Project Report

Medieval Fragments Revealed with FragmEndoscopy: A Pilot Project to Detect and Record Spine Linings with an Endoscopic Camera

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Abstract: The pilot project FragmEndoscopy applied borescope cameras to document the presence of fragments in situ in bookbindings as spine linings. This entailed developing a methodology for the safe and effective use of endoscopic cameras and for the transformation of the (video) imagery into two-dimensional images of the manuscript fragments. Three case studies validate the proposed methodology, showing that it produces excellent results while keeping financial and time expenditures to a minimum.

Keywords: in situ fragments, manuscript endoscopy, borescope, spine linings

During the early modern period, many medieval manuscripts were cut into strips of parchment which were used by bookbinders to reinforce the bindings of newly printed books.[1] So far, these reused pieces of parchment only came to light when the early modern book binding was damaged or dismembered. As a result, initiatives within the field of fragmentology have mainly relied on collections of such fragments that were once removed from book bindings during conservation efforts. In recent years, scholars are increasingly turning

1 See, e.g., N. Pickwoad, "The Use of Fragments in Medieval Manuscripts in the Construction and Covering of Bindings on Printed Books", in *Interpreting and Collecting Fragments of Medieval Books*, ed. L.L. Brownrigg & M.M. Smith, London 2000, 1–20.

their attention to those fragments that are still located in places where they had originally been applied to reuse, most notably inside book bindings that are still intact.[2] The challenge of accessing these fragments without damaging the structure of the early modern book has led to the experimentation with non-destructive techniques, including macro-XRF scanning, hyper spectral imaging and computed tomography.[3] While these advanced techniques proved relatively successful in gaining access to the medieval manuscript fragments, they are costly and time-consuming. Moreover, the early modern books often need to be relocated from their holding institution to a laboratory with the proper examination facilities; the scanning process for a single book can take up to 24 hours, followed by additional processing of the resulting data to visualize the fragments. This short article reports on a pilot project that explores the potential of a faster, simpler and cheaper solution: endoscopy.

1. FragmEndoscopy: Towards an effective and safe procedure

Endoscopy involves the use of a fiberscope or borescope camera to inspect small, difficult-to-reach places. The technology is used by doctors, e.g. in a bronchoscopy or colonoscopy procedure, as well as by plumbers and car mechanics. Fitted with a light and a mirror, an endoscopic camera can be used to take images within narrow passageways inside the human body, machines and tubing in order to detect deficiencies and damages. The pilot project

2 See, e.g., J.R. Duivenvoorde, A. Käyhkö, E. Kwakkel and J. Dik, "Hidden Library: Visualizing Fragments of Medieval Manuscripts in Early-Modern Bookbindings with Mobile Macro-XRF Scanner", *Heritage Science* 5 (2017), art. 6 (https://doi.org/10.1186/s40494-017-0117-6).

3 Duivenvoorde et al., "Hidden Library"; E. Pouyet, S. Devine, T. Grafakos, R. Kieckhefer, J. Salvant, L. Smieska, A. Woll, A. Katsaggelos, O. Cossairt & M. Walton, "Revealing the Biography of a Hidden Medieval Manuscript Using Synchrotron and Conventional Imaging Techniques", *Analytica Chimica Acta* 982 (2017), 20–30 (https://doi.org/10.1016/j.aca.2017.06.016); J.E. Ensley, K.H. Tachau, S.A. Walsh et al., "Using Computed Tomography to Recover Hidden Medieval Fragments beneath Early Modern Leather Bindings, First Results", *Heritage Science* 11 (2023), art. 82 (https://doi.org/10.1186/s40494-023-00912-9).

'FragmEndoscopy' applied this method to early modern books as a minimally invasive way to gain access to medieval manuscript fragments that were used as spine linings.[4] The project took place over the course of the academic year 2023–2024 at Leiden University Library and the Noord-Hollands Archief, Haarlem, under the supervision of conservation staff.[5]

The FragmEndoscopy project experimented with two endoscopic cameras within the price range of 400–600 EUR. The first was a Novascope VS91285HD, a borescope originally intended for cavity wall inspection. This borescope has a side-facing camera (90 degrees), two adjustable LED lights, a diameter of 9 mm and a focus distance of 1–20 cm. While this camera did yield some results, the focus distance in particular was problematic. The second camera used was a Novascope TSNTG500H, a borescope designed for gun barrel inspection. This borescope has a forward-facing camera with five attachable mirrors (for guns of different calibers), six white LED-lights, a diameter of 5 mm and a focus distance of 1–20 mm (with mirrors). With its smaller diameter and focus distance, this camera proved to be much more effective and is the one referred to as the 'FragmEndoscope' in the remainder of this article.

The FragmEndoscopy procedure makes use of the natural mechanics of the binding of the early modern book, which creates a space between the spine (the side of the text block where the pages are connected by sewing) and the spine covering whenever the book is opened (as long as the spine covering is not glued onto the spine). This space is large enough to allow access to the FragmEndoscope with its 5 mm diameter: a representative sample of books of differing formats, opened at an angle of *c.*140 degrees, showed a gap between spine and spine covering with an average width of between 1.5 and 3 cm, depending on the format of the book (octavo, quarto,

4 For the use of an endoscopic camera to record medieval fragments inside musical instruments, see J.-P. Échard and L. Albiero, "Identifying Medieval Fragments in Three Musical Instruments Made by Antonio Stradivari", *Fragmentology* IV (2021), 3–28 (https://www.fragmentology.ms/article/view/stradivari/2831).

5 The authors would like to thank Karin Scheper and Godelieva van der Randen (Leiden University Library) and Julia Owczarska and Hannah Goedbloed (Noord-Hollands Archief, Haarlem) for their assistance and advice.

DOI: 10.24446/h9ht

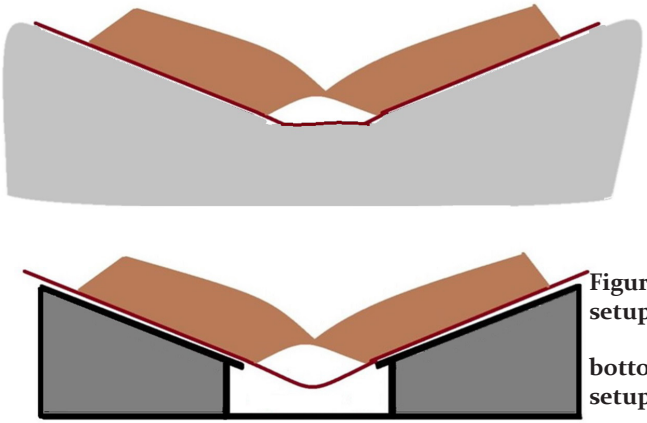

Figure 1, top: FragmEndoscopy setup with a pillow

bottom: FragmEndoscopy setup with slanted foam blocks

folio) as well as the number of pages. The books were supported by a pillow or slanted foam blocks; the latter proved particularly useful in cases where flexible spine coverings were pushed upwards by the pillow, which resulted in a narrower gap [Figure 1].

A number of measures were taken in order to mitigate the risk of damaging the early modern book bindings due to the insertion of the FragmEndoscope. First, we chose to use a rigid rather than a flexible endoscope, since the movement of a flexible endoscope would be harder to control. In addition, the rigid FragmEndoscope was placed on a foam block with a gutter, which made it possible

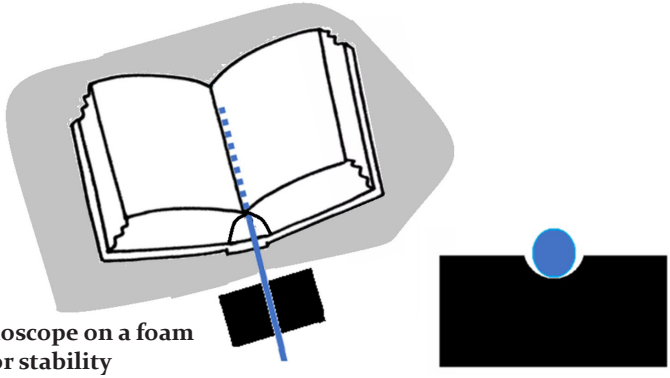

Figure 2: FragmEndoscope on a foam block with gutter for stability

Figure 3: A mirrored photo of part of a spine lining, reading the word 'God'. Leiden, University Library, Special Collections, 617 F 19

to stabilize the camera and further minimize the risk of sudden, uncontrolled movement [Figure 2].

As a preliminary measure, the FragmEndoscope's forward-facing camera was moved gently through the gap between the spine and its covering in order to identify any potential obstructions, such as loose-hanging spine linings, sewing supports, etc.[6] Once it was ascertained that the gap was clear of obstructions and that spine linings with parts of text were present, a mirror was attached to the camera, which allowed recordings to be made at an angle of 90 degrees.

2. Framing the fragments: Basic image manipulation

The FragmEndoscope, once inserted into the gap between spine and spine covering and fitted with a mirror, was able to produce high-quality images of the spine linings. However, due to the minimal distance between the camera and the fragment, single photos of the fragments only showed small parts of the spine lining, often no more than a few letters [Figure 3]. Moreover, given the limited manoeuvrability inside the gap between spine and covering, it was not easy to make consecutive images of the various parts of the spine linings. For these reasons, making a video with the FragmEndoscope

6 For a video of a forward-facing endoscopic camera moving along a book's spine, see: https://youtu.be/39FMuUGuzZk.

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Figure 4: Aligning different screenshots with opacity, difference and perspective settings

hovering across the full spine lining proved a more effective way to obtain an overall view of the fragment. These hovering videos were next edited as follows: the image was mirrored and parts of the video were cut, pasted and reversed so as to show the spine lining's text from left to right and from top to bottom.[7]

This edited video was then used to produce an assemblage of images that gives an overview of the full fragment. For this project, we made use of the web-based photo and graphics editor Photopea, using settings and functionalities that are also available in other imaging software programmes, such as Adobe Photoshop. Screenshots from the video were cleaned up and aligned using different settings, including difference, opacity and perspective [Figure 4]. The latter function was particularly useful in cases where shifting camera angles made it difficult to fully align directly adjacent letters.

These shifting camera angles also caused differences in lighting and colour discrepancies between different screenshots; these

7 For an example of such an edited video, see: https://youtu.be/2MFBK1CYk-s.

Figure 5, top: An assemblage of *c.*20 screenshots before the transitions were softened with photo editing software; bottom: the transition between two screenshots before and after PhotoPea's 'autoblend' function

Figure 6: Assemblage of screenshots representing a spine lining with a Middle Dutch text: "*mijn mont sal voertkundigen dijn lof. God wilt dencke*". Leiden, University Library, Special Collections, 617 F 19

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differences were resolved by manually adjusting the colour saturation of the images or by using PhotoPea's 'autoblend' function [Figure 5]. The end result of this process is an assemblage that produces a full view of the spine lining [Figure 6].

3. Three case studies

The three case studies below demonstrate the value of the results produced with FragmEndoscopy. Each reveals how it is possible to identify the text of spine linings on the basis of the images produced.

3.1. Middle Dutch Book of Hours by Geert Grote

The spine lining reproduced in Figure 6 was one of the subjects of the 2017 article by Duivenvoorde et al., which demonstrated their method of using macro-XRF scanning techniques to make medieval fragments visible. The text, which reads "mijn mont sal voertkundigen dijn lof. God wilt dencke" [my mouth shall proclaim your praise. May God think] was identified by Duivenvoorde et al. as belonging to a manuscript dated to ca. 1400 of the Book of Hours translated by Geert Grote (†1384).[8] A comparison between Figure 4 and the colour reconstruction produced by Duivenvoorde et al. is insightful.[9] On the one hand, it demonstrates the accuracy of their reconstruction on the basis of their macro-XRF scans; on the other, it reveals how the FragmEndoscopy reconstruction shows less interference from chemical elements on the back of the spine lining and, therefore, produces a more legible result, which is particularly clear in the case of the capital *G*.

3.2. Two fragments with musical annotation: *Versus alleluiaticus*

Two spine linings were recorded inside Haarlem, Noord-Hollands Archief, 165 G 5. They were cut from the same leaf and show text in a fourteenth-century Gothic hand with musical notation.[10] A search in *The Gregorian Repository* suggests that this could be a

8 Duivenvoorde et al., "Hidden Library".

9 For their colour reconstruction of this spine lining, see https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-017-0117-6/figures/7

10 An edited video of both spine linings is available at https://youtu.be/DLOzRVhR1uw.

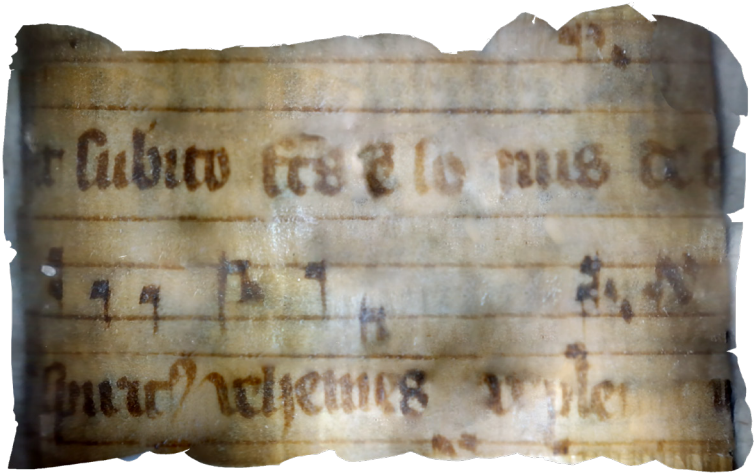

Figure 7: Assemblage of screenshots representing a spine lining with musical notation. Haarlem, Noord-Hollands Archief, 165 G 5

version of the *versus alleluiaticus* from a Gradual,[11] the text of which is given below with the parts in bold representing the writing on the spine linings:

> Dum **complerentur die**s Pentecostes,
> erant **omnes pariter** dicentes : alleluia :
> et **subito f(ac)t(u)s e(st) sonus de c**aelo, alleluia,
> tamquam spiri**t(us) veheme(n)s repleu**it totam domum.[12]

One particular difficulty in creating the assemblage [Figure 7] for these spine linings on the basis of the recorded video was the musical notation, which was hard to reproduce given both the curvature of the spine lining and the limited manoeuvrability of the FragmEndoscope within the gap between the spine and its covering. In order to achieve straight lines for the musical notation, the perspective

11 https://gregorien.info/chant/id/2498; https://cantusindex.org/id/g01112.1. Alternatively, it might be the Responsory for Matins for Pentecost Sunday, from an Antiphonal, https://cantusindex.org/id/006536. We are grateful to the peer reviewers for pointing out this alternative possibility.

12 https://gregorien.info/chant/id/2498/0/en

DOI: 10.24446/h9ht

of some of the screenshots in the assemblage had to be adjusted, resulting in a slightly blurrier image.

3.3. Middle Dutch translation of Henrico Suso's *Hundert Betrachtungen und Begehrungen*

The challenge offered by the spine lining reconstructed for the final case study [Figure 8] is the fact that it was somewhat creased and partly obscured by the endband and tie-downs.[13] Moreover, the spine lining turned out to be cut vertically from a manuscript page, which means that most of the visible words are incomplete. In spite of these difficulties, we were ultimately able to identify this text as a Middle Dutch version of Henrico Suso's *Hundert Betrachtungen und Begehrungen*, e.g. by postulating that the sequence "Pyla" could be expanded to "Pylatus" [Pilate]:

> Eya ewege waerheit heere ihesus, ic ver**mane u he**den der scameliker noet die u [sali]**ghe siele l**eet, doen ghi waert **voer Pyla**tus **scandelike(n)** gebrocht, **valschelik**e gewroecht **en(de) ter scand**eliker doot **sonder** scout be**wijst**.[14]

The script is a textualis script that allows us to date this manuscript to the fifteenth century.

Conclusion

The three case studies presented above demonstrate that the FragmEndoscopy procedure effectively allows for the identification

13 For an edited video of this spine lining, see https://youtu.be/hN_IPOom96k.

14 Bold text represents one of the spine linings in Haarlem, Noord-Hollands Archief, 157 M 4. The rest of the text is from the Middle Dutch version of Henrico Suso's *Hundert Betrachtungen* edited in *Middelnederlands geestekijk proza*, ed. C.C. de Bruin, Zutphen 1940, 115. That version of the text does not contain the word "salighe"; this word is reconstructed on the basis of an alternative version edited in Jose van Aelst, *Passie voor het lijden: De Hundert Betrachtungen und Begehrungen van Henricus Suso en de oudste drie bewerkingen uit de Nederlanden*, Leuven 2015, 282–283: "*O ewige waerheit, heer Jhesus, ic vermane di huden der scameliker noet die dijn salighe ziele leet, doe du wordes over Pylatus ghebrocht, valschelic ghewroecht ende ter scameliker doet sonder schout verwijst*."

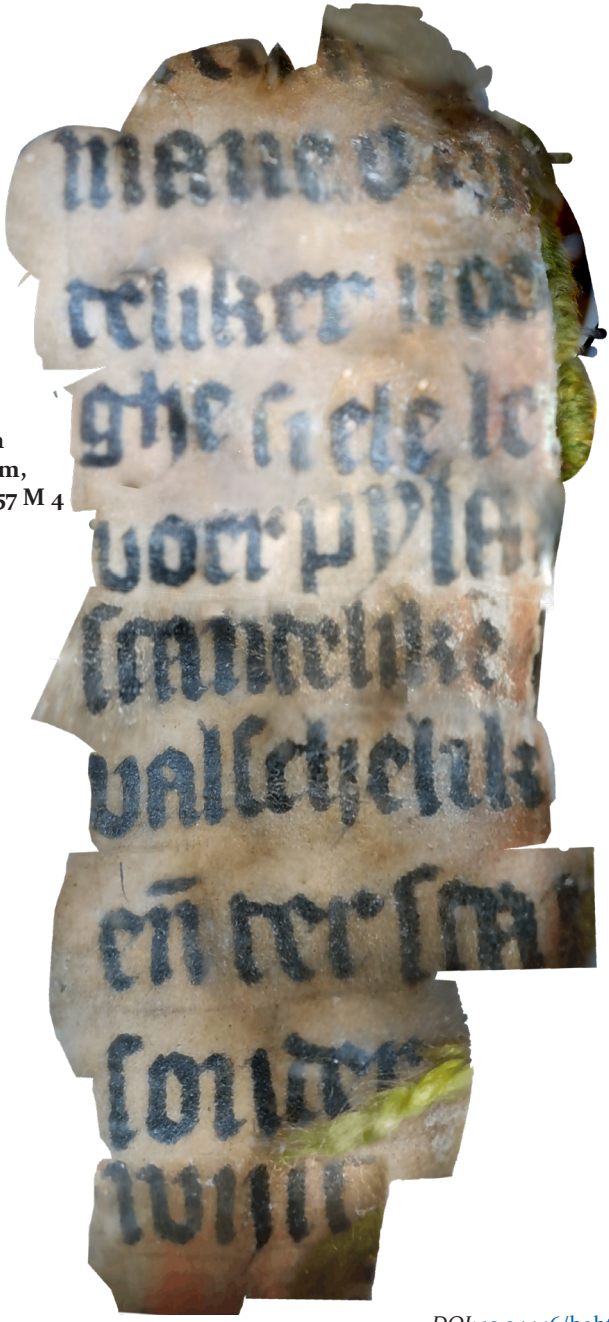

Figure 8: Spine lining with Middle Dutch text. Haarlem, Noord-Hollands Archief, 157 M 4

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of text and dating of spine linings inside intact early modern books. Compared to more complex techniques with special scanning equipment, FragmEndoscopy is not only relatively affordable (400–600 EUR), it is also time-efficient: the recordings were made within minutes on location; the basic image manipulation per fragment took no longer than two hours. This particular pilot project was run with minimal means; it is to be expected that higher-quality endoscopic cameras and editing software will yield even better results, both in terms of image quality and time efficiency. The ease of detection of hidden fragments, offering the possibility to make a relatively quick preselection from a series of books for further investigation, adds to the value of the ensdoscopic camera. As a non-destructive way to identify the presence (and nature) of medieval manuscript fragments inside book spines, FragmEndoscopy could also be used as a preliminary identification procedure, before more advanced scanning techniques are applied. These techniques may yield better results for parts of the spine linings that are hard to record with an endoscopic camera, such as the outer edges of the spine linings and the reverse side of the fragment. Overall, we conclude that the endoscopic camera could be a promising new weapon in the arsenal of the fragmentologist.

Funding statement

This publication is part of the project "FragmEndoscopy: An Innovative Way to Discover Hidden Heritage inside Early Modern Book Bindings" with file number 406.XS.01.006 of the research program OC-XS which is (partly) financed by the Dutch Research Council (NWO).