Chapter 3

ASSESSING MANUSCRIPT CO-CREATION USING COMPUTATIONAL METHODS

THE CORPUS OF available Paris bibles is rich in possibilities for research into scribal practices, not only on account of the number of extant, digitized copies, but also for existing evidence and scholarly literature about their fabrication. Studies of the *pecia* system have brought to light the social and economic system by which the need for books, especially in medieval university towns such as Paris or Bologna, was met by the controlled circulation of *pecia* exemplars, that is, parts of manuscripts loaned out to a distributed group of actors who cooperated in its copying.[1] Along with the professionalization of the copyist, scholars have emphasized the resources that emerged from the religious orders with this scaled up process of textual criticism: the *correctoria* (a list of critical notes on the biblical text), the *distinctiones* (verbal concordances) and the like.[2] Despite this substantial body of criticism about the production of bibles in the context of the medieval university, little is known about the copyists themselves and the ways in which they worked.

This chapter looks at claims that are made about manuscript objects such as Paris bibles and their scribes in the scholarly and reference literature, and considers possible ways that we might go about assessing such claims through a combination of computational methods. We explore a few of the ways that medieval manuscripts—once they have been digitized and then transcribed with the methods described in Chapter 2—can be studied as data. We apply such an approach to a focused set of twelve Paris Bibles, using computational modelling to examine features such as abbreviation practices, graphetic variation, and distinctive letterforms. While studies suggest promising avenues for analysis, considerable work remains to be done across different languages, genres, and manuscript traditions in order to assess both the broader applicability and the methodological limitations of the approach. That is to say, we do not assume that such modelling will be effective for all manuscript corpora. What is clear, however, is that the utility of this method is contingent upon the presence of certain

1 Rouse and Rouse, *Manuscripts and Their Makers.*

2 Dahan, "Paris Bibles and Scholarship."

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scribal features—most likely a degree of abbreviation, variation in spelling, or the use of distinctive allographetic forms—and at the least several dozens of folios of transcription from a variety of manuscripts. These are conditions that, we imagine, apply to many textual situations in medieval studies. The precise threshold of such variation required for meaningful analysis remains uncertain. Yet, given the growing adoption of HTR in the production of machine-readable transcriptions, we anticipate that further applications of this method will shed light on these questions, refining our understanding of the conditions under which computational modelling of scribal practices is most productive. As we have explained in the previous chapter, we use a non-normalizing transcription schema within state-of-the-art HTR technology that not only allows much more text to be transcribed than ever before by a human hand, but also allows certain graphetic features of medieval writing found in manuscript to be recorded on demand, with significant (but not perfect) accuracy.

As we also discussed in Chapter 2, contemporary medieval studies have adopted different approaches to the graphetic features found in manuscript, with editorial practices largely favouring their normalization, but with some computer philological approaches favouring non-normalization and at other times attempting a combination of both. We believe that there is value in employing some well-established methods in computational textual creation and analysis, to assess claims that have been made about codex creation, either by scribes who indicate their participation through including a colophon, or by contemporary book historians and expert cataloguers who indicate the number of hands they can identify in a manuscript. This assessment might be to formulate new hypotheses about how scribes operated when copying manuscripts, but it could equally help to confirm existing hypotheses with new forms of evidence.[3]

Automatic transcription of Paris bibles using a pre-defined scheme and the analysis of these transcriptions are an example of *computational modelling*: that is, these two methods are "explicit explanatory, exploratory and empirical strategies of inquiry" that allow us both to create data from objects of humanistic study—in our case, hand-made and hand-copied documents—and to interact with these objects iteratively and creatively to explore specific research questions in mind.[4] As we have explained previously, the most important features in our data that we capture are scribal abbreviations

3 Eve, *The Digital Humanities and Literary Studies*, 131.

4 Flanders and Jannidis, *The Shape of Data*; Ciula et al., "Models and Modelling."

Table 5. List of the computational experiments in Chapter 3, organized by their appearance in the chapter. Data by authors.

No.	Shelfmark	Dating	Size (mm)	Digitization
1	Cambridge, Corpus Christi College (hereafter CCC), MS 49	thirteenth	345 × 225	Parker on the Web
2	Philadelphia, University of Pennsylvania (hereafter UPenn), MS Codex 236	ca. 1220	218 × 148	OPenn
	Paris, Bibliothèque Mazarine (hereafter Mazarine) MS 6	thirteenth	392 × 265	BNIF
3	BnF, MS latin 40	third quarter, thirteenth	255 × 180	Gallica
	BnF, MS latin 10428	third quarter, thirteenth	240 × 165	Gallica
	Città del Vaticano, Biblioteca Apostolica Vaticana (hereafter BAV), MS Vat. lat. 36	1250–1258	269 × 182	DigiVatLib
4	Girona, Arxiu Capitular de la Catedral, MS 52	fourteenth	430 × ?	HMML
	Lisboa, Biblioteca nacional de Portugal (hereafter BnP), MS IL 93	1251–1300	324 × 217	BnP
	BnF, MS latin 179	end of thirteenth to fourteenth	235 × 150	authors
	BnF, MS latin 211	end of thirteenth to fourteenth	165 × 110	authors
	BnF, MS latin 15477	1251–1275	286 × 196	authors
	Philadelphia, Free Library of Philadelphia (hereafter Free Library), MS Lewis E242, a.k.a the "Patou bible"	ca. 1250	175 × 120	Internet Archive
	Sarnen, Kollegiumsbibliothek, Stiftsarchiv Muri-Gries (hereafter Sarnen KB), MS Cod. membr. 16.	before 1267	250 × 170	HMML

and letterforms, and in this chapter we explain how we use these features to nuance what we believe to be true about Paris bible manuscripts as well as to open new evidence-based pathways for exploration of them.

Table 5 lists the dozen Paris bibles we have used in this chapter to create both partial and full automated transcriptions with HTR. These manuscripts are not the most famous exemplars of the Paris bible, nor do they originate from specific decades of the thirteenth or fourteenth centuries. Instead, we have chosen them, for three main reasons. First and foremost, for questions

Figure 4. Four images from a single manuscript, Mazarine, MS 6, visualized in several panes of Mirador, one of the viewers for the International Image Interoperability Framework (IIIF), comparing suspected shifts in scribe: from the OT (at left, fol. 5v), the end of the OT and colophon (centre top, fol. 429r), the beginning of the book of Matthew (upper right, fol. 430r) and the Interpretation of Hebrew Names (lower right, fol. 523v). Images courtesy of the Institut de France.

of access. The availability of digitized images of the manuscripts—either from official online repositories or via self-digitization—is a precondition for computational transcription and analysis. This criterion of selection, of course, limits us in terms of the issues that we might want to investigate. If we do not have access to specific manuscripts, if we cannot travel to see them or if the library does not allow us to take images for private research purposes, computational analysis is effectively off limits. Second, our choice of manuscripts has been made on the basis of existing material evidence documented by scholars about their fabrication, such as the number of hands, the presence of a colophon, and the attribution to a group of manuscript makers. Third, where we saw that other cognate manuscripts would be interesting for comparison, and we were able to visit the manuscript room, we digitized some limited samples of the manuscript ourselves on the fly using a regular smartphone camera.

Computational Experiments Based on Single Manuscripts or Groups of Manuscripts

Against the backdrop of the mass copying of the Paris bibles, what we know about the scribes themselves and how they worked is not much. In isolated cases we do have some names of scribes or dates associated with codices.[5] A thirteenth-century Latin bible, Mazarine, MS 6, contains a colophon at the end of the OT (fol. 429r): "Explicit Vetus Testamentum per Johannem de Cristemanneford scriptum, cui Deus reddat premium" ("Here ends the Old Testament, copied by John of Cristemanneford, whom God will reward.") Such colophons tend to be recorded as part of the metadata of manuscripts in collections, along with incipits or explicits, as an identifying or descriptive marker of the document.

Much has been made of the ability to carry out "dynamic" or synoptic readings of manuscripts, by which is understood the ability to deliver, display, and compare digital images of these manuscripts in display formats such as the International Image Interoperability Framework (IIIF) for human reading and examination.[6] A dynamic view in IIIF would certainly facilitate traditional palaeographic analysis of the manuscript (instead of seeing the manuscript in person or on microfilm) and a scholar might notice, for example, the ways in which the hand seems to change at the beginning of the book of Matthew (see Figure 4). Quantitative codicologists with access to digitized manuscripts might go a step further to compare manually the kinds of abbreviations used by different hands on a few pages of the New Testament (hereafter NT) with those found a few pages back. In the case of a manuscript of 549 folios, such as those making up Mazarine, MS 6, much more can be done than laying out multiple views of the document for a researcher to investigate visually. New computational methods are made possible by full digitization and access to high quality scans available in open access.

It is worth pausing for a moment to wonder what kinds of questions might be investigated in the case where we have material evidence such as a colophon. In the case of Mazarine, MS 6 with the colophon at the end of the OT, we might notice that the hand appears to change in the NT, and our investigation could end there. Alternatively, since the hand of the same scribe might also vary somewhat according to different factors such as fatigue, reaching the end of a quire, or changing from the hair to the flesh side of the parchment, we could pursue a deeper investigation looking at

5 Ruzzier, *Entre université et ordres mendiants*, 283.

6 Nichols, "Dynamic Reading of Medieval Manuscripts."

the hand over many folios, or at extended linguistic features in the hand to examine if there is a change in the way that the text is copied.[7] If we confirm that the scribe, or scribes, of Mazarine, MS 6 who took on the NT and the Interpretation of the Hebrew Names are in fact different, we could go on to establish what orthographic and abbreviation patterns are typical. We illustrated such analysis in Figures 2 and 3 in Chapter 2. Such investigation, although it involves tiring attention to a significant amount of detail, can nonetheless pave the way for other avenues of research. Did John of Cristemanneford copy the whole section on which he signed his name? If not, why might he have put the colophon on fol. 429v? Was he copying the text faithfully—abbreviations, letterforms and all—from another exemplar? Or does he alter the wording here and there? In this manuscript, is this the case of a single scribe writing in different hands? Or of multiple scribes converging on similar versions of a similar hand? We enumerate this list of rhetorical questions not to suggest that they are all appropriate for Mazarine, MS 6, but instead to suggest the kinds of analysis one might do based on manuscript transcriptions. The need for computational tools and machine learning arises in these scenarios when capturing such detail falls beyond the threshold of human attention to detail, that is, when there are simply too many details to record and to analyze.

Drawing on Chapter 2, in which we argue for the importance both of creating transcriptions from the complex and deeply layered manuscript traditions and interpreting this material in dialogue with humanistic knowledge, this chapter approaches the dozen or so Paris bibles listed in Table 5 through the lens of the *computational experiment*. By this we mean the process of modelling historical copying practices in manuscript, assembling evidence from digitized manuscripts, and assessing them using computational methods. We saw one such experiment in Chapter 1, with the example of prologues collected from manuscripts of differing geographical production. We have mentioned how Paris bibles provide an excellent corpus given its size and geographic scope. It is important to state, however, that our intention here is not to apply a one-size-fits-all approach to the entire Paris bible corpus. Instead, we home in on an accessible selection of them, in order to explore to what extent computational methods can confirm, revise, or nuance hypotheses we have (or others have had) about manuscripts from the thirteenth or fourteenth century. We address questions about the trustworthiness of colophons and how manuscript

7 Guéville and Wrisley, "Transcribing Medieval Manuscripts."

historians draw connections between manuscripts that they believe have been created by the same hands or in the same groups. In what follows, we offer a series of case studies that demonstrate both the possibilities and potential shortcomings of computational analysis based on HTR-created transcription. The interpretation of such models is not automatic, nor can it be far from humanistic knowledge, but it instead pays careful attention to what the transcription is designed to do, the assumptions that it makes and the limitations of method.

We feature four different scenarios identified from the Paris bible corpus in which we believe computational analysis of single manuscripts or groups of manuscripts might shed new light on our understanding of these book objects. We proceed in order of increasing complexity of these scenarios—not because the manuscripts themselves are materially more complex—but rather because the assertions that critics have made about them depend on different forms of evidence of varying complexity, ranging from small material details in individual manuscripts to larger claims about groups of copyists working together. In the first experiment, we analyze CCC, MS 49 in order to map changes of hands within a single manuscript and assess if methods such as computational stylistics (also called stylometry) are able to confirm what is otherwise visible to the human eye. The second experiment focuses on the two manuscripts UPenn, MS Codex 236 and Mazarine, MS 6 to assess if claims made in a colophon or in a catalogue description are computationally detectable and if we can perhaps confirm, nuance or disprove them. The third experiment analyzes three manuscripts claimed to have been produced (that is illustrated) by the Master of the Bible of Manfred. According to the colophons in two of the manuscripts, BnF, MS latin 40 and Città del Vaticano, Biblioteca Apostolica Vaticana (hereafter BAV), MS Vat. lat. 36 were copied by the scribe, Johensis, while the scribe of the third manuscript, BnF, MS latin 10428, is unknown. We explore the possible attribution of the scribe to the same scribe as the previous two, Johensis. Our fourth and last experiment focuses on attribution claims to a group first identified by Branner, the so-called Atelier of Johannes Grusch, looking at a number of manuscripts attributed to that circle in order to understand better if only the illuminators, or perhaps also the scribes, worked together.[8]

8 Branner, "The Johannes Grusch Atelier."

Stylometry with Medieval Texts: Challenges and Opportunities

Before we turn to our four case studies, it would be salutary to mention one approach in computational analysis commonly applied to medieval texts, stylometry. Stylometry—the quantitative analysis of countable features in a text—is, in fact, an umbrella term for a variety of related methods for the statistical analysis of textual features that has become important in recent decades.[9] Here is not the place to elaborate on all of the details of such methods, but it is helpful to highlight how they have been applied, particularly given the complexities of medieval textuality.

Many medieval works are unattributed to an author, a scribe, or a group of writers, and questions of authenticity and attribution loom over the scholarly literature. We know that the input of scribes in different textual traditions has been fundamental to, and sometimes constitutive of, the traditions themselves. Classic approaches to the puzzles of authorship in medieval texts have used vocabulary, grammar, rhyming patterns or material clues in manuscripts. With the rise of contemporary computational approaches, it has not become simpler to solve mysteries in book or literary history, but such approaches have certainly shifted focus with respect to the kinds of evidence, the means by which such questions can be asked, and the ways that new hypotheses can be proposed. Robust case studies exist in the critical literature of stylometry applied to medieval texts addressing questions of author, scribe, genre, dialect, and dating.[10] So far, in our assessment, there is no one-size-fits-all solution for how to handle the specifics of different textual scenarios, but we feel strongly that method of transcription has an intimate relationship with the kinds of research questions we ask, and like Bode, we feel that critical corpus construction in tandem with knowledge of the materiality of the sources is essential for critical computational analysis.[11]

Although there have been many studies in the stylometry of medieval texts, three particular examples might serve as critical reference points for our discussion here. Edlich-Much and Edlich-Much used function words and lemmatized tokens from digitized normalized editions of Malory to study the influence of Old French and Middle English sources on the Middle English *Morte Darthur*, seeking to resolve questions about source adaptation

9 The elegant, yet simple definition of style as a set of countable features is provided by Herrmann et al., "Revisiting Style."

10 De Gussem, "Computational Stylistics."

11 Guéville and Wrisley, "Transcribing Medieval Manuscripts."

and editorial originality.[12] They contribute to a body of Malory scholarship about authorship, revision, and textual unity, with their approach foregrounding the intersection of adaptation and stylistic agency. On the other hand, Camps and colleagues created a diplomatic transcription of a manuscript compilation of unattributed saints' lives, BnF, français 412, engaging with the hypothesis of Paul Meyer about hagiographic "series," or distinct groups, perhaps reflective of common authorship or source traditions.[13] More recently, Vandyck and Kestemont created a hyper-diplomatic transcription preserving brevigraphs and abbreviations using the HTR platform Transkribus (similar to the method used in the Paris Bible Project) and carried out Term Frequency-Inverse Document Frequency (TF-IDF) weighted analysis using character bigrams to establish the chronological order of manuscripts created by the Speculum scribe at the well-documented scriptorium, the Herne Charterhouse.[14]

Of these three approaches, the one that bears the least resemblance to ours is that of Edlich-Muth and Edlich-Muth, not because of the vernacular context of the source material, but on account of its reuse of critical editions and focus on content analysis as a means of accessing influence. Similar to Camps and colleagues, we also adopted a multi-step pipeline using HTR, but we eschew lemmatization and normalization. Their research workflows produce imperfect transcriptions like ours do, but we do not depend on questions of authorship or editorial groupings per se for our source material. Our method is the closest to that adopted by Vandyck and Kestemont, although we are working with a corpus which is simultaneously much larger and far less documented from the perspective of scribal attribution. Our method emphasizes, with Vandyck and Kestemont, three main aspects: scribal profiling over content analysis, a reliance on sufficient HTR quality, and character-level modelling.

Viewed together—and alongside other studies not cited here—these three contributions illustrate a spectrum of stylometric approaches, each attuned to the particular historical and material conditions of medieval textuality. They demonstrate how stylometry can enrich the study of unattributed corpora by detecting patterns suggestive of shared authorship or scribal networks. The scholarly humanistic and computational techniques offer new ways to trace individual or collective participation in textual

12 Edlich-Muth and Edlich-Muth, "A Computational Approach to Source Adaptation."

13 Camps, et al., "Noisy Medieval Data."

14 Vandyck and Kestemont, "Abbreviation Application."

production. Although they differ in transcription strategy, degrees of literary-historical certainty, and disciplinary historiographies, all three share a commitment to integrating computational modelling and interpretive inquiry. Crucially, the accelerating development of HTR for medieval manuscripts is without a doubt transforming the field. It allows researchers to work with transcriptions drawn directly from manuscript sources, capturing not only the authorial layer—typically accessed through normalized texts—but also the scribal and transmissional layers, through character-level modelling of individual documents. This dual focus expands the analytical horizon, enabling scholars to study computationally both the creation and the transmission of medieval texts.

Experiment 1: Mapping Hands Visible to the Eye to Scribal Behaviour

Manuscript catalogues are full of examples of descriptions of codices in which multiple hands have been identified. Usually, such descriptions are limited to a brief mention of the use of several hands, mention of a particular number of hands, or perhaps an indication of the specific folios on which a hand changes. It is unusual for such an observation to be accompanied by a folio-by-folio description of the hands, mapped onto observations about the hand changes and collation, however. The work of palaeographic analysis and collation is time-consuming, after all, and also highly dependent on both expertise and the material state of the binding of manuscripts.

According to the early twentieth-century Cambridge cataloguer James, there were three scribes involved in the copying of an English bible in the Paris bible style dated to ca. 1270–1280 from their collection, CCC, MS 49. In his description in the college's manuscript catalogue, James remarked that one hand wrote the "Pentateuch (?), Psalms, Maccabees etc.," another can be seen in "Proverbs etc.," and a third is visible in the Prophets and Epistles.[15] Such a terse and approximate description is not to be blamed, as the short catalogue descriptions were probably not designed to provide more detailed information. These comments by James encouraged us to examine the manuscript more closely, however, and the existence of a high-quality digital reproduction of the manuscript made available by the Parker Library on the Web provided us with the perfect opportunity to carry out our own palaeographical and codicological analysis. We were able to expand and

15 James, *A Descriptive Catalogue*, 98–100.

Table 6. Data from our visual analysis of the hand changes in CCC, MS 49, an English bible in the Paris bible style dated to ca. 1270–1280. Numbers in parentheses are implied based on the prose description provided by James. Data by authors.

Span of biblical books	Begin fol.	End fol.	James's judgement	Our judgement	Other naming	Comments
Letter of Jerome to Damasus–Letter of Jerome to Paulin	1r	3v	(1)	1	1.1	
Genesis–Deuteronomy	5r	72v	1	1	1.1	
Prologue to Joshua and Judges–Psalms	72v	215v	(1)	1	1.1	
Prologue to Proverbs–Proverbs	215v	223v	2	2	2.1	Hand changes at 216r
Ecclesiastes–Ecclesiasticus (or Sirach)	223v	246v	(2)	2	2.1	
Prologue to Isaiah–Isaiah	247r	247r	3	1	1.2	Hand changes at 247r
Prologue to Jeremiah–Ezekiel	263v	303v	3	2	2.2	Hand changes at 257v
Prologue to Daniel–Malachi	304r	331r	3	3	3.1	Hand changes at 288v
Prologue to 1 Maccabees–2 Maccabees	331r	349v	1	1	1.3	
Prologue to Gospels–Revelation (or Apocalypse of John)	349v	444r	–	3	3.2	No mention in James

nuance James's analysis of hands, gathering more granular information about their changes as well as the collation of the quires and the books, visualized in Table 6.

We also transcribed the whole manuscript using the HTR platform Transkribus, using an early version of the Latin model we trained at the beginning of our research in 2021. The resulting transcription amounts to approximately 700 thousand Latin tokens. The method we chose to analyze the full transcription of CCC, MS 49 is known as "rolling stylometry," which combines supervised machine learning classification with sequential analysis. Rolling stylometry looks across texts, in the words of the creator of the R package that features it, as "a set of linearly sliced chunks, in order to test their stylistic consistency."[16] It has been used primarily to

16 Eder, "Rolling Stylometry."

study authorial attribution in texts and to analyze co-authorship, as well as the role played by re-writing, translating and editing.[17] Rolling stylometry works by moving across the text and comparing the most frequent words in any given slice to a list of most frequent words of a portion of text that can be with certainty associated with a specific author (or in our case, hand). Since our transcription schema has preserved elements of medieval special letterforms, brevigraphs, and abbreviations, our experiment expands the notion of rolling stylometry as a practice used most often with printed texts to consider the scribal contribution of a manuscript. By stylistic consistency in the context of the Paris bibles, we do not mean only the specific word choices that occur from book to book of the biblical text—although such detail is definitely something that the algorithm could detect—but we consider an expanded notion of style that includes the features we have trained the HTR system to recognize in manuscript. Our hope, in short, was that a sequential analysis of the full transcription of the manuscript might detect the same shifts that a visual palaeographic analysis was able to identify. This method is interesting, of course, not because we are simply confirming human observation with an identical computational analysis of features, but because we are looking at a subset of features visible from the same hand-copied document.

Upon examination of CCC, MS 49, we concurred with James that three hands (1, 2, and 3) were involved, but as detailed in Table 6, the hands are interwoven across the manuscript as we encounter it bound today. We label each of these hands according to our visual detection of their appearance in the codex: 1.1, 1.2, 1.3, 2.1, 2.2, 3.1, and 3.2 (where 1.3 is the equivalent of the third occurrence of hand 1). It is important to note that the hands did not participate equally in the copying of CCC, MS 49, nor are each of the segments of equal length.

Our first question was whether rolling stylometry could, via linguistic features including medieval ones, recover the same hand shifts that we observed by eye. We applied a standard rolling-classification procedure known as "rolling delta" from the Stylo package in R that assigns labels to sequential chunks across CCC, MS 49. In the top plot of Figure 5, the candidate classes we used included Hand 1 (full contribution), Hand 2.1 (a subset of Hand 2), and Hand 3 (full contribution). Here we were testing

17 Notable examples from medieval French literature are provided for Chrétien de Troyes, as well as for Clément Marot's controversial 1526 edition of the *Roman de la Rose*. See, respectively, Reilly and Dillon, "Virtuous Circles of Authorship Attribution," and Eder, "Rolling Stylometry."

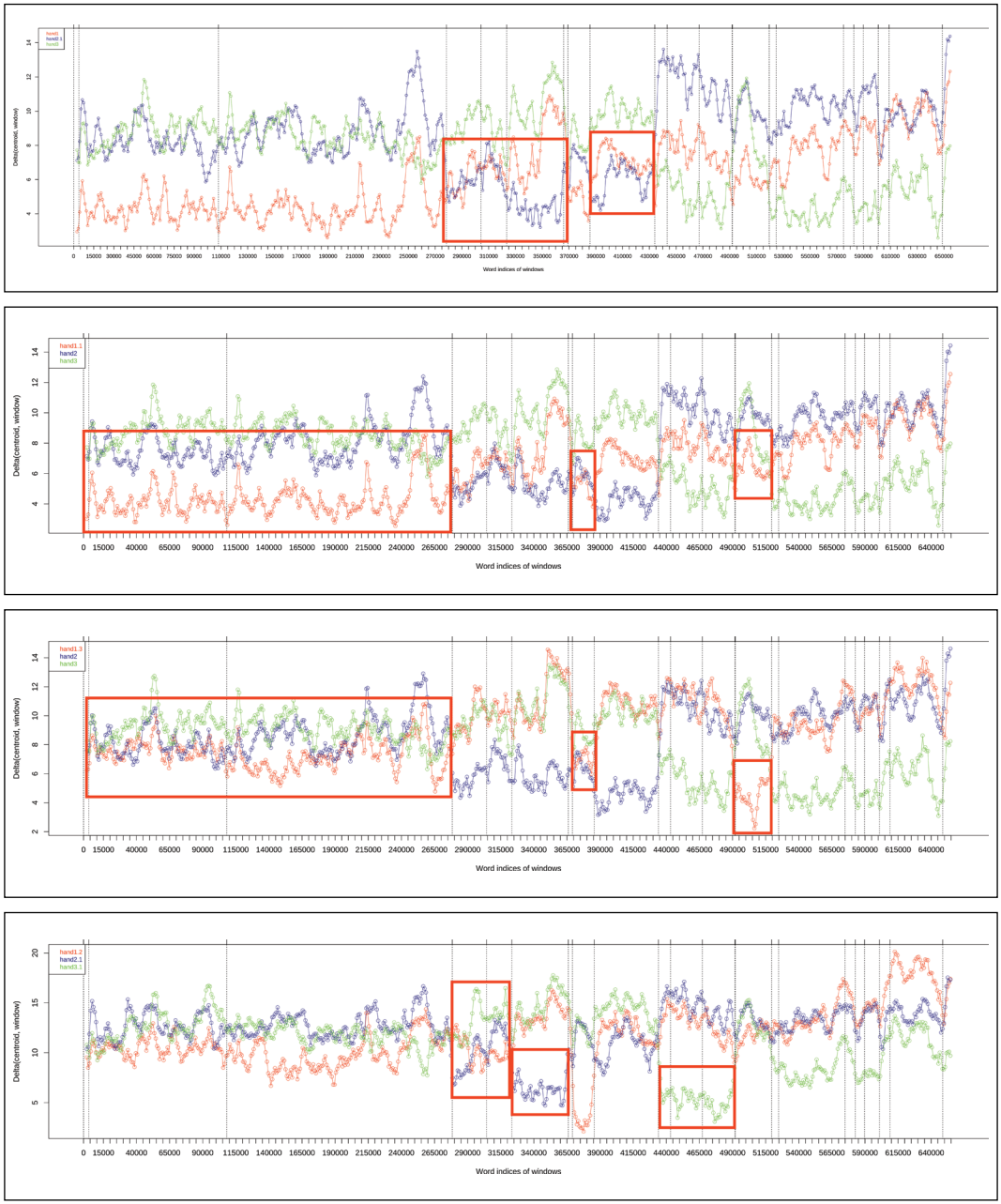

Figure 5. Rolling stylometry analysis of the different hands identified in the manuscript CCC, MS 49. The plot first from the top visualizes Hand 1 (red), 2.1 (dark blue) and 3 (green). The plot second from the top visualizes Hand 1.1 (red), 2 (dark blue) and 3 (green). The third plot from the top visualizes Hand 1.3 (red), 2 (dark blue) and 3 (green). The last plot visualizes Hand 1.2 (red), 2.1 (dark blue) and 3.1 (green). Transcription in Transkribus. Visualization created in R and Stylo by authors (rolling.delta function, 500 MWF, Classic Delta, Slice length 5000 with overlap of 1000, Milestones represent changes in hand, section and quire), adapted from graphs previously published in Guéville and Wrisley, "Transcribing Medieval Manuscripts."

whether using a small portion Hand 2.1 would generalize to the remainder of Hand 2 (Hand 2.2). The lowest curve at any position in the plots indicates the most likely class. The outcome of this first run of Stylo was encouraging: the rolling analysis reproduces our visual segmentation, even with a smaller portion of a given hand. The top panel clearly distinguishes the hands and their boundaries, supporting the view that abbreviations and medieval letterforms yield a stable stylometric signal characteristic of individual scribes.

We then wanted to test how much data was necessary to obtain such results. In the first plot, larger samples made attribution relatively straightforward. To test data limitations, we compared two subsets of Hand 1: a longer one (Hand 1.1, about 45 per cent of the manuscript) and a shorter one (Hand 1.3), in second and the third plot from the top. Using 1.1 as reference, the model easily recognized other Hand 1 sections. But using the shorter 1.3 as reference made recognition of a similar-length segment (Hand 1.2) more difficult. Finally, we tested whether even shorter samples—Hand 1.2, Hand 2.1, and Hand 3.1—could still detect hand shifts in the bottom plot. While results were less distinct than with longer samples, meaningful patterns still emerged. Signals sometimes overlapped (e.g., Hand 1.1 and 2.1), but with appropriate parameters, stylometry proved capable of identifying scribal identity. Importantly, we also discovered that relatively small text samples can suffice to track significant shifts across a manuscript. This finding is a pleasant surprise for our character modelling method, given that many who work with data will state that a significant amount of data is required to achieve high quality results in computational analysis, perhaps more than the typical humanist would have.

The results of this first experiment echo other findings from stylometric studies in a medieval context, where subtle layers of scribal or authorial intervention can be computationally distinguished if the appropriate features are modelled. It suggests that stylometry—when applied carefully to whole codices—can complement traditional palaeographic analysis, offering a reproducible way to detect shifts in scribal hands. While larger samples naturally yield clearer separations—we did automate the transcription of the entire manuscript, after all—our study suggests that even modest amounts of carefully transcribed and sampled material might preserve enough scribal signal to map individual activity across a codex.

Experiment 2: Mapping Multiple Hands to Different Signals

Mentions of multiple scribal hands in manuscript catalogues, as we saw in the previous example, are relatively common, but it is much rarer to find colophons that provide the name of a scribe or a date by which a manuscript can be situated in time or space. Ruzzier has compiled an important handlist of such manuscripts, which provides a valuable starting point for identifying candidate bibles for further analysis.[18] However, with a few additional examples we have identified to expand that list, such attributed bibles remain rare: Ruzzier's appendix lists only thirty-six manuscripts, and currently only about half of those manuscripts are accessible in digitized form. What makes a colophon naming a scribe particularly significant for computational analysis is the opportunity it offers us to study the manuscript forensically, as we did in the previous example with the anonymous (but visible) hands, testing where patterns of scribal behaviour might be detected by computational methods. A named individual offers something rarer: a direct link between a physical document and the historical record, grounding the manuscript in a particular context. In a largely anonymous world of medieval textual production, we might consider a named manuscript as an anchor, by which we mean a precious data point of certainty, providing a fixed point from which to map broader patterns of scribal practice, manuscript circulation, or historical agency.

In this section we turn to two manuscripts of particular interest to us: UPenn, MS Codex 236, a French bible attributed to Paris in the 1220s, and Mazarine, MS 6, likely to be French and dating from the thirteenth century. Although no direct connection between these two manuscripts has previously been asserted, they form an interesting pair for comparative analysis, given the claims made about their production. UPenn, MS Codex 236 does not contain a colophon, and its scribe(s) is/are unknown. However, a precise collation exists in the catalogue, alongside an unnamed manuscript cataloguer's assertion that the manuscript seems to be the product of "probably more than one hand, though it appears to be the work of a single scriptorium."[19] We interpret this comment to suggest a visual and stylistic consistency across the manuscript, in both decoration and handwriting. Our own careful visual inspection confirmed this impression of uniformity.

This uniformity raises an important question. Whereas we know something about the production of bibles in some urban contexts, we do not know

18 Ruzzier, *Entre université et ordres mendiants*, 283.

19 University of Pennsylvania Libraries, "Biblia sacra manuscripta."

everything about the genre. What was the nature of the coordinated effort to copy UPenn, MS Codex 236? Was this bible copied by a single, yet unattributed scribe, or could it be the product of a particularly well-coordinated collaborative effort—one subtle enough that it might only be detectable through computational methods? If the latter, might collation patterns offer additional evidence about how labour was divided during the manuscript's production? At the same time, we can also ask whether the scribal profile detected through computational analysis reflects unconscious, individual habits or whether it could have been consciously adopted—or imitated—by expert scribes contributing to the collective effort of producing a codex. These possibilities frame our investigation into the internal structures of the manuscript and the methods best suited to uncovering them.

The second manuscript, Mazarine, MS 6, with which we began this chapter, presents a different problem. At the end of the OT (fol. 429r), a colophon identifies a certain Johannes de Cristemanneford as the scribe. But does this attribution mean Johannes copied the whole Old Testament, only a section of the OT, or the entire manuscript? Can a named scribe anchor the manuscript securely to a specific time and place, or was Johannes more akin to a manager or overseer of its production? Similarly, if a date is included in a colophon, as in the case of Dole, Médiathèque de l'hôtel Dieu, MS 5, does it indicate the actual date of completion of copying, or a more arbitrary or ceremonial moment? The question we pursue in this experiment is whether colophons can be trusted as reliable witnesses to the creation of a manuscript. As Cohen has suggested, "it is uncertain, however, whether the scribe is to be believed in all cases and whether the meaning of his words is being interpreted correctly."[20] Scribes could claim credit for work they only partially completed, and modern scholars may sometimes overinterpret the limited evidence a colophon provides. Through computational analysis, we aim to test what the manuscript itself reveals, to see how the colophon fits within the broader production context, to uncover hidden forms of scribal labour, and to explore whether a single name may in fact conceal a collaborative effort.

Using a recent HTR model trained on the variety of manuscripts detailed in Table 4, we transcribed the two manuscripts in their entirety. In this experiment, we change methods from sequential stylometric analysis in favour of a method for text classification known as Term Frequency-Inverse Document Frequency (TF-IDF), also used by Vandyck and

20 Cohen, "Can Colophons Be Trusted?."

Kestemont, as explained above. The transcription was exported page by page, following the organization of the digitized manuscripts in Transkribus, producing many hundred files per manuscript. TF-IDF is a well-known method for textual corpus analysis that quantifies the significance of words, characters, or n-grams within each file relative to their occurrence across the full corpus, with frequent local terms and rare global terms receiving higher weight.[21] After building the TF-IDF matrices, we applied Principal Component Analysis (PCA) to reduce the dimensionality of the dataset. In the case of this experiment, PCA identifies the two principal components—that is, the axes along which variation is strongest—and projects the complex data into two dimensions for visualization. These visualizations allow us to explore clusters of folios that share similar patterns of abbreviated words or distinctive scribal features, suggesting underlying structures that would otherwise be impossible to observe across large amounts of raw manuscript transcription.

We use this method for two main reasons: once transcriptions are available, it is relatively easy to apply and does not rely on extensive manual tagging. As discussed earlier in relation to stylometry, such an approach typically requires prior knowledge of a corpus, and some form of certainty, such as visible scribal hands, or a colophon, or the claim by a scholar that a specific text can be attributed to a particular person. A stylometric experiment is then structured around confirming or refuting an attribution based on that data. As in the section above about CCC, MS 49, multiple hands are compared to see which one predominates, using samples of known attribution to classify unknown sections. In this section with UPenn, MS Codex 236 and Mazarine, MS 6, our goal varies slightly. With the former, we have no indication where one hand begins or ends; with the latter, we have a colophon. Moreover, following Vandyck and Kestemont, we restrict analysis to character n-grams containing abbreviations or distinctive letterforms. Brevigraphs, they argue, function much like frequent words in authorship attribution, serving as distinctive markers of scribal practice, that is, they "are distinctive choices made by the scribes themselves, they are relatively content independent and they are spread evenly throughout the entire corpus."[22]

21 More specifically, we implement the TfidfVectorizer of the skikit-learn library, using character 4-grams using the top 500 features and full TF-IDF weighting to emphasize distinctive terms. TfidfVectorizer converts all text to lowercase, but no stopword removal is implemented.

22 Vandyck and Kestemont, "Abbreviation Application."

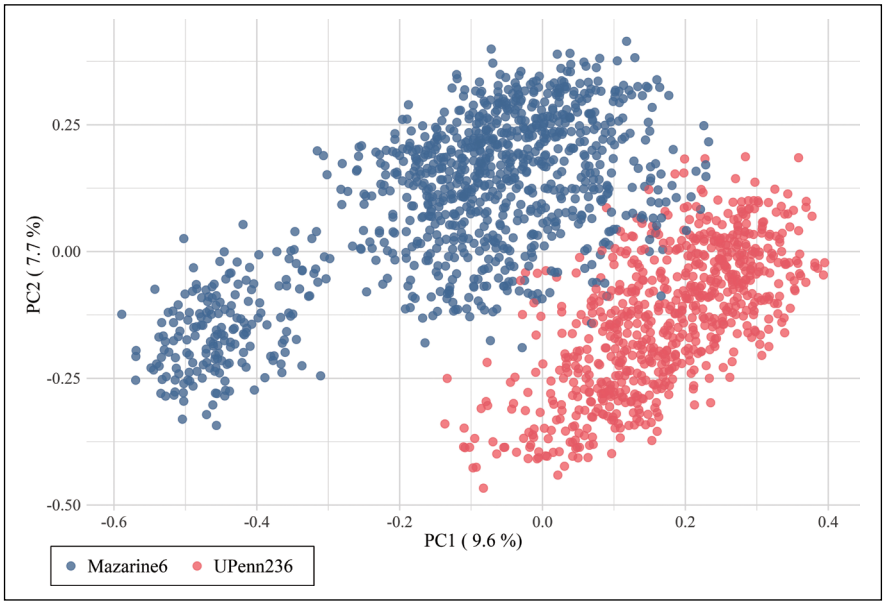

Figure 6. A 2D Principal Component Analysis (PCA) plot of a TF-IDF analysis of HTR-created transcriptions of two manuscripts, filtered for character 4-grams containing medieval letterforms, brevigraphs and abbreviations, Mazarine, MS 6 (in blue) and UPenn, MS Codex 236 (in pink). Transcriptions created in Transkribus. Visualization by authors, created in Python using TfidfVectorizer from scikit-learn and R using FactomineR and Plotly. Code adapted from Vierthaler, "NYU Abu Dhabi Stylometry," and from Stutzmann, Tensmeyer and Christlein, "Writer Identification and Script Classification." Eigenvalues: PC1=0.045 and PC2=0.036.

Adopting their approach, we processed our transcriptions to retain only character 4-grams that contain abbreviations or unique script features.[23]

TF-IDF analysis of transcriptions made from UPenn, MS Codex 236 did not result in clearly distinctive clusters belonging to parts of the manuscript, suggesting to us a higher degree of uniformity in the scribal profile. Although the divide between OT and NT chunks commonly appears when analyzing the text from the automated transcription, it is not as visible in the PCA in Figure 6. Several hypotheses may explain this finding. One possibility is that the manuscript was copied by a single scribe, making it difficult to distinguish multiple scribal habits. Alternatively, the manuscript may have been produced by a group of scribes with a strong house style, by which

23 We did not find that limiting our language sample to abbreviations, brevigraphs, and words containing special letterforms was effective in reducing the full textual signal. This finding can most likely be attributed to some abbreviations and brevigraphs corresponding to a uniquely NT lexicon.

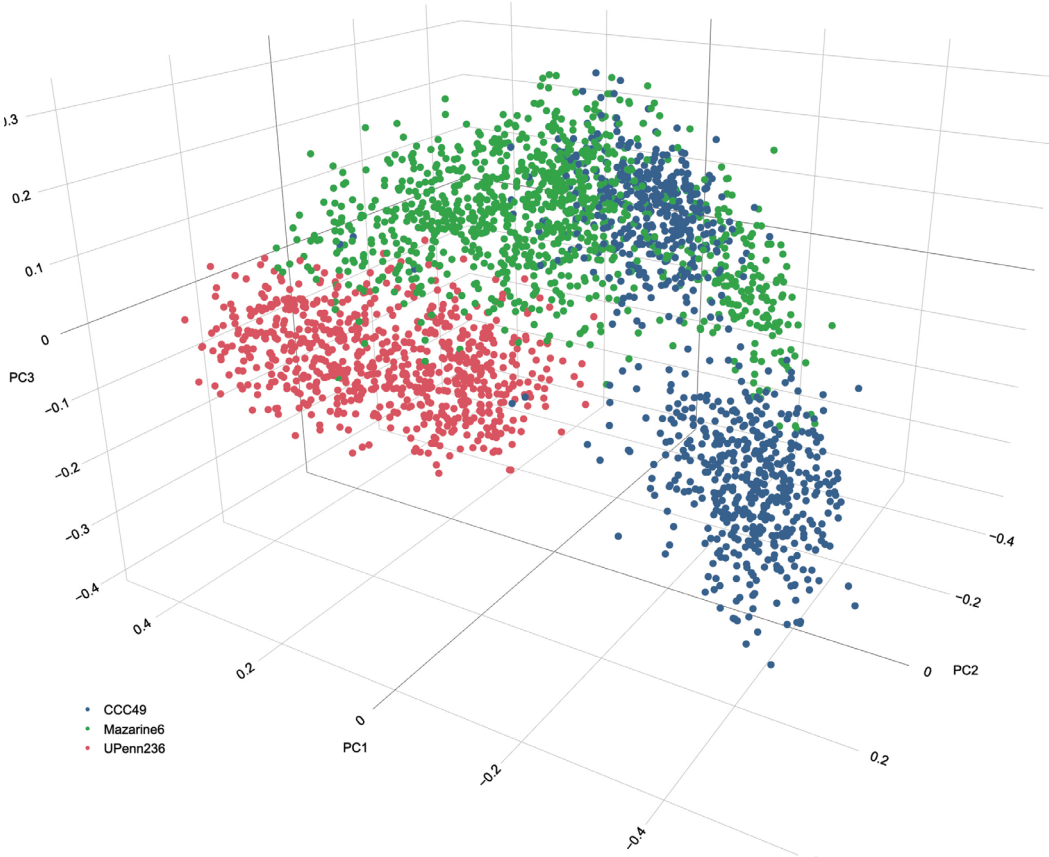

Figure 7. A 3D Principal Component Analysis (PCA) plot of a TF-IDF weighted analysis of HTR-created transcriptions of three manuscripts, filtered for character 4-grams containing medieval letterforms, brevigraphs, and abbreviations, Mazarine, MS 6 (in blue), UPenn, MS Codex 236 (in pink), and CCC MS 49 (in green). Transcriptions created in Transkribus. Visualization by authors, created in Python using TfidfVectorizer from scikit-learn and R using FactomineR and Plotly. Code adapted from Vierthaler, "NYU Abu Dhabi Stylometry," and from Stutzmann, Tensmeyer and Christlein, "Writer Identification and Script Classification." Eigenvalues: PC1=0.055, PC2=0.036, PC3=0.023.

we do not mean necessarily that they were working within the same physical space, but rather that they had an agreed upon copying style to which they conformed. Finally, they may have been copying faithfully from another unknown, yet uniform, exemplar. Our current results support the cataloguer's assertion that the manuscript was copied with a degree of regularity and the participation of multiple scribes cannot be definitively ruled out. If there were several scribes, a significant effort to converge on one style appears to be present. Future research using alternative techniques may be able to help provide different answers.

In the case of Mazarine, MS 6, the PCA of the TF-IDF analysis clearly distinguishes between the OT and the NT, in contrast to the previous example where the two sections are nearly indistinguishable. This difference is so pronounced that it suggests the NT was written by an entirely different scribe, or different scribes, distinct from John of Cristemanneford. And such evidence may confirm the reliability of the colophon in this instance: John links himself only to the OT and there is no proof at any point that he may have copied or been involved in any way with the production of the NT. The reliability of colophons depends both on their placement within the codex and the nature of the information they provide. Our positive results in the case of Mazarine, MS 6, should still be considered as hypothetical, and we caution against overgeneralizing information from colophons. While these can provide useful information, the results of our experiment reflect only one example and the way that we have modelled the entire manuscript. The method we outline here, instead of adding certainty to the analysis of manuscripts, can be useful for adding layers of new information for scholarly decision-making.

To explore our results with these two manuscripts further, we decided to evaluate them together with the manuscript from the first section of this chapter: CCC, MS 49. To reiterate, there is nothing that directly links these three manuscripts together, and we expect them to exhibit different features. Their distinctiveness is visualized in Figure 7. Interestingly, this three-dimensional analysis yielded similar results: all folios from UPenn, MS Codex 236 remain grouped together (in pink) whereas both Mazarine, MS 6 (in blue) and CCC, MS 49 (in green) are split in two. In CCC, MS 49, while one group seems to contain exclusively folios from the OT, the second group contains folios from both Testaments. This finding is also an interesting departure from the results from the first experiment where we could distinguish between three hands. Here, only two are visible: what corresponds to hand 1 and hand 3 in the first experiment. One possible explanation for the absence of hand 2 could be that this specific scribe copied only small portions of text, about sixty folios at the end of the OT. It may also be that his scribal signal or his abbreviation pattern may be similar to either of the other scribes. Additional analysis would be required to understand why we obtained these results and why the second hand is not as clearly visible as the others.

Experiment 3: Three Bibles by the Same Scribe as the Master of the Bible of Manfred?

The first two experiments in this chapter illustrated how the method of modelling scribal behaviour in transcription is able to confirm, or nuance, what the trained palaeographer is able to distinguish in manuscript. For us, these experiments serve as a proof of concept: the method is robust and can be applied to cases in which expert opinion is not settled. In the next two computational experiments carried out in this chapter, we draw attention to the contexts of manuscript production. In this experiment, we assess a series of manuscripts created in the milieu of Manfred (1232–1266), son of Emperor Frederick II, Prince of Taranto and then King of Sicily starting in 1258. An unnamed illuminator, likely active in Naples around the third quarter of the thirteenth century, who decorated a bible for Manfred has been named the "Master of the Bible of Manfred." The manuscript in question is BAV, MS Vat. lat. 36 and it contains a colophon identifying him as the patron, and a certain Johensis as the scribe on fol. 494v: "Princeps Mainfride regali styrpe create, Accipe quod scripsit Johensis scriptor, et ipsum Dignaris solita letificare manu." (Prince Manfred, born of royal lineage, receive what Johensis the scribe has written, and deign to make him happy with your customary hand).

Aspiring to the patronage of his father, Manfred commissioned several sumptuous manuscripts, among which BAV, MS Vat. lat. 36 is the best known. The Master of the Bible of Manfred is believed to have had an atelier and to have worked both for the imperial court and for a clientele of scholars and wealthy students.[24] Given the historical details that we have around the creation of these manuscripts, the case of the Master of the Bible of Manfred raises a number of questions: what was the relation of the master illuminator to other illuminators working around him? With what copyists, parchmenters, and binders did illuminators like the Master of the Bible of Manfred work? Did they have a working relationship over time? Our method of detecting similar features in the scribal contribution to manuscript creation cannot answer all of these questions, some being better left to art historians, but it can detect the appearance of a scribal hand in more than one manuscript.

Scholars have identified a number of other manuscripts, including many bibles, likely produced by the Master of the Bible of Manfred or his group. In total, the manuscripts which have been proposed as belonging to his artistic direction are Palermo, Biblioteca Nazionale, MS I. C. 13; BnF, MS latin 40;

24 Toubert, "Trois nouvelles bibles."

Table 7. List of the pages that we automatically transcribed from three manuscripts using Transkribus for Experiment 3 in this chapter: BnF, MS latin 40; BAV, MS Vat. lat. 36; and BnF, MS latin 10428. Data by authors.

Manuscripts	Book of Vulgate	Fols.
BnF, MS latin 40	Exodus	23r–25r
	Numbers	40v–42v
	Josue	69r–71r
	Matthew	352r–354r
	Mark	366r–368r
BnF, MS latin 10428	Exodus	21r–23r
	Numbers	41r–43r
	Josue	63r–65r
	Matthew	289v–291v
	Mark	300r–302r
BAV, MS Vat. lat. 36	Exodus	24v–26v
	Numbers	31v–33v
	Josue	81v–83v
	Matthew	386v–388v
	Mark	400r–402r

London, British Library (hereafter BL) MS Add. 31830;[25] Turin, Biblioteca Nazionale, MS E IV 14;[26] BnF, MS latin 10428; Bourges, Bibliothèque municipale, MS 5; and BnF, MS latin 217.[27] Tourbert has argued that some manuscripts were painted by the master himself, rather than by his entourage (BnF, MS latin 40, BAV, MS Vat. lat. 36, and BnF, MS latin 10428), although BnF, MS latin 40 probably had two helpers, perhaps apprentices or associates. BnF, MS latin 10428 is less lavish in appearance than BAV, MS Vat. lat. 36 and is of a considerably smaller size, details which distinguish it from the courtly works created for Manfred and which have led to the suggestion of

25 Daneu-Lattanzi, *Una Bibbia prossima alla Bibbia di Manfredi*; Daneu-Lattanzi, "Ancora sulla scuola miniaturistica," 105–62; Daneu-Lattanzi, *I manoscritti ed incunaboli miniati*; Daneu-Lattanzi, *Lineamenti di storia.*

26 Pettenati, "Un'altra 'Bibbia di Manfredi,'" 7–15.

27 Toubert, "Trois nouvelles bibles."

another client.[28] BnF, MS latin 10428 falls chronologically between BAV, MS Vat. lat. 36 and the slightly later Bible, BnF, MS latin 40.[29] But do they form a tight unit of manuscripts created under the supervision of the master and copied by the same hand?

The reconstruction of the manuscript illumination around Manfred draws on the collective expertise of generations of art historians, but what makes this scenario interesting to our work in computational textual analysis is that both BnF, MS latin 40 and BAV, MS Vat. lat. 36 contain colophons attributing them to the same scribal name: Johensis. Were we to be able to confirm the scribal contribution of Johensis in these two manuscripts, we would be in an interesting position to help add to the knowledge about the creation of the codices. While Johensis explicitly identifies himself in colophons within BnF, MS latin 40 ("Explicit expliceat ludere scriptor eat. Johensis" (fol. 432) and BAV, MS Vat. lat. 36 (cited above), BnF, MS latin 10428 lacks such a colophon and its scribal attribution remains uncertain. There are, of course, other manuscripts mentioned above; however, the convergence of scholarly hypothesis in Tourbet's strong assertion about the Master's direct involvement in these three manuscripts with the fact that these three manuscripts are already digitized provide an ideal scenario for computational analysis. Their existence in digitized format makes it possible to design a computational experiment that centres the role of the copyist, or the copying hands (rather than the artist's hands) in such a co-produced object. For these reasons, in the third experiment, we explore the possibility that the medieval scribe Johensis mentioned twice may be the same person and that he may have also been responsible for copying BnF, MS latin 10428.

To conduct this analysis, we used a selection of transcriptions extracted from these three manuscripts. The folios we used for our sample are listed in Table 7.[30] Our sampling method included twenty-five pages per manuscript, extracted as sequential excerpts of five pages from specific books of the Vulgate (Exodus, Numbers, Josue, Matthew, and Mark). Prologue pages were omitted to maintain consistency in lexicon.

We applied the same method of filtering the HTR-created text for character 4-grams, including special letterforms, brevigraphs, and abbreviations. As in the case of Mazarine, MS 6, from our second experiment, the

28 Avril et al., *Dix siècles d'enluminure italienne*, 53.

29 Avril et al., *Dix siècles d'enluminure italienne,* 54.

30 Since HTR can be a computationally demanding process, our choice to sample texts came from a dual interest in the sustainability of resources and material reasons. We discuss these reasons in the last section of this chapter.

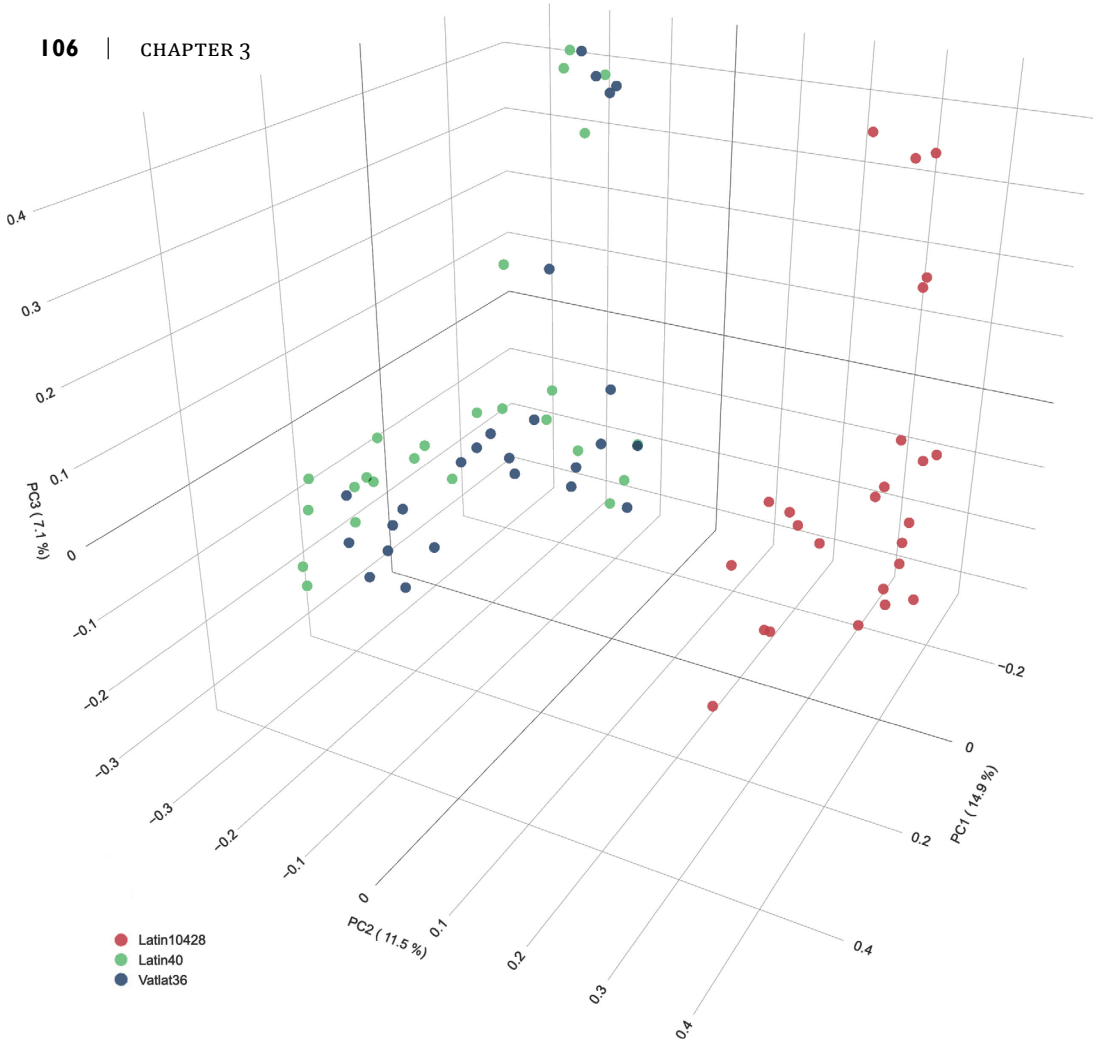

Figure 8. A 3D Principal Component Analysis visualization of a TF-IDF weighted analysis of character 4-grams containing special letterforms and abbreviations filtered from a sample of pages transcribed from BnF, MS latin 40 (green), BAV, MS Vat. lat. 36 (blue), and BnF, MS latin 10428 (red), as detailed in Table 7. Transcriptions created in Transkribus. Visualization by authors, created in Python using TfidfVectorizer from scikit-learn and R using Plotly. Code adapted from Vierthaler, "NYU Abu Dhabi Stylometry," and from Stutzmann, Tensmeyer and Christlein, "Writer Identification and Script Classification." Eigenvalues: PC1=0.078 PC2=0.06 PC3=0.037.

differentiation between the OT and NT books remained clear when working with filtered 4-grams. A second component of the PCA analysis also proved effective in distinguishing between individual scribes. Figure 8 illustrates the results of the TF-IDF analysis of the seventy-five pages sampled from each manuscript, but reduced to three dimensions in this case. The analysis clearly suggests that the scribe of BnF, MS latin 40 and BAV, MS Vat.

lat. 36—both identified as Johensis in two colophons—are indeed the same person. Furthermore, based on the clustering of data points, we can now assert, not only that the colophons with the name Johensis seem to point to the same scribe, but also that the scribe of BnF, MS latin 10428 appears not to be Johensis.

Although BnF, MS latin 10428 was decorated by the Master of the Bible of Manfred, its material and scribal features differ significantly from the others illuminated in the same atelier. It is significantly smaller, less lavish, and now we know it was clearly produced by a different scribe, perhaps pointing to a different patron. This case highlights how our method can be used with a group of manuscripts for which there are a number of existing theories, but also raises important questions about how medieval "ateliers" operated and the dynamics between scribes and illuminators. It suggests that scribes and illuminators did not always work in fixed partnerships; instead, illuminators might collaborate with different scribes depending on the nature of the commission, the intended patron, or the resources available. It would be interesting to compare with samples digitized from the other manuscripts evoked at the beginning of this section—which would require considerable effort on behalf of the libraries or scholars to visit them in person—but provided the analysis we have been able to carry out so far, the work of the Master of the Bible of Manfred across different manuscripts thus reflects a more fluid and project-based model of production over a rigidly organized workshop of long-term partnerships.

Experiment 4: Attributing Hands to a Scribal "Atelier"

From the previous example for which the context of manuscript production is not only specific—the patronage of the son of Frederick II of Sicily—but also well documented, we move to another example, perhaps more complex and significantly more protracted in time than that of the Italian example discussed above: that of the so-called Johannes Grusch atelier. The notion of there being an "atelier" associated with a certain style of Parisian manuscript painting seems to have been asserted for the first time in the landmark book about thirteenth-century illumination by Branner.[31] Branner's research was carried out around the same time that Toubert made her argument about the atelier of the Master of the Bible of Manfred. He comes up with the name "the Johannes Grusch atelier" and identifies it as a decades-long group of

31 Branner, *Manuscript Painting in Paris*.

artists and decorators of manuscripts, spanning the period generally corresponding to the reign of King Louis IX.

The historical record indeed contains the name of a scribe "Joanne Grusch," a scribe of a thirteenth-century bible in the Paris style, now held in a Swiss collection. His name is included in the colophon to Sarnen, Kollegiumsbibliothek, Stiftsarchiv Muri-Gries (hereafter Sarnen KB), MS Cod. membr. 16 containing a *terminus ante quem*: "Sacra Biblia scripta a Fr. Joanne Grusch O.S.B. Mon. Morenj. qui anno 1267 die 24 Martii obiit (ex Necrologio Murenji) annum agens 49" (This Holy Bible was copied by Frater Johannes Grusch O.S.B. of Kloster Muri (?) who died at the age of 49, on March, 24 1267). An important distinction must be made, however, in Branner's attribution of an atelier named after Grusch. It was not, in fact, based on the identification of Grusch's contribution in the copying of other manuscripts he attributes to the atelier, but based on his scholarly judgement that the illumination of Sarnen KB, Cod. membr. 16 bears a resemblance to the illumination of the other manuscripts. Branner asserts a similar logic in labelling an unnamed illuminator after a named scribe in an earlier article about BL MS Royal I. D. i.[32] In it, he explains that the artist of the latter is known as the William of Devon Painter because he illuminated a bible copied by the eponymous scribe. The process of identifying the illuminator(s) and naming them was a metonymic one: "For lack of a better term I shall call the Parisian atelier that of the Johannes Grusch painter, Johannes Grusch being, like William of Devon, the scribe of one of the manuscripts."[33] And such names persisted.

In *Manuscript Painting in Paris During the Reign of St. Louis* other ateliers, shops, and groups besides the Johannes Grusch Atelier are enumerated in Appendix V, the "Working Lists of Manuscripts": the Almagest Shop, the Alexander Shop, the Blanche Shop, the Atelier of the Vienna Moralized Bibles, the Toledo and Oxford Moralized Bible Ateliers, the Amiens Atelier, the Guines Atelier, the Pierre de Bar Atelier, the Gautier Lebaube Atelier, the Soissons Atelier, the Duprat Atelier, the Mathurin Atelier, the Bari Atelier, etc. Branner's persistent metonymic naming practice, associating groups of manuscripts with a scribe, a place, another person, the name of a work or manuscript, corresponds to a grouping of similar production according to known qualities or styles in others. Indeed, giving name to stylistic

32 Branner, "The Johannes Grusch Atelier," 24.

33 Branner, "The Johannes Grusch Atelier," 25.

groupings had important implications for the ways in which illuminated manuscripts from Paris have been received since the late 1970s.

Kidd has argued that Branner's terminology equating "ateliers" with "styles" is "highly problematic," mentioning that there has also been no monograph-length scholarly work published since to revise Branner's take on manuscript illumination at the time of Louis IX.[34] Branner's interchangeable use of the terms "style" and "atelier" has led to widespread confusion, suggesting that manuscript production was collocated in physical space, in a much more situated condition of manuscript creation than was probably the case. The Parisian book trade would most likely have been much larger an operation than the patronage circles of Manfred. In Paris they depended on networks of specialized skills of production by lay people: binders, parchmenters, scribes and illuminators.[35] Kidd contends that many illuminators likely worked independently, in similar, but distinct styles, rather than within shared paintshops (Branner's term). Kidd also contests the uncritical echoes of Branner's style labels in subsequent scholarship and dealer catalogues.[36] The Grusch group, perhaps because of its identification with the name of a scribe, has led to confusion of the role and perhaps over-attribution, lending prestige to manuscripts or manuscript fragments for sale. With Kidd, we believe that a cautious, evidence-based approach to manuscript attribution that avoids the perpetuation of outdated or oversimplified frameworks, is a way forward.

For a convenient shorthand in this chapter, let us call the network in which Grusch was an actor, the "Grusch network" for short. At the time we are writing, some of the manuscripts identified as associated with the Grusch network are available in digitized form, and the methods we have developed in previous examples provide us with the opportunity of thinking about these manuscripts through the optic of scribal contribution. The six manuscripts we used in this experiment include Sarnen KB, MS Cod. membr. 16; BnF, MS latin 15477; BnP, MS IL 93; Free Library, MS Lewis E242; BnF, MS latin 179; and BnF, MS latin 211. In reality, many more manuscripts were listed in Branner's Appendix, yet we chose to focus only on the Paris bible genre for the relative thematic coherence it provides us. That left us with six manuscripts to which we have access. It is worth mentioning—as is not atypical of much scholarship in the humanities—that Branner was not

34 Kidd, "Introduction," 9.

35 Rouse and Rouse, *Manuscripts and Their Makers*.

36 Kidd, "Introduction," 12.

uniformly certain about the attribution to his category of the Grusch atelier. In fact, his definition of the atelier is broad: a group of illuminators and copyists working over many decades to produce a number of styles.

Compared with the previous three sections of this chapter, we faced significant material challenges in collecting the data for this computational experiment. Of the six Paris bibles mentioned in Branner's handlist of the Johannes Grusch atelier, only three of them were digitized and only two are openly available online. The original manuscript signed "Joanne Grusch" was made available to us by a digitized microfilm from the Hill Manuscript Museum and Library. The other three (BnF, MS latin 179; BnF, MS latin 211 and BnF, MS latin 15477) are undigitized, but readily accessible in the manuscript consultation room at the BnF, where photography for private research purposes is thankfully permitted.

Following the sampling methodology detailed in the third experiment of this chapter, we assembled 125 pages of transcription drawn from six manuscripts, totalling 750 pages. The selection was in part shaped by the desire to have a sampling of text from the whole Bible, from both the OT and NT, but also was also dictated by the material conditions of the objects under study: many thirteenth-century bibles cannot be fully opened without risking damage due to their stiff and compact bindings. Consequently, the choice of books—Exodus, Numbers, Joshua, Matthew, and Mark—was determined pragmatically, based on the sections most accessible with a simple, non-invasive camera setup. Rather than waiting for large-scale institutional digitization efforts, we adopted an agile, on-demand digitization practice, enabling scholarship to proceed flexibly within the constraints posed by manuscript materiality. For us, this approach represents a carefully considered compromise between respecting the integrity of the manuscript as a physical artifact and still pursuing the pathways provided by computational analysis.

Here we sought to explore the extent to which the scribal profile of the identified copyist of Sarnen KB, MS Cod. membr. 16 resembles those found in other manuscripts identified by previous scholarship as associated with the same "Grusch network" of production. In this network, the roles of scribes, decorators, patrons, and intermediaries overlapped and shifted, prompting us to ask whether certain actors worked together repeatedly across multiple projects. Using a TF-IDF-weighted computational analysis of our transcriptions, we generated a three-dimensional principal component analysis (PCA) to visualize similarities in scribal practices (Figure 9). The results provided one strong conclusion that we did not set out to understand from the beginning: BnF, MS latin 179 and Paris, BnF, MS latin 211 exhibit very

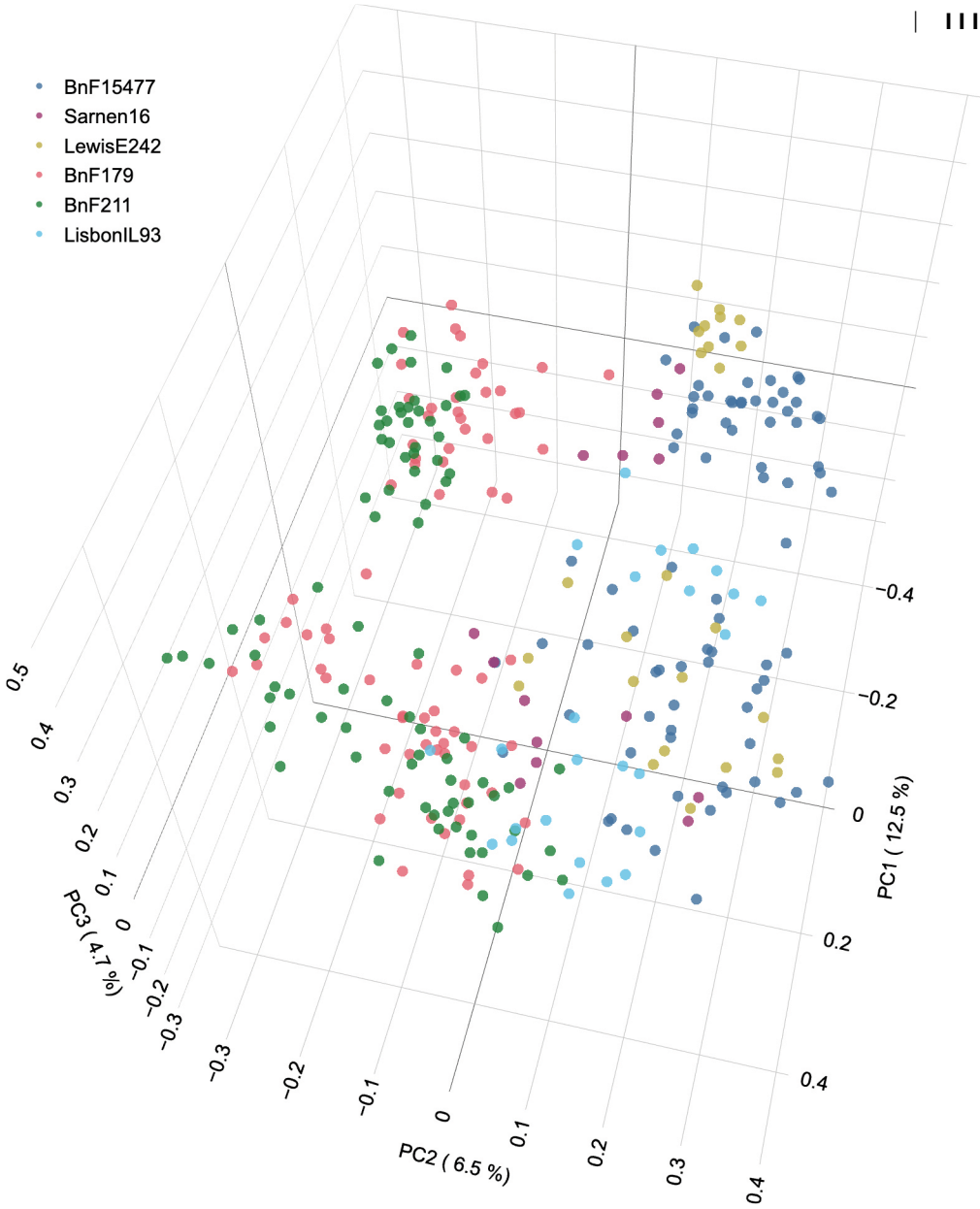

Figure 9. A 3D Principal Component Analysis (PCA) of a TF-IDF weighted analysis of HTR-created transcriptions of six manuscripts, filtered for character 4-grams containing medieval letterforms, brevigraphs, and abbreviations filtered, Sarnen KB, MS Cod. membr. 16; BnF, MS latin 15477; Free Library, MS Lewis E242; BnP, MS IL 93; BnF MS latin 179; and BnF MS latin 211. Transcriptions created in Transkribus. Visualization by authors, created in Python using TfidfVectorizer from scikit-learn and R using Plotly. Code adapted from Vierthaler, "NYU Abu Dhabi Stylometry," and from Stutzmann, Tensmeyer and Christlein, "Writer Identification and Script Classification." Eigenvalues: PC1=0.068, PC2=0.035, PC3=0.026.

different scribal behaviour than the other six manuscripts. Not only do they suggest that not all manuscripts previously grouped under a single "atelier" share the same copying practices, but the data suggest that the copyist(s) of these two manuscripts are indeed the same, or follow very similar scribal conventions.

The relationships among the other four manuscripts are more nuanced. Free Library, MS Lewis E 242 shares a scribal profile more closely aligned with that of Sarnen KB, MS Cod. Membr. 16 and BnF, MS latin 15477, although the latter without such a clear overlap. For what concerns the OT, there could be a relation between the sampled sections of BnP, MS IL 93 and Sarnen KB, MS Cod. Membr. 16, but the NT segment of the former is definitely not the scribal profile of Grusch in the latter. While more comprehensive transcription would be necessary to pursue a chronostylometric analysis capable of testing hypotheses about temporal phases of activity, these preliminary findings already complicate assumptions about stable workshop models. They point instead to a more flexible and dynamic configuration of collaboration, where groups of actors might come together for particular commissions, but not continue to collaborate after that.

Scholars in the field of book history have argued that *librarii* of the thirteenth and fourteenth centuries served as central coordinators of manuscript production, orchestrating the efforts of various craftsmen to deliver finished volumes. Nevertheless, data concerning the frequency with which copyists were subcontracted by booksellers remains incidental. If, as Rouse and Rouse and Kidd contend, manuscript production operated through a flexible and decentralized system involving many semi-independent workers contracted by booksellers, then the systematic examination of a broader set of manuscripts—particularly those with known origins and dates—may reveal previously unrecognized affinities between works, especially among manuscripts lacking explicit attribution. It is important to underscore that for the last two case studies discussed here—the networks surrounding Grusch and Manfred—other scribes may well have participated regularly in manuscript copying activities. In this chapter, we have deliberately focused on relatively small, curated sets of manuscripts in order to deepen our analysis of named individuals within the archival record; indeed much more research needs to be carried out.

In Table 8, we summarize, based on our analysis, the early, middle, and late periods into which Branner categorized manuscripts of the so-called Grusch atelier. In the fourth column, we present our own assessment, derived from the TF-IDF analysis discussed above. In the rightmost column, we further propose what we term a possible "companion scribal

Table 8. An overview of previous scholarly attributions of scribal identity (notably from Branner) along with our assessment of the identification with Grusch as copyist for six manuscripts: Sarnen KB, MS Cod. membr. 16; BnF, MS latin 15477; Free Library, MS Lewis E242; BnP, MS IL 93; and BnF, MSS latin 179 and latin 211. The last column offers a possible companion style, based on the data analysis of the scribal profile found in Figure 9. Data by authors.

Shelfmark	Digitization	Scholarly attribution of illumination group	Our attribution to Grusch copyist	Possible companion scribal style
Sarnen KB, MS Cod. membr. 16	HMML	Late Grusch atelier (Branner, *Manuscript Painting*)–Colophon	—	BnF, MS latin 15477 Free Library, MS Lewis E242 BnP, MS IL 93 - OT
BnF, MS latin 15477	authors	Late Grusch atelier (Branner, *Manuscript Painting*)	Perhaps	Sarnen KB, MS Cod. membr. 16 Free Library, MS Lewis E242 BnP, MS IL 93 - OT
BnP, MS IL 93	BnP	"Perhaps" Grusch Atelier (de Sousa, *Sacra Pagina*)	OT perhaps; NT no	NT is another scribe
Free Library, MS Lewis E242	archive.org	Early Grusch atelier (Branner, *Manuscript Painting*)	Yes	Sarnen KB, MS Cod. membr. 16 BnF, MS latin 15477 BnP, MS IL 93 - OT
BnF, MS latin 179	authors	Middle Grusch Atelier (Branner, *Manuscript Painting*)	No	BnF, MS latin 211
BnF, MS latin 211	authors	Late Grusch atelier (Branner, "Johannes Grusch Atelier" and *Manuscript Painting*)	No	BnF, MS latin 179

style," identifying manuscripts that exhibit notable affinities according to the exploratory data analysis. This column gestures toward the unconnected mass of medieval manuscripts alluded to earlier—those works whose relationships have remained largely unexplored and for which we are likely never to have attributions to name. Although these suggestions remain provisional, one potential trajectory for computational humanities approaches

to medieval manuscript studies may lie in the development of metrics that, while distinct from traditional palaeographic methodologies, offer alternative perspectives for exploring co-production networks. Although such distant metrics would require further articulation and validation, it is conceivable that by integrating multiple elements of manuscript production—such as scribal profiling, illumination characteristics, and material features—scholars might be able to construct innovative new layers of data. These, in turn, could substantially enrich the interpretive frameworks available to book historians seeking to reconstruct the labour structures of medieval manuscript creation.

Conclusion

In this chapter, we have returned to the broader question of metadata and description in both manuscript cataloguing and scholarship—particularly the way that forms of attribution stem from decorative, script, or material impressions left in manuscripts. Our analyses have demonstrated that evidence gleaned from computational modelling sometimes confirms the material record and the intuitions of book historians, but also offers critical refinements that go beyond what is visible to the naked eye. Our study demonstrates a proof of concept for a method of studying manuscripts for which material evidence already provides an answer, but can add layers of confirmation to palaeographic and codicological arguments. It is also a computational method that can be used exploratively to suggest relationships between manuscripts for which we do not yet have robust data.

The historiography of manuscript studies has often privileged illumination and decoration as the main method for understanding the handmade codex, where it comes from and how it was put together, leaving the figure of the scribe relatively underexamined. Yet, as our experiments in modelling scribal practice suggest, understanding the copyist(s)—especially in traditions as variably transmitted as Paris bibles—is challenging, but still possible. Each of the four experiments we carried out illustrates different aspects of this potential. With CCC, MS 49, computational results aligned closely with traditional manual analysis, but perhaps reached their limits with short textual samples of one of the hands. With our experiment using Mazarine, MS 6, and UPenn, MS Codex 236, we were able to confirm the colophon of the former, but by contrast, revealed that adjusting feature sets—such as emphasizing character 4-grams—allow other structural signals to disappear or to surface. In the third and the fourth experiment, computational analysis takes us beyond confirming what has been assumed by scholars to be true

to nuancing our stance on scribes. In our investigation of the scribe Johensis, a partial transcription provided strong confirmation of attribution in two manuscripts and rejection of attribution in another, suggesting that computational methods may provide the opportunity to uncover relationships between art historical evidence, patronage networks, and scribal practice through sampling methods that respect the physical integrity of the codex and are more economical than full transcription. Moreover, the analysis of the six manuscripts attributed to the so-called Grusch atelier demonstrated the serendipitous nature of computational scholarship: while drawing into question the basic assumptions of previous scholarly categories, we are still able to surface patterns such as the likely participation of Grusch—or scribes imitating Grusch—in three out of six manuscripts studied.

Beyond the mass of detail that automated transcription creates, the integration of computational methods into the study of scribal trends radically reshapes our epistemic relationship to evidence from manuscripts. HTR-based transcriptions offer a different way of seeing, closer to the way that a medieval reader would have experienced a manuscript, but also one that allows for features across documents to be aggregated. The abstraction inherent in modelling does not necessarily flatten the manuscript totally, but exchanges tactile, up-close experience of the book object and the possibility of capturing larger patterns rooted nonetheless in the materiality of these objects. We have mentioned Andler's notion of the double enigma suggesting that artificial intelligence in this context has a tendency to promise interpretive insight. What HTR systems surface are sequences of characters without understanding their linguistic, cultural, or intentional significance. Any application of AI in manuscript studies must be accompanied by a critical reflexivity concerning the gap between what we model with these systems and what we claim they reveal. Such reflexivity must come through scholarly judgement and contextual sensitivity.

Looking ahead, several avenues for future research present themselves. A truly large-scale analysis across a broader corpus could test the scalability of these methods, particularly with more advanced machine learning tools. Expanding computational inquiry to non-textual features—such as stylometry of images, analyses of colours, decorative motifs, or iconographic microvariation—could forge new methods that bridge text-based and art-historical manuscript studies. Such work remains heavily dependent on the availability and quality of digitized resources, however. The manufacture of thirteenth- and fourteenth-century bibles, while moving toward standardization, remained deeply artisanal. The handcrafted nature of these objects—evident in scribal idiosyncrasies, variations in layout, and inconsistencies in

textual execution—offers critical points of entry for computational inquiry. At the same time, it poses significant obstacles to the "perfect" digitization that HTR and modern machine learning methods often presume. The mass transcription and computational study of these manuscripts expose both the potential and the limits of digital tools, foregrounding the complex interplay between human craftsmanship and computational abstraction in the analysis of medieval book production. The sheer number of surviving thirteenth- and fourteenth-century bibles—often described as the first mass-produced book in the West—further amplifies these complexities, since the tension between standardization and individual variation becomes a defining element in the study of their digital avatars. It is precisely within these frictions, between the scale of production and the handmade nature of each object, that some of the most inventive and creative moments of the Paris Bible Project have emerged, inviting new methodological approaches that acknowledge both human and machine in the reconstruction of medieval textual cultures.

That is to say, that when we speak of a large manuscript tradition of a couple thousand manuscripts, in reality, this tradition is not in the truest sense of the term accessible and open, the way that a national corpus of thousands of nineteenth-century novels might be considered to be open, so that we can present results in a reproducible fashion as is the case with more and more research in the computational humanities. For now, HTR-created custom transcriptions allow us to assess some of the claims made about manuscripts and from these preliminary results to create and refine workflows that will allow us—hopefully—to collect much more data for an inquiry into the larger corpus. As methods in the age of artificial intelligence evolve—and they are doing so rapidly in the second half of the 2020s—the methods that we use here may indeed be eclipsed by forthcoming technologies, allowing the means of data collection and capture, as well as the analytical frameworks for studying these data, to be refined. Only time will tell how rapidly the computational study of manuscripts will advance. One point is clear: it will be difficult to include undigitized manuscripts, or digitized copies of manuscripts that sit in dim or dark archives, in our future analyses.