeare text) (Cheesman et al., 2 13). ShakerVis does not represent Viv values as such, but the scatterplots can be read as indicators of Viv: Viv is highest where the distances are greatest, i.e. there is least clustering. This is visually intuitive and effective. It turns out that ShakerVis provides evidence of an Othello Effect, visible in Figure 3, which is highly interesting for the study of literary translations.

The sample of seven segments from Othello was chosen to include seven speeches by: Othello, the plays hero (segment 6); Desdemona, his wife (1 and 7); Brabantio, her father (2 and 4); and the Duke of Venice (3 and 5). The expectation was that Desdemonas speeches would be more variously translated than others, because the interpretation of her speeches in the sample is known to be controversial: her character, her behaviour, her values as presented in the play are a topic of much debate, and her specific speeches in this sample provoke disagreements among critics and other interpreters (including directors and actors, and presumably translators). In Figure 3, we see the scatterplots for all seven segments and all ten versions. The changing variation and clustering seems random. As for Desdemonas segments, segment 1 shows quite a lot of clustering; segment 7 shows greater distances. But (in this small sample) there is no sign of a Desdemona Effect a collective tendency to translate her speeches more variously. Instead, with all due caution due to the small sample size, it looks as if we may have an Othello Effect. In segment 6, the distances between all versions are greatest: six of ten versions are at the sides of the scatterplot, and four others are almost equally distant from them and from one another. This segment is the only speech in the sample by Othello, the hero of the play. It seems that in this speech, the selected translators have most differentiated their texts from one another, whether consciously or not (most translators knew some other translations, but none of them knew them all). As before, the findings suggested by the tool need to be checked by close reading. Recall that this sample includes two variants of Baudissins famous version: Baudissin and Brunner. On re-reading them, it becomes clear that when Brunner edited Baudissins text, in segment 6 he went to greater lengths to alter Baudissins version than he did in other segments in the sample. The two didactic versions, generally rather similar, are also more different from one another in segment 6 than in other segments. The outlier, Zaimoglu, is less distant from all others in the segment 6 scatterplot than in other scatterplots, not because he translates segment 6 more similarly to any other version, but because the other nine are all more distant from one another in segment 6 than in other segments. When we use the tool to re-scale the sample of versions, while still comparing all segments, e.g. by excluding the Baudissin pair and/or the didactic pair and/or Zaimoglu, the Othello Effect appears to persist: in this segment, the translations are least stable, or have highest aggregate distance from one another highest Viv value. Like all the other results of the ShakerVis experiment so far, the Othello Effect needs to be conrmed by analysing a larger sample of versions and segments, more texts and in more languages. We plan to do this in future research. But ShakerVis has enabled us to establish a new, plausible and investigatable hypothesis: in multiple re-translations of a play text (and perhaps also in re-translations of other speaker-based literary texts, such as dialogue-rich or multi-perspectival fiction, or philosophical symposia), the level of overall variation in speaker-associated segments relates to the perceived importance of the speaking character. Here, importance may be a quantifiable factor, based on how many words and in a play how many speeches are associated with the speaker. For a more important speaking character, we hypothesise, translators tend to make more investment of thought and imagination to remake the words in their own way, compared to rival translators. This hypothesis is in accord with studies of re-translation based in Bourdieus concepts of distinction and cultural capital, which depict re-translators as being in a state of implicit struggle with one another for social and cultural standing (Hanna, 2005). But such studies tend to draw evidence chiefly from paratexts (translators self-justifying introductions and comments). It is new and exciting to find that digital tools make it possible to explore translators implicit struggles with one another, using the evidence of the actual fabric of their translations.

ShakerVis, particularly when we have integrated its key features with our online tools, will make important contributions to increasing knowledge and developing new theory in the innovative area of visualization-based re-translation corpus study, which has the potential to open important new horizons in the exploration and analysis of major works of world culture.

7 CONCLUSION AND FUTURE WORK

In this paper, we have derived statistical metrics, such as Eddy and Viv value to measure the stability of segment translation of *Othello*. Based on these metrics, we are able to develop an interactive visualization system for presenting, analyzing and exploring segment variations between German translations of *Othello*. Our system is composed of two parts, one is the context views which utilize parallel coordinates and scatterplots to explore variations between multiple segments. The other part is the detailed views including the term-document frequency heat map and textual visualization to compare different translations in the same segment. Our result is evaluated by the domain experts and help them explore some interesting findings. They noted this tool is making important contributions to increasing knowledge and developing new theory in the innovative area of re-translation corpus study. In the future, we will work with a larger corpus of 88 (or more) segments and 32 (or more) versions. This will add challenges for user navigation. We also need to work with non-contiguous, nested and overlapping segments and one-to-many segment alignments. We must combine the selecting/filtering options in this visualization with those offered by other Translation Arrays interfaces (e.g. segments grouped by speaker, length).

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