Methodologies in the Digital Humanities for Analyzing Aural Patterns in Texts

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ABSTRACT

Increased access to large-scale repositories of text begs questions about how scholars can use such repositories in their research. It is essential that iSchools are aware of tools being created in the Digital Humanities since the processes and tools that are being developed by this transdisciplinary community are changing the preservation and curation of humanities data. This paper will discuss a use-case study that uses theories of knowledge representation and research on phonetic symbolism to develop analytics and visualizations that help users examine aural patterns in text. This work includes (1) identifying OpenMary as a base analytic; (2) creating a routine in MEANDRE (a semantic-web-driven data-intensive flow execution environment) that produces a tabular representation of the data for predictive modeling; and (4) developing an interface (ProseVis) for seeing these comparisons across text collections.

Categories and Subject Descriptors

H.3.7 [**Digital Libraries**]: *Systems issues, User issues, User interfaces*; H.3.6 [**Library Automation**]: *Large text archives*

General Terms

Management, Performance, Design, Experimentation, Human Factors, Standardization

Keywords

iSchools, interdisciplinarity, digital humanities, design research, knowledge representation

1. INTRODUCTION

Humanities data, for which cultural institutions such as libraries and museums are ultimately responsible, is, like all data: increasing exponentially. As well, scholars have increasingly responded to this expanded access by augmenting their fields of study with theories and practices that correspond to methodologies within Digital Humanities. These methodologies include using advanced computational analysis such as text mining and visualizations as a means for providing new modes of access to and analysis of these large data sets. It is essential that iSchools become involved in this work as the processes and tools that are being developed by this community are useful and necessary to all information specialists across many disciplines.

Digital Humanities scholars Johanna Drucker (2011), Julia Flanders (2009), Jerome McGann (2005), and others have noted the increased number of studies that include multimodal interactions with linguistic and visual data. This abundance of data and new tools for access has led to what Flanders calls "a lively field of study" in which "the graphical meaning of text can be explored alongside its linguistic meaning" (Flanders 2009). Drucker, who calls for alternative perspectives in looking at "data" (or the "given") as "capta" (or the "taken"), discusses how visual displays of data often lead us to believe that we are seeing something akin to "fact." Even in a conversation in which the importance of how we visualize and what we see is not taken for granted, this work does not mention other modes of knowledge production such as sound.

This use case involves analyzing features of sound in text and considering the extent to which exploring these features affects our understanding of these cultural artifacts. This use-case is supported by the Andrew W. Mellon Foundation for a grant titled "SEASR Services" that is being conducted through Stanford Libraries. Other collaborators include Humanities professors from Stanford, George Mason University, and University of Illinois Urbana-Champaign. All of the use cases include research on how humanities scholars can use textual analytics and data mining with visualizations to interpret large digital collections such as those represented by Google Books, Hathi Trust Digital Library or the Internet Archive among others. In particular, we are trying to show how humanities scholars can use SEASR (Software Environment for the Advancement of Scholarly Research) developed by the informatics experts at the University of Illinois at Urbana-Champaign's National Center for Supercomputing Applications and Graduate School of Library and Information Science.

The following discussion includes the theories and research that underpin this work (knowledge representation and phonetic symbolism). As well it introduces the analytic workflows and user interfaces we have developed to facilitate this study. Making these theories and development work transparent is important for the interdisciplinary iSchool community which must ultimately engage the communities of scholars, researchers, librarians, and users that seek to develop and use these tools and methodologies.

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2. KNOWLEDGE REPRESENTATION

Relying on theories of knowledge representation put forth by computer scientists and AI experts, we have chosen to use the logic of aurality to model and analyze sound in text. Before defining "aurality," however, it is useful to discuss why a logic of the definition is useful for this project. John F. Sowa writes in his seminal book on computational foundations, that theories of knowledge representation are particularly useful "for anyone whose job is to analyze knowledge about the real world and map it to a computable form" (Sowa, 2000, p. xi). In other words, theories of knowledge representation are transparent about the fact that computers afford representations ("knowledge representations") of how we think about the world. This perspective is important when developing projects that include computational analytics since we realize that knowledge representations supported by computational analytics are unproductive if the logic and ontology which shape applicatiosn in a certain domain are unclear: "without logic, knowledge representation is vague, Sowa writes, "with no criteria for determining whether statements are redundant or contradictory," and "without ontology, the terms and symbols are ill-defined, confused, and confusing" (p. xii). In other words, if we are unclear about what we are representing, it is difficult to create a model of knowledge in computable form.

In his seminal article, "What is Humanities Computing and What is not?" John Unsworth argues that facilitating "navigation and exchange" are the most important factors in a Humanities Computing project (2002). Like Sowa, Unsworth argues that navigation and exchange are facilitated by our ability to map "disciplines, ontologies, and concepts" to computable forms (2002). For this reason, Unsworth completes the very useful exercise of identifying various aspects of digital humanities projects that adhere to the aspects of knowledge representation put forth by AI scientists Davis, Shrobe, and Szolovits (1993). Namely, the authors claim that knowledge representation poays five distinct roles(Davis, *et. al*, 1993). In the interest of defining our logic and ontology for this project, we will likewise map our project to these same parameters.

Listed below is each of the five roles that knowledge representation plays in a project according to Davis, *et al*. Below each role, I discuss briefly how the role plays out in our project. A more thorough discussion of each role follows in the rest of the paper.

1. A knowledge representation is a surrogate "used to enable an entity to determine consequences . . . by reasoning about the world rather than taking action in it" (Davis, *et. al*, 1993).

   Example: We are defining sound as *the pre-speech promise of sound* as it is signified within the structure and syntax of text. This theory of sound adheres to Charles Bernstein's notion of aurality, which is the "sounding of the writing" as opposed to the sound of the poet speaking with "breath, voice, and speech" (Bernstein, 1998, p. 13).

2. Knowledge Representation is "a set of ontological commitments, i.e., an answer to the question: In what terms should I think about the world?" (Davis, *et. al*, 1993)

   Example: In this project, the ontologies we are choosing reflect research on phonetic symbolism in which researchers have found meaningful relationships between the phonetic structure of language and symbolism or meaning [Plamondon (2006), Sapir (1929), Saussure (1916), Shrum and Lowrey (2007), Smolinsky and Sokoloff (2006)].

3. Knowledge representation is "a fragmentary theory of intelligent reasoning, expressed in terms of three components: (i) the representation's fundamental conception of intelligent reasoning; (ii) the set of inferences the representation sanctions; and (iii) the set of inferences it recommends" (Davis, *et. al*, 1993).

   Example: We are using ontologies for representing aurality that are based on standards for pronunciation that have been developed over decades by researchers such as the CMU (Carnegie Mellon University) Pronouncing Dictionary (http://www.speech.cs.cmu.edu/cgi-bin/cmudict#about), which seeks to represent North American English and General American (the "standard" dialect of English in the US).

4. Knowledge representation "is a medium for pragmatically efficient computation" that sets forth organized information that can be used "to facilitate making the recommended inferences" (Davis, *et. al*, 1993).

   Example: Based on our logic and mindful of the ontologies created by the above-mentioned standards, we are using OpenMary (Modular Architecture for Research on speech sYnthesis), an open-source text-to-speech system to analyze text. OpenMary creates MaryXML that represents text as features of sound as defined by these standards. As well, we are using SEASR services to perform clustering and predictive modeling on this pre-processed text. These processes reflect a logic concerning the aurality of text.

5. "It is a medium of human expression, i.e., a language in which we say things about the world" (Davis, *et. al*, 1993).

   Example: An essential aspect of this project is ProseVis, a visualization tool that allows a user to map the results of these analytics to the "original" text thereby facilitating a user's ability to read and analyze the results in human readable form. This allows for the simultaneous consideration of multiple representations of knowledge.

2.1 The Logic: Textual Aurality

The sound of text is meaningful. That is, the sound of text makes meaning. Charles Bernstein has written that "[t]he relation of sound to meaning is something like the relation of the soul (or mind) to the body. They are aspects of each other, neither prior, neither independent" (Bernstein, 1998, p. 17). While French theorist Ferdinand de Saussure argued that the relationship between sound and meaning was arbitrary (except in some circumstances) (1916), Socrates previously argued there was a "sound" relationship there (Plato 1892). Walter Ong proclaims a deep tie between orality and literacy and has noted that 'Reading' a text means converting it to sound, aloud or in the imagination, syllable-by-syllable in slow reading or sketchily in the rapid reading common to high-technology cultures" (Ong, 2002, 8).

While Ong focuses on the "orality" of text, Charles Bernstein focuses on the "aurality" of text. Bernstein makes an important distinction between the two that becomes useful for this study, writing that "By aurality, I mean to emphasize the *sounding* of the *writing*, and to make a sharp contrast with *orality* and its emphasis on breath, voice, and speech . . .*Aurality precedes orality*, just as language precedes speech" (Bernstein, 1998, p. 13). Bernstein makes further distinctions with pre-speech aurality as a perspective (1) that focuses on the poem rather than the poet; (2) that considers the aurality of text a kind of music that presents sound in amorphous shapes of patterns and grand sweep—in this sense, aurality that does not depict the exactness of traditional metered scansion; and (3) aurality is a perspective that takes the noise-profuse, context-driven reading performance into account by creating a space for discovery that can incorporate chaos, inexactitude and confusion (Bernstein, 1998, p. 13-14).

In short, the logic of aurality says that the *possibility* of sounds are expressed in written language. Scholars have not had much opportunity to analyze the features of text that correspond to aurality—their phonemes and prosodic elements—much less compare these features with similar features across collections. In this project and keeping in mind Drucker's sense of data as "capta", we use this logic to define (or map) our ontology of sound to a computable surrogate.

2.2 Committing to an ontology: phonetic symbolism and literary study

Much research has been done on how sound makes meaning. In literary studies, sound is represented by a text's "prosody," which has been defined by linguists such as Jennifer Cole as comprising intonation, stress, rhythm; conveying linguistic meaning through phrasing and prominence; reflecting a speaker's identity, gender, regional dialect, ethnolect, affect and emotional engagement, cognitive process; can be used to study human behavior, culture, and society (Cole, 2011). As well, there is a body of research in linguistics and psychology called phonetic symbolism that dates back to controlled studies done by Edward Sapir (1929) and his student Stanley Newman (1933). In these studies and subsequent ones (a comprehensive survey of this literature is conducted by Shrum and Lowrey, 2007), links are established between the sounds of vowels and consonants and readers' perceptions of size (big and small), speed (fast and slow), intensity (dull and sharp) and value (pleasant and unpleasant). Similarly, Dwight Bolinger defines the term "intonation" to include not only accents and stress but also symbolic meaning, arguing that "intonation" is generally used to refer to the overall landscape, the wider ups and downs that show greater or lesser degrees of excitement, boredom, curiosity, positiveness, etc." (Bolinger, 1986, p. 11)

Further, Digital Humanities literary scholars have also used phonetic symbolic research creating tools that mark and analyze sound in poetry. Marc Plamondon created AnalysePoems to analyze the Representative Poetry Online (RPO) website (http://rpo.library.utoronto.ca). Plamondon's goal with AnalysePoems was to "automate the identification of the dominant metrical pattern of a poem and to describe some basic elements of the structure of the poem such as the number of syllables per line and whether all lines are of the same syllabic length or whether there are variations in the syllabic length of the lines in an identifiable pattern" (Plamondon, 2006, p. 128). Like ProseVis, AnalysePoems is not a tool that attempts to represent the "reality" of a spoken poem, a feat that is impossible because of the ephemeral elements of performance of which a poetry reading comprises. Instead, AnalysePoems is "built on the prosodic philosophy that a full scansion of a poem is an impermanent performance . . . there are basic interpretations upon which most will agree, but individual variations will inevitably arise" (Plamondon, 2006, p. 129). Plamondon's work has been important for the development of the processes described here as it creates a precedent and model for analyzing sound from a perspective that also values the messiness business of attempting to model the pre-speech promise of sound (aurality) in order to analyze phonetic symbolism.

Another tool that is built on the kinds of research that phonetic symbolists have conducted is Pattern-Finder. In particular, the creators of Pattern-Finder—Smolinsky and Sokoloff—were interested in inventing a tool to examine how the "phonetic/phonological structure of a poem may contribute to its meaning and emotional power" (Smolinsky and Sokoloff , 2006, p. 339). Smolinksky and Sokoloff's hypothesis—"that feature-patterning is the driving force in the 'music' of the poetry" (p. 340) is also important for the creation of our visualization tool, ProseVis. With this tool, we are also interested in allowing users to identify patterns in the analyzed texts by facilitating their ability to highlight different features within the OpenMary data. These features currently include parts-of-speech, phonemes, stress, and groups of vowel and consonant sounds, but like the creators of Pattern-Finder, we are interested in allowing users to make groupings of consonant sounds that include plosives, frications, and affricates and groupings of vowels that include those formed in the front or the back of the mouth. Phonetic symbolic research and the creation of these tools demonstrates a precedent for facilitating readings that uses these features to analyze the textual meaning.

2.3 A fragmentary theory of intelligent reasoning: the OpenMary data model for text-to-speech conversion

Theories in aurality and research in phonetic symbolism underpin our choice to use OpenMary (http://mary.dfki.de/) to analyze the aurality of texts. OpenMary is an open-source text-to-speech system that represents text as features of aurality. Created to generate audio files of spoken text from written transcripts, OpenMary captures information about the structure of the text that is meaningful for creating comprehensible speech—it is therefore capturing the *possibilities* for generating speech. This information includes "tokens along with their textual form, part of speech, phonological transcription, pitch accents etc., as well as prosodic phrasing" ("Adding support for a new language to MARY TTS"), all of which are important indicators of how the text is "heard" to a reader. Specifically, OpenMary takes a plain text file and creates an XML document (MaryXML) with attributes such as accent, phonetic spelling, part-of-speech, pitch, range, and break index (or syntactic part showing whether a sound is part of a phrase, sentence, or paragraph.

In order to model this data, OpenMary uses the CMU (Carnegie Mellon University) Pronouncing Dictionary, which seeks to represent North American English and General American English (the "standard" dialect of English in the US). The procedure for adding words to OpenMary that are not in the CMU lexicon involves generating a lexicon of known pronunciations from the most common words in Wikipedia or entering them manually ("Adding support for a new language to MARY TTS").

2.4 Pragmatically efficient computation: SEASR Services

The SEASR group has been working for many years on creating a computational environment in which users who are interested in analyzing large data sets can develop data flows that push these sets through various textual analytics and visualizations (Clement 2008). Further, SEASR seeks to "[foster] collaboration by empowering scholars to share data and research in virtual work environments" – a goal that works well within the data-rich, infrastructure-poor library and museum environment. Until now, however, the ability to explore these "meanings" of text has not extended—within SEASR or in digital humanities in general—to include meanings generated by a text's aurality.

The workflow we created in Meandre uses the MaryXML to create a tabular representation of the data that includes these fields: paragraph_id, sentence_id, phrase_id, word, part_of_speech, accent, phoneme, tone, break_index. This data keeps the word boundaries so that each word can be parsed out into accent and phoneme and part-of-speech but it also keeps the word's association with the phrase, sentence, and paragraph boundaries. The ultimate benefit to creating this flow in MEANDRE is that it is meant to be accessible to future users who wish to produce or tweak similar results.

One flow we tested for machine learning analysis was based on an analysis for comparing the sound of Gertrude Stein's *Tender Buttons* to that of the *New England Cook Book*. Margueritte S. Murphy hypothesizes that *Tender Buttons* "takes the form of domestic guides to living: cookbooks, housekeeping guides, books of etiquette, guides to entertaining, maxims of interior design, fashion advice" (Murphy, 1991, p. 389). By writing in this style, Murphy argues, Stein "exploits the vocabulary, syntax, rhythms, and cadences of conventional women's prose and talk" (pps. 383-384) to "[explain] her own idiosyncratic domestic arrangement by using and displacing the authoritative discourse of the conventional woman's world" (pps. 384). Murphy sites *The New England Cook Book* (Turner, 1905) as a possible source with which to compare the prosody of *Tender Buttons*.

In order to make this comparison evident with predictive modeling, SEASR's David Tcheng developed a machine learning algorithm for predictive analysis as a potential flow in Meandre. One of the most compelling aspects of the algorithm Tcheng designed is the fact that Tcheng did not use the exact words or phonemes. Instead, Tcheng ran the comparison on elements closely associated with prosodic markers: part_of_speech, accent, stress, tone, and break_index. With these features only, Tcheng compared *Tender Buttons* to several other Stein texts that represented many genres including two portrait poems titled "Matisse" and "Picasso", the novelas of *Three Lives*, and the novel *The Making of Americans*. Tcheng also included in this comparison, Joyce's *Ulysses*, Homer's *Iliad* and *Odyssey* (based on research I had done on how these texts compared to Stein's *The Making of Americans*), and Turner's *The New England Cook Book*.

Describing this work as "a new and promising approach to comparing texts based on Prosody," Tcheng ultimately bases his ontology for creating a machine-learning algorithm on the logic of aurality (Tcheng, personal communication). At first, Tcheng is adamant that in order to analyze the sound of text, good machine learning can only improve and that "much more ground truth from human experts needs to be collected"; Tcheng continues:

> We need to gather all prosody predictions made by people, and then analyze the corresponding texts. We need to build interactive systems that allow people to read random snippets of text to make prosody comparisons. We need to learn how to select and weight available prosody features to create a system that can best simulate the human data. (Tcheng, personal communication)

While testing live readers is still a future goal in the project, however, the algorithm that Tcheng ultimately develops represents an aural philosophy of sound in text (i.e., the possibilities of sounds). In fact, the manner in which Tcheng discusses the "success" of the comparison is in terms of the computer being "confused" about these possibilities:

> To test if experts [sic] original hypothesis was correct, that Tender Buttons and The New England Cook Book should be most similar, we look at the distribution of actual classes when the system predicts Tender Buttons or The New England Cook Book. If our hypothesis is correct then we would expect to see Tender Buttons and The New England Cook Book most confused. This IS the case using both feature based representations for prosody! (Tcheng, personal communication).

Figure 1 shows the results of Tcheng's predictive anlaysis by showing the percentage of times the computer "picks" *Tender Buttons* as the same as *The New England Cook Book*. In the visualization, column five shows the results for *Tender Buttons* as the text that the computer "confuses" most often when trying to predict *The New England Cook Book*, the prediction for which is expressed in column seven. Another prediction that shows the algorithm's success is expressed in columns two and three, which show that the computer confuses *The Odyssey* and

The Iliad –texts that are known to be very similar in terms of prosody—almost exactly the same number of times.

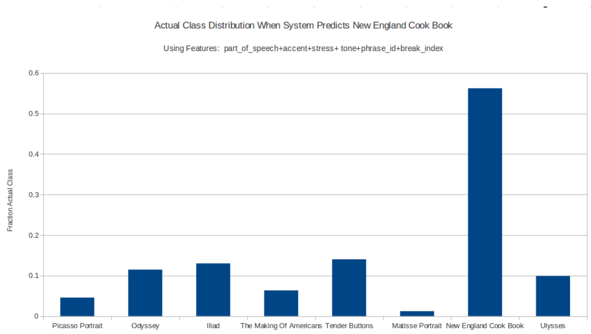

Figure 1: Machine Learning results on comparing Tender Buttons to *The New England Cook Book*

In some sense, Tchengs's algorithm is based on the logic of aurality, much like that reflected in the OpenMary system, which is not as focused on representing sound as it is focused on how people perceive how to sound out a word. For example, Tcheng started his comparison with windows of fourteen phonemes since he wanted to "use an example representation that I thought would be natural to people" (Tcheng, personal communication). Tcheng writes, "since I thought people were using a small window, the size of a phrase, to perceive prosody, I gave the machine the same representation, 14 symbols" (Tcheng, personal communication).

Finally, Tcheng determines that "since the goal is not accurate text identification using prosody features, but rather to tests [sic] prosody hypotheses about how similar texts should be, what we are really interested in is the mistakes made by the computer and what it reveals about the similarity between texts" (Tcheng, personal communication). In other words, the ultimate benefit to scholarship is determining where the model breaks down and where the ontology must be tweaked. Keeping in mind that we are modeling the possibility of sound as it *could be* perceived opens space for discovery and illumination. In other words, what we are identifying in this process is not necessarily which text is more like the other (though this is interesting). Rather, by focusing on where the ontology breaks down under the weight of computation, we are learning more about our knowledge of how we think sound makes meaning in this domain. In this way, we are considering the data as "capta" --- as if we are analyzing the perspective of a photograph we ourselves have chosen to take.

2.5 A medium of human expression: ProseVis

Ultimately, our goal is to allow users to think about how we identify patterns of sound across large text collections. The final stage of development includes creating an interface with which users can explore the MaryXML and predictive classification data. The tools we have begun developing is called ProseVis. ProseVis has been developed in a two-stage process, first as VerseVis: Visualizing Spoken Language Features in Text by graduate students Christine Lu, Leslie Milton, and Austin Myers as part of a graduate course in visualization with Ben Shneiderman at the University of Maryland, College Park. Megan Monroe further developed the prototype as ProseVis under the auspices of this grant. Both VerseVis and ProseVis allow a user to color the text based on the features that have been marked by the analytical engines (in this case, OpenMary and the components comprising the Meandre flow). Monroe, however, takes the user a step further by allowing the user to color the text according to consonant and vowel patterns—much like Smolinsky and Sokoloff did with Pattern-Finder (see how ProseVis breaks down the phoneme in Table 1. In particular, ProseVis allows a user to highlight the leading consonant sound (Figure 2), the vowel sound (Figure 3), and the end consonant sound (Figure 4).

Table 1. Phoneme Breakdown in ProseVis

Word	Phoneme	Lead Consonant	Vowel Sound	Final Consonant
strike	s tr I ke	s	I	ke

The visualizations show the extent to which Stein uses repetition but it also shows "hot spots" of color such as the purple highlights in Figure 2 and Figure 4 and the pink highlights in Figure 3 that reveal interesting points of difference and discovery for scholars looking for patterns and aberrations. Allowing users to discover the data as it is expressed by humans—as an overlay on the original text—is a feature unique to ProseVis. It is a feature that speaks to the theories of knowledge representation that underlie this work and is an important augmentation for the discovery of sound patterns in large text collections.

3. Conclusion

This project, in which we are attempting to analyze patterns of meaning in the sound of text is an example of the kinds of transdisciplinary work that is being conducted in the Digital Humanities. iSchool collaborators must be aware of these practices not only because the iSchool environment is also transdisciplinary but because these tools represent the kind of work that humanities scholars want to do with large text collections. In general, humanities scholars do not want to answer questions about texts or data as objects that are "given" or somehow static. Instead, humanities scholars want to discover questions about how we ask questions, about the process of creating "capta", about differing perspectives and the processes of creating environments where differing perspectives are facilitated, and about making all of these practices more transparent so we can ask more questions. The work discussed in this use case points to the kinds of resources that cultural institutions such as libraries and archives must be available to engage in developing and curating humanities data.

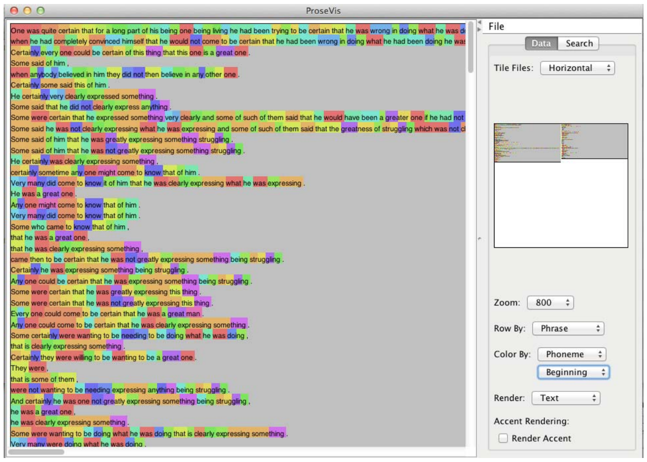

Figure 2: Beginning consonant sounds in "Picasso"

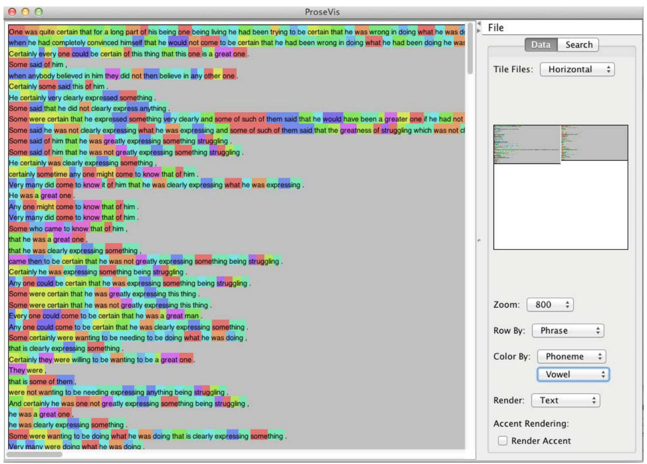

Figure 3: Vowel sounds in "Picasso"

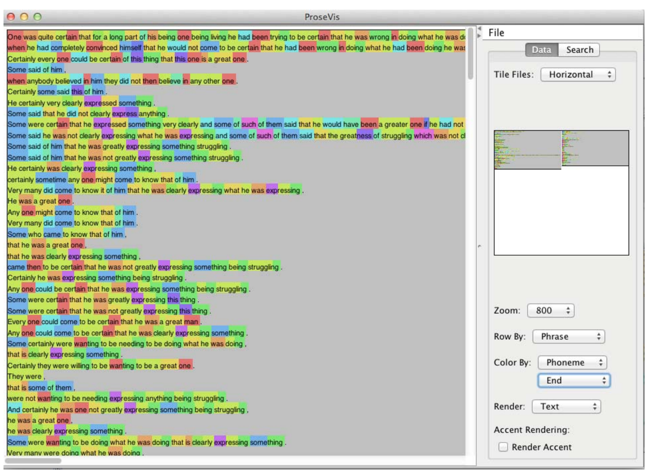

Figure 4: End consonant sounds in "Picasso"

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