ALLC: The European Association for Digital Humanities (ALLC)
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Digital Humanities 2013

Conference Abstracts

University of Nebraska–Lincoln, USA

16-19 July 2013

Primary Encoder: Laura Weakly
Designer: Karin Dalziel
Encoders and Proofreaders:
Matt Bosley
Matthew Lavin
Elizabeth Lorang
Keith Nickum
Erin Pedigo
Hannah Vahle
Illustration: University of Nebraska–Lincoln Communications
Available online at: http://dh2013.unl.edu

ISBN: 978-1-60962-036-3 (paperback)
Published by the Center for Digital Research in the Humanities

The 24th Joint International Conference of the Association for Literary and Linguistic Computing and Association for Computers and the Humanities
and
The 5th Joint International Conference of the Alliance of Digital Humanities Organizations

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Special thanks to Computer Operations and Research Services at UNL Libraries for technical support.

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Papers

and Roberts have found that *thinking about* and *thinking with* the discipline, a method that many digital scholars employ in their research, is also an effective way to design a course, and appeals to students who are new to the discipline, fostering enthusiasm for its use in their own often conventional humanities scholarship. The authors hope that this approach contributes to the growing conversation about teaching digital humanities, while also reflecting and adapting to the dynamic topics within the field.

Stylometry and the Complex Authorship in Hildegard of Bingen's Oeuvre

Kestemont, Mike
mike.kestemont@ua.ac.be
University of Antwerp, Belgium

Moens, Sara
sara.moens@ugent.be
Ghent University, Belgium

Deploige, Jeroen
jeroen.deploige@ugent.be
Ghent University, Belgium

Hildegard of Bingen (1098–1179) is one of the most influential female authors of the Middle Ages (Newman, 1998). The numerous texts attributed to this prophetess are versatile, with topics ranging from her visionary works, over medical issues, to music. Recent decades have seen an increase in the scholarly interest in Hildegard's works and persona. From the point of view of computational stylistics, the oeuvre attributed to Hildegard is fascinating, because of the exceptionally complex authorship underlying it. Hildegard dictated her texts to secretaries in Latin, a language of which she did not master all grammatical subtleties (Ferrante, 1998; Deploige, 1998). She therefore allowed her scribes to correct her spelling and grammar. A number of manuscripts survive, produced under Hildegard's supervision. Fig. 1 shows a detail of fol. 77 in the most important manuscript of Hildegard's *Liber operum divinorum* (Ghent, University Library, MS 241) with a sample of the numerous adjustments made by Hildegard's scribes. From these it is evident that multiple scribes have polished Hildegard's original texts (Derolez, 1972; Derolez & Dronke, 1996). Many of Hildegard's assistants are known by name, including Volmar, Ludwig of Saint Eucharius and Godfrey of Disibodenberg (Ferrante, 1998).

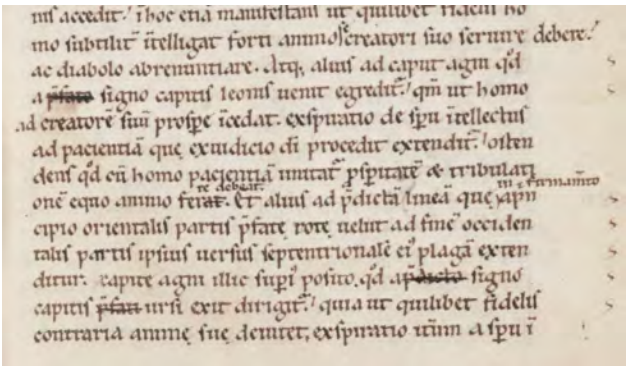

Fig. 1

The extent to which these copy-editors have interfered with Hildegard's style has been the subject of intense scholarly debate. Especially Hildegard's last collaborator, Guibert of Gembloux (Moens, 2010), seems to have heavily reworked her works during his secretaryship. Whereas her other scribes were only allowed to make superficial linguistic changes, Hildegard would have permitted Guibert to render her language stylistically more elegant. This is at least what can be deduced from the *Visio ad Guibertum missa*. Deploige and Moens are currently finalizing an edition (fortcoming in Brepols's *Corpus Christianorum*) of the *Visio ad Guibertum missa* (MISSA) and the lesser known *Visio de sancto Martino* (MART), both of which Hildegard allegedly authored during Guibert's secretaryship. Guibert's interventions in these texts nevertheless seem so far-reaching that one could wonder to what extent they are still attributable to Hildegard (Newman, 1987).

In this paper we will focus on Guibert's role. At the same time, this case study carries wider relevance for stylometry, especially because medieval Latin prose has been rarely studied in the stylometric community. Stylometrists typically focus on high-frequency function words: as opposed to content words, these function words only carry a bleak, grammatical meaning (Pennebaker, 2011). In the case of Hildegard, it were exactly these grammatical words that were often corrected by her scribes. It would be interesting to assess whether Hildegard's oeuvre is still a stylistically coherent corpus that is distinguishable from that of contemporary authors or from the stylistically more ornate body of works which she published during Guibert's secretaryship.

We researched a corpus provided by Brepols's *Corpus Christianorum Library & Knowledge Centre*, including works by Hildegard, Guibert and Bernard of Clairvaux. Medieval Latin, like other historical languages,

is characterized by spelling variation. We therefore had to normalize the orthography in the corpus using lemmatization. We have trained the *Morfette* lemmatizer (Chrupala et al. 2008) on the annotated *Index Thomisticus Treebank* (Passarotti & Dell'Orletta 2010). All experiments described below were carried out on the lemmatized corpus, some using the script suite 'Stylometry for R' (Eder & Rybicki, 2011). All content words and personal pronouns were manually "culled" from the set of most frequent lemmas. All analyses were thus restricted to a set of 65 lemmas of high-frequency function words.

A first analysis (Fig. 2) was performed on the *epistolaria* in the corpus, using *Principal Components Analysis* (PCA; Kestemont 2012). This analysis excludes the letters by Hildegard which were probably reworked by Guibert. The resulting scatterplot yields an excellent authorial separation (samples of 10,000 lemmas), with Guibert's samples (GUI_EP) clustering in the top-right corner, Hildegard's in the left part (HILD_EPNG) and Bernard's in the lower-right area (BERN_EP). The component loadings (lightgrey) draw attention to Hildegard's extravagant use of the preposition *in* ('in') or Guibert's exorbitant use of *et* ('and'). The latter remark is in line with earlier observations by philologists, noting Guibert's clear preference of *et* to the alternative conjunctions *ac* or enclitic *–que*, esp. in compound sentences (Derolez, 1972). To test how long samples from these authors should be for a correct attribution, we carried out a leave-one-out validation using Burrows's Delta for different samples sizes (Fig. 3). Samples sizes of 2,000 lemmas or more generally lead to reliable attributions (> 95% accuracy).

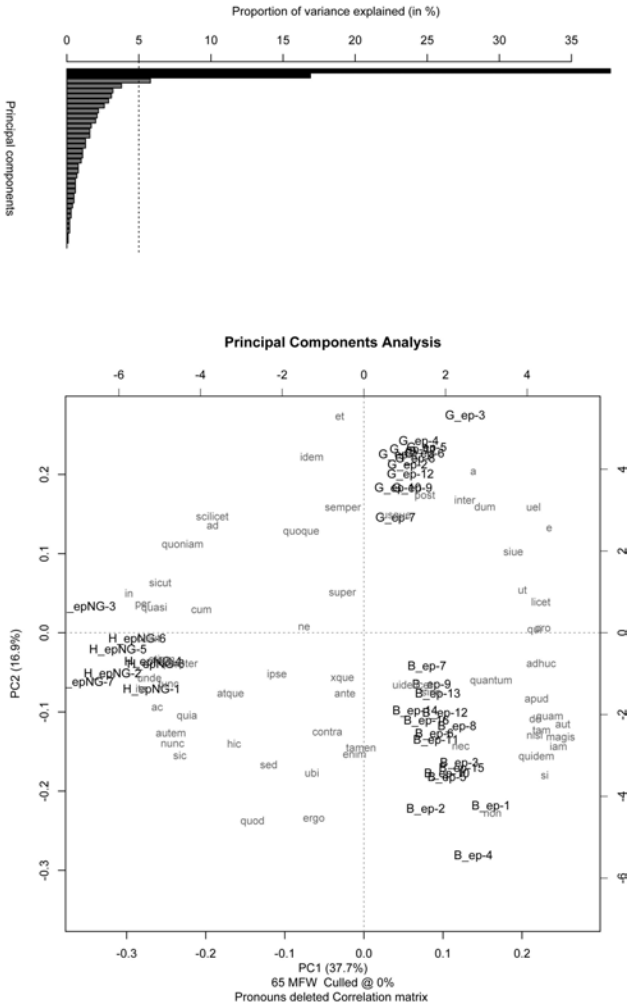

Fig.2

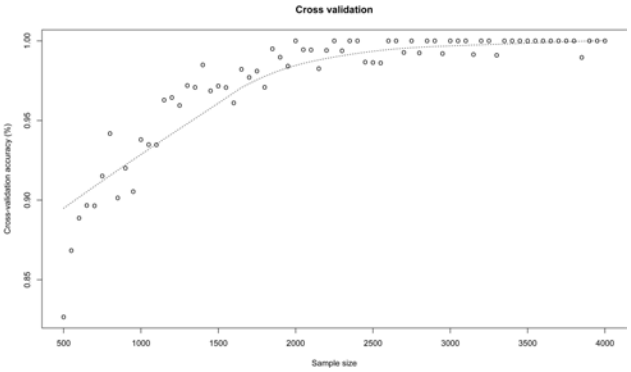

Fig. 3

In Fig. 4 we have focused on the differences in writing style between Hildegard and Guibert. In this PCA, we have included Guibert's letters (GUI_EP), Hildegard's letters during Guibert's secretaryship (HILD_EPG), as well as Hildegard's letters unrelated to Guibert (HILD_EPNG). There is a firm horizontal separation between both

authors. Apart from the *et-in* opposition, we also see a marked contrast with respect to the use of *e* ('out') or *cum* ('with'). The samples from letters that result from their "collaboration" (HILD_EPG) cluster in the lower-left corner: they appear to be on Hildegard's side of the stylistic spectrum, but interestingly, their position is rather isolated from the other Hildegard samples. This result is reminiscent of the Synergy Hypothesis, suggesting that texts resulting from collaboration can display a style markedly different from that of the (average of the) collaborating authors (Pennebaker 2011).

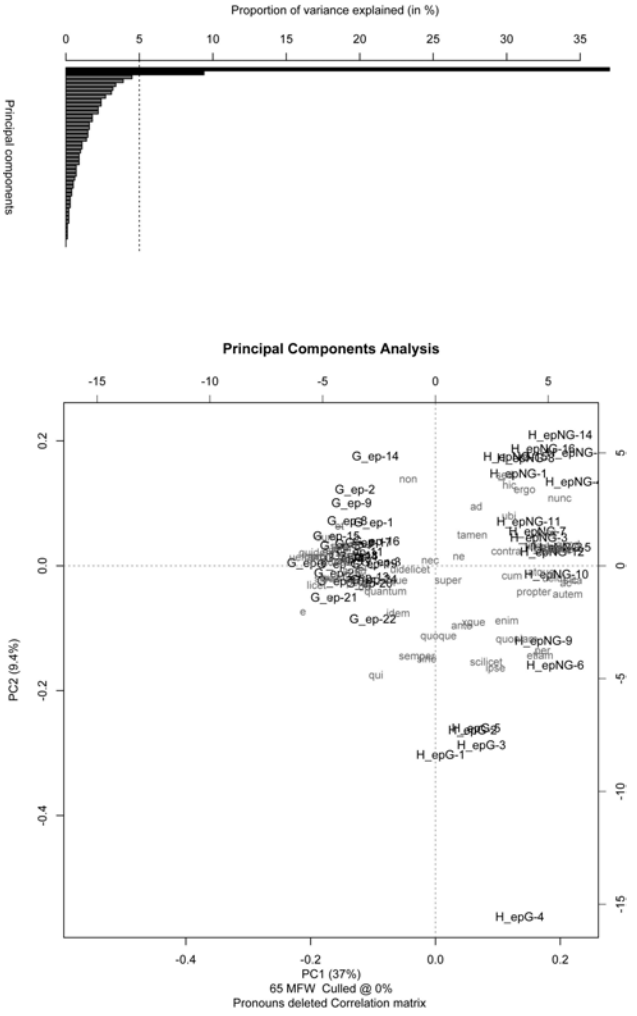

Fig. 4

These results demonstrate the general validity of the stylometric approach for the present corpus. It would therefore be interesting to assess how stylometric methods would react to the authorship in the two texts which were our point of departure. Fig. 5 shows the results of a PCA that confronts the *epistolaria* (Figs. 2 & 3) with the text pair of dubious authorial signature (MART and MISSA, prefixed "D(UBIOUS)".

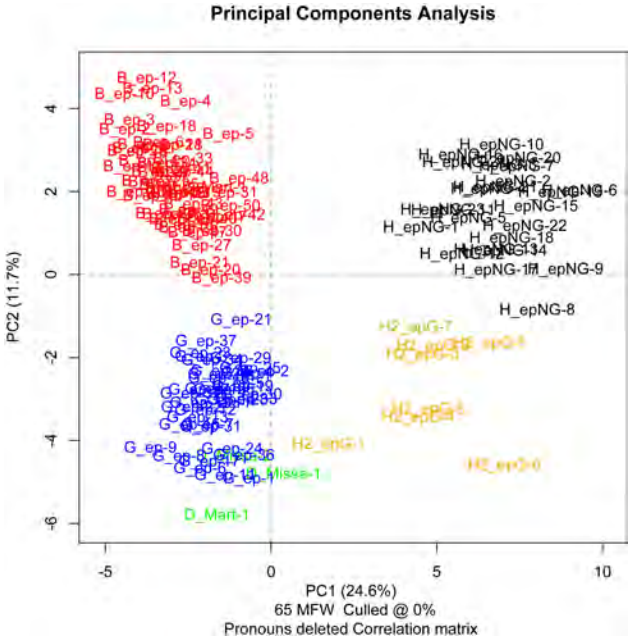

Fig. 5

Fig. 5 offers a clear-cut confirmation of the previously voiced doubts concerning Hildegard's authorship for MART and MISSA (sample size=3,304). If indeed anything of Hildegard's authorial style was ever present in these texts, Guibert seems to have reworked them to such an extent that style-oriented computational procedures are far more inclined to attribute the texts to Guibert than to Hildegard. This result thus yields a quantitative affirmation of the opinion asserted in previous Hildegard scholarship about Guibert's stylistic reworkings of Hildegard's oeuvre (Klaes, 1993; Newman, 1987), as well as fresh evidence regarding the Synergy hypothesis with respect to collaborative authorship in general (cf. the "co-authored" H2_EP samples in Figs. 4 & 5).

The results reported in this paper obviously only scratch the tip of the iceberg in Hildegard scholarship. We nevertheless hope to have illustrated the huge potential of stylometric methods in dealing with medieval Latin text collections and similar historical corpora. Quantitative techniques can be used as a refreshing means to falsify or strengthen hypotheses formulated in traditional scholarship (e.g. Guibert's stylistic influence). Future research will have to consider in what other respects stylometry could advance the traditional Hildegard scholarship, e.g. by isolating the more subtle linguistic influence of her other scribes on her works.

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Word-level Language Identification in "The Chymistry of Isaac Newton"

King, Levi
leviking@indiana.edu
Indiana University, United States of America

Kübler, Sandra
skuebler@indiana.edu
Indiana University, United States of America

Hooper, Wallace
whooper@indiana.edu
Indiana University, United States of America

Introduction

Language Identification is the task of determining the language of short text snippets, much shorter than for e.g., text classification. In Computational Linguistics (CL), language identification is generally considered a solved problem—but these methods assume that a text is monolingual, and at least 100 characters long. Furthermore, such methods cannot be used for multilingual texts in which the author switches between languages within a sentence, as in the "Chymistry of Isaac Newton" (Walsh and Hooper 2012), a collection of 119 alchemical manuscripts written by Newton over a 30-40 year period beginning in the mid-1660s. The team behind The Chymistry of Isaac Newton Project at Indiana University has transcribed these manuscripts and is publishing a digital scholarly edition at www.chymistry.org . Attempts to automatically analyze this corpus, even with basic levels like POS markup and lemmatization, are difficult because Newton frequently switches between English, Latin, and French within a paragraph or sentence, as shown in the following sentence: "The short lived & despicable plant [[LAT Paronychia folio Rutaceo [[ENG infused in beer, doth wonders in curing the kings evill." For this reason, we developed a new method for automatically identifying the language for single words rather than for complete texts. This method requires more information because the classification is finer-grained than standard methods, which have access to more text.