Artists' Paper

A Case in Paper History

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Content

Annex

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LEOcode Goes Live: A Dynamic Resource for Paper Studies

Abstract

LEOcode (leocode.org) is a free, web-based resource that presents the results of detailed encoding and visualization of three internal manufactured patterns found in the papers contained in two notebooks by Leonardo da Vinci (1452–1519): watermarks, chain line intervals, and laid line densities. Moving beyond Leonardo's papers, LEOcode provides easy-to-learn computational tools that can be used by anyone wishing to precisely characterize pre-machine European papers.

Computational "coding" is the process whereby a researcher examines and transforms a digital image of the watermark and chain lines in a sheet of paper into a numerical code that can be compared to codes derived from other papers. Computational coding is straightforward and uses readily available digital photographs of the recto and verso and a transmitted light digital photograph of the paper in question. The scale and resolution of the images do not need to be the same. The procedure involves:

- enhancement or "de-noising" of the paper's internal structure (watermarks, chain line intervals, laid line densities) by the virtual removal of surface writing and drawing,
- marking and measurement of unique watermark features and chain line intervals and the generation of the codes,
- comparison and matching of the codes to identify paper mouldmates and their probable twins.

The results of coding, i. e., mouldmate matches, can be presented via static visualization graphs or by animated overlays. Dynamic looping videos take advantage of the close looking skills of users and allow for individual decision-making. Sharing the videos via traditional scholarly journals, however, is problematic due to their temporal nature.

LEOcode describes other aspects of the project, and also includes rapid recognition line drawings for each mouldmate group, every watermark type found in and shared between the two notebooks, and a growing accumulation of animated overlays. In addition, instructions for the use of the software suite are available to researchers. The authors hope that increasing interest in the software will encourage future collaborations.

Keywords: *watermarks, mouldmates, Leonardo da Vinci, animations, chain lines, laid lines.*

LEOcode (leocode.org) est une ressource Web gratuite qui présente les résultats de l'encodage détaillé et de la visualisation de trois éléments de fabrication internes trouvés dans les papiers à la forme de deux cahiers de Léonard de Vinci (1452–1519): les filigranes, l'intervalle des fils de chaînette, et la densité des vergeures. Au-delà des papiers de Leonardo, LEOcode fournit des outils de calcul faciles à maitriser qui peuvent être utilisés par toute personne souhaitant caractériser avec précision les papiers européens pré-industriels.

Le « codage » informatique est le processus par lequel un chercheur examine et transforme l'image numérique du filigrane et des fils de chaînettes dans une feuille de papier en un code numérique qui peut être comparé aux codes dérivés d'autres papiers. Le codage informatique est simple et s'appuie des photographies numériques facilement disponibles du recto et du verso et sur une photographie numérique en lumière transmise du papier en question. L'échelle et la résolution des images n'ont pas besoin d'être les mêmes. La procédure implique :

- l'amélioration de l'image de la structure interne du papier (filigranes, intervalles des fils de chaînettes, densité des vergeures) par la suppression virtuelle de l'écriture et du dessin de surface,
- le marquage et la mesure des caractéristiques uniques du filigrane et des intervalles des fils de chaînette et création des codes,
- la comparaison et l'assortiment des codes pour identifier les forme d'origine (mouldmates) du papier et leurs probables formes jumelles.

Les résultats du codage, c'est-à-dire les correspondances de formes, peuvent être présentés via des graphiques de visualisation statiques ou par des superpositions animées. Les vidéos en boucle dynamique font appel aux compétences et à la capacité d'observation de près des utilisateurs. Leur caractère temporel, rend toutefois problématique le partage des superpositions animées via les revues savantes traditionnelles.

Une ressource comme LEOcode permet un engagement et une prise de décision actifs de la part du chercheur. Le site contient des liens vers des informations générales sur les différents aspects du projet, ainsi que des dessins au trait de chaque groupe de «mouldmates», tous les types de filigranes trouvés à l'intérieur des deux cahiers et une accumulation croissante de superpositions animées. De plus, des instructions d'utilisation de la suite logicielle sont incluses et à disposition des chercheurs. Les auteurs espèrent que l'intérêt croissant pour le logiciel engendrera d'avantage de possibilités de collaboration avec d'autres chercheurs.

Mots clé: *filigranes, forme d'origine (mouldmates), Leonardo da Vinci, animations, fils de chainette, vergeures.*

LEOcode (leocode.org) ist eine kostenlose, webbasierte Ressource, die die Ergebnisse einer detaillierten Kodierung und Visualisierung von drei beim Herstellungsprozess in das Papier eingebrachte Strukturen präsentiert: Wasserzeichen, Abstand der Stegdrähte und Dichte der Rippdrähte. Untersuchungsobjekte hierfür sind zwei Notizbücher von Leonardo da Vinci (1452–1519). Über Leonardos Papiere hinausgehend bietet LEOcode für jedermann einfach zu erlernende computergestützte Werkzeuge an zur präzisen Analyse europäischer Papiere aus der Zeit vor der maschinellen Herstellung.

Bei der computergestützten „Kodierung" wird ein digitales Bild des Wasserzeichens und der Kettlinien eines Papierblattes in einen numerischen Code umgewandelt, der mit Codes von anderen Papieren verglichen werden kann. Computergestützte Kodierung ist unkompliziert und greift hier auf verfügbare digitale Aufnahmen der Vorder- und Rückseite des Papiers sowie eine digitale Durchlichtaufnahme zurück. Maßstab und Auflösung der Bilder müssen nicht identisch sein. Das Verfahren umfasst:

- eine Verbesserung hinsichtlich der Sichtbarkeit der Papierstruktur (Wasserzeichen, Kettenlinienintervalle, Rippkettendichte) durch virtuelle Entfernung der Oberflächenschrift und -zeichnung,
- die Markierung und Messung von eindeutigen Wasserzeichenmerkmalen und Kettlinienabständen des Weiteren die Generierung der Codes, sowie
- den Abgleich der Codes zur Identifizierung der Papiermarken und ihrer wahrscheinlichen Zwillingsmarken.

Die Ergebnisse der Kodierung, also Übereinstimmungen der Herstellungsmerkmale, können durch statische Visualisierungsgraphen oder durch animierte Overlays dargestellt werden. Dynamische Looping-Videos erlauben dem Nutzer eine genaue Analyse. Die nur temporäre Verfügbarkeit animierter Overlays macht eine Publikation in herkömmlichen Fachzeitschriften jedoch problematisch. Eine Ressource wie LEOcode ermöglicht eine aktive Beteiligung und Entscheidungsfindung seitens des Nutzers.

Die Website enthält Links zu allgemeinen Informationen über das Projekt sowie Strichzeichnungen jeder Schöpfsieb-Gruppe, jedes Wasserzeichentyps, der in den beiden Notizbüchern zu finden ist, und eine wachsende Anzahl animierter Overlays. Darüber hinaus sind Anleitungen für die Nutzung der Software enthalten, die den Nutzern zur Verfügung stehen. Die Autoren erhoffen sich durch das wachsende Interesse an der Software mehr Kooperationsmöglichkeiten mit weiteren Fachleuten.

Schlagworte: *Wasserzeichen, Schöpfsiebe, Leonardo da Vinci, Animationen, Stegdrähte, Rippdrähte.*

1 Introduction

Over the past decade, a team of researchers has worked together to identify historic papers formed from the same papermaking mould through the application of novel software tools. The procedure was preceded by C. Richard Johnson, Jr., William A. Sethares, and Margaret Holben Ellis's investigations into the presence of mouldmates among the papers of Rembrandt's prints, in the Chain Line Pattern Matching Project (CLiP), using the positioning of chain lines.[1] Further software development was undertaken to produce a software capable of clarifying the structural features (watermarks, chain lines, and laid lines) in transmitted light images from Leonardo da Vinci's (1452–1519) Codex Leicester (Gates Collection).[2] Working with images shared by the British Library, papers from Leonardo's Codex Arundel (MS 263, British

1 "Mouldmates" is a term describing papers formed with the same papermaking mould, first introduced in Johnson et al. (2015); see also Johnson et al. (2017).

2 Sethares et al. (2020).

Library) were next studied using an expanded suite of programs, that analyse multiple paper features in tandem.[3] As the field of digital humanities expands, these remote software-aided archaeological investigations of paper open new avenues of discovery, while accommodating established connoisseurship traditions.

Margaret Holben Ellis, C. Richard Johnson, Jr., and William A. Sethares dubbed the process of this software-aided identification of mouldmates "computational coding."[4] The term encompasses a user-driven process that compares ratios of measurable points found in watermarks, chain lines, and laid lines in two sheets of paper in order to determine how likely it is that they were formed on the same papermaking mould. The process begins with the images, which are marked using the software tools, and ends with the comparison of ratios – or codes – generated from the process. The team has determined numerical thresholds that correspond with these processes, that can suggest or discount mouldmate status.

One of the final software developments from the team produces superimposed videos in .GIF format by a user-driver point matching process.[5] These videos, also called animated overlays, fade from an image of a watermark in one paper to the watermark in another, aligned to make their similarity or difference visually apparent. These videos allow for a final visual confirmation and documentation of mouldmate status. They also take advantage of the close looking skills of users and allow for individual decision-making. While theoretically this dynamic evidence could be widely useful to a larger scholarly community, videos are difficult to share via traditional print-based scholarly publications. Therefore, an online resource was implemented thanks to generous funding from the Getty Foundation: LEOcode.org. The website features downloadable images and videos from the coding process of papers from Leonardo's Codex Leicester and Codex Arundel. Other resources available on the site, including links to download the computational coding software, are intended for use not only by Leonardo

3 Holben Ellis et al. (2021).

4 Ibid.

5 Johnson et al. (2021).

scholars, but any party interested in the critical study of establishing mouldmate status from images of historic papers.

2 The Codices

The circumstances surrounding the original compilation of Leonardo's extant notebooks is, in many cases, uncertain. After his death, many of his papers were grouped and bound together, sometimes arbitrarily. Scholars of the artist's brilliant and singular mind have long attempted to understand the context of his notebooks' creation, by analysing their contents, binding evidence, and collation.[6] This legacy of scholarship provided the foundation on which to build a study of the actual papers found in the Codex Leicester and Codex Arundel in particular.

The Codex Leicester (The Gates Collection), is currently disbound; hence its untrimmed folio format made it possible to image the structural features made by entire paper moulds in transmitted light. Leonardo's dense manuscript notations and schematics on both sides of the eighteen sheets of the notebook detail his observations on fluid dynamics. In addition, it is one of the few of his notebooks that may have survived reordering after his death, making it a likely candidate for the discovery of mouldmates. Leonardo's dense, closely spaced writing obscures the paper features to such a degree that the watermarks are difficult to discern via transmitted light.

The Codex Arundel (The British Library) comprises a much larger collection of the artist's papers in a smaller quarto format. The 285 folios are also disbound and have been imaged in transmitted light. Unlike the Codex Leicester, which finds watermarks in the center of the page due to its folio format, the quarto format of the Codex Arundel finds watermarks in the gutter, or fold, of approximately half of the bifolia. These sections of the notebooks typically received little writing and, therefore, reveal more details of the watermarks.

6 Pedretti/Vecce (1998), Pedretti (1987), see also Bambach (2019) and Barone (2019).

3 The Computational Coding Process[7]

The steps for computational coding are:

- Enhance ("de-noise") the watermark, chain, and laid lines by virtually removing the writing or drawing that appears on the surface of the paper (currently in active development);
- Mark, measure, and report in ratios specific features of the watermark and chain line intervals;
- Map the laid line density patterns (currently in development);
- Compare and match the watermarks and chain line intervals to identify mouldmates;
- Create animated overlays of watermarks for visual confirmation.

Not every one of these steps is required but taken together, can confirm mouldmates with a high degree of certainty.

The first step of "de-noising" images of paper in transmitted light by subtracting media captured in regular illumination has precedence in a variety of digital techniques.[8] As opposed to other techniques such as radiography or rubbings, de-noising provides a safe, remote method to review the structural features of the papers through the use of imagery already extant and made available by the owners of both codices.[9]

Computational coding was applied to de-noised images from the Codex Arundel and Codex Leicester. First, the watermarks were marked using a program called watermarkMarker. This program allows the user to select a number of distances between elements in the watermark, in sequence. This program measures the distances between two points selected, and outputs an image of the distances measured on the watermark, alongside a table of ratios comparing their lengths. Before marking and comparing another watermark, it is important to orient images in the same position; if there are multiple "correct" orienta-

7 The software resources discussed in this section and available on LEOcode.org were written and designed by William A. Sethares and C. Richard Johnson, Jr. See also Fucci, Johnson and Sethares, presentation at IPH Congress 2022.

8 van Staalduinen (2006). See also Hornbachner and Köhn, this volume, pp. 484ff..

9 Find a more in-depth description of the process undertaken here in Sethares et al. (2020).

tions, all versions should be analysed. Two watermarks thus processed may be compared numerically with these values.

A complementary program, chainLineMarker, is especially suited for use alongside watermarkMarker. The program begins with the same image, in the same orientation, and this time the user marks the chain lines along a horizontal axis point, which may be lined up against any element of the watermark. Like the previous program, chainLineMarker outputs a table of ratios that may be compared across multiple sheets that are marked similarly. If the distances between chain lines vary widely, then the candidates are not likely to be mouldmates.

Laid line density maps, whose software is still under development, may also illuminate the status of two sheets of paper that may be mouldmates. Images of sufficient resolution allow the program to measure and colour code the distances between laid lines, producing a map that visually represents these distances through shades of red and blue. Visually comparing maps of multiple papers may yield similarities or distances that further suggest or discount mouldmate status.

The final pair of software programs, watermarkPointMarker and visualizeOverlays, work in tandem to create the dynamic overlay videos that are the centerpiece of the visual resources on LEOcode.org. In watermarkPointMarker, individual points are selected in sequence by a user on a specific watermark. Easily-locatable points are preferable. If an image is of a partial sheet or watermark, in order to be compared with others, the correct number of each point that exists must be the same as the others; this may be accomplished by selecting "skip point" in the software until the correct number is reached. The output of this program is a set of three files necessary to run the next step of computational coding.

In visualizeOverlays, two watermark images processed as described above in watermarkPointMarker are selected to produce an overlay video. The user may specify whether to keep the points visible in the final animation, and the speed at which the animation should run. In order for this to load properly, all three files from watermarkPointMarker must be in the same file (directory), and the user must indicate for visualizeOverlays to look in that directory.

The computational coding process as described above was applied strategically to papers in the Codex Leicester and Codex Arundel with six most common types of watermarks: “cardinal’s hat”, “flower”, “eagle”, “bull’s head”, “scissor”, and “horn”. Multiple sets of mouldmates were found in each watermark type, and are detailed and named in Tab. 1.

Watermark Type	Group	Occurrence
Cardinal’s Hat	A	Leicester Sheet 9
		Leicester Sheet 10
		Leicester Sheet 11
		Leicester Sheet 12
		Leicester Sheet 13
		Leicester Sheet 16
		Arundel ff. 208–209
	B	Leicester Sheet 14
		Leicester Sheet 15
		Leicester Sheet 17
		Leicester Sheet 18
	C	Arundel ff. 1–14
		Arundel ff. 3–12
		Arundel ff. 7–8
		Arundel ff. 22–23
		Arundel f. 26
		Arundel f. 30
	D	Arundel ff. 5–10
		Arundel ff. 20–28
	E	Arundel f. 152
	F	Arundel f. 207

Watermark Type	Group	Occurrence
Flower	A	Leicester Sheet 7
		Leicester Sheet 8
	B	Leicester Sheet 6
	C	Arundel ff. 16–17
		Arundel ff. 173–176
		Arundel ff. 282–283
	D	Arundel ff. 104–107
		Arundel ff. 201–202
		Arundel ff. 212–213
		Arundel ff. 237–242
	E	Arundel ff. 178–179
Eagle	A	Leicester Sheet 1
		Leicester Sheet 2
		Leicester Sheet 4
	B	Leicester Sheet 3
		Arundel ff. 66–67
	C	Arundel ff. 239–240
Bull's Head	A	Arundel ff. 161–168
		Arundel ff. 244.247
		Arundel ff. 279–280
	B	Arundel ff. 36–39
	C	Arundel ff. 109–110
	D	Arundel ff. 177–180
	E	Arundel ff. 197–198
Scissor	A	Arundel f. 18
		Arundel ff. 79–93
		Arundel ff. 81–91
		Arundel ff. 83–89
		Arundel ff. 147–148
		Arundel ff. 271–178
		Arundel ff. 273–276
	B	Arundel ff. 42–43

Watermark Type	Group	Occurrence
Horn	A	Arundel ff. 34–35
		Arundel ff. 122–125
	B	Arundel ff. 146–150

Tab. 1 Inventory of moldmate Groups found in the Codex Leicester and Codex Arundel, organized by Watermark Type

4 LEOcode.org: An Online Compendium

In order to present the findings of the coding process of the papers found in the Codex Leicester and the Codex Arundel, an online compendium, LEOcode.org, was created. The website is meant to be a research tool specific to the study of Leonardo's papers, as opposed to simply a database of watermarks. For example, the entries for the different watermarked papers in Leonardo's codices are organized into mouldmate groups, for example, eagle watermarks formed from the same mould. This organization of the data is meant to be more easily browsable and informative than a standard watermark database format, where each entry is typically grouped according to the watermark type, i. e., all eagle watermarks.

The body of the online compendium consists of a series of scrollable pages, one for each group of mouldmates. Generic information about the group is found in an introductory header section, including a description of the watermark, how it differs from other watermark groups of the same type, and a list of which specific folios from which codices have been found to contain the mouldmates (Fig. 1). Following the header, each specific paper has its own section, including the denoised watermark detail, and any overlays available of the watermark and others of the same type, both mouldmates and non-mouldmates (Fig. 2). These resources are all available to download and be shared by users.

Another way that LEOcode.org differs from a standard watermark database is how the images are accessed. For example, scholars interested in a particular folio in the Codex Arundel can find it listed in the Browse by Source page (Fig. 3). Where images are available, the user can navigate to the relevant page on the website to view de-noised images of the watermark, and any overlay videos. There is also an option to browse by watermark type (Browse by Watermark page; see Fig. 4), which allows for rapid identification of digital tracings of different kinds of watermarks, organized by type (for example, "Cardinal's Hat", "Flower", "Eagle", etc.).

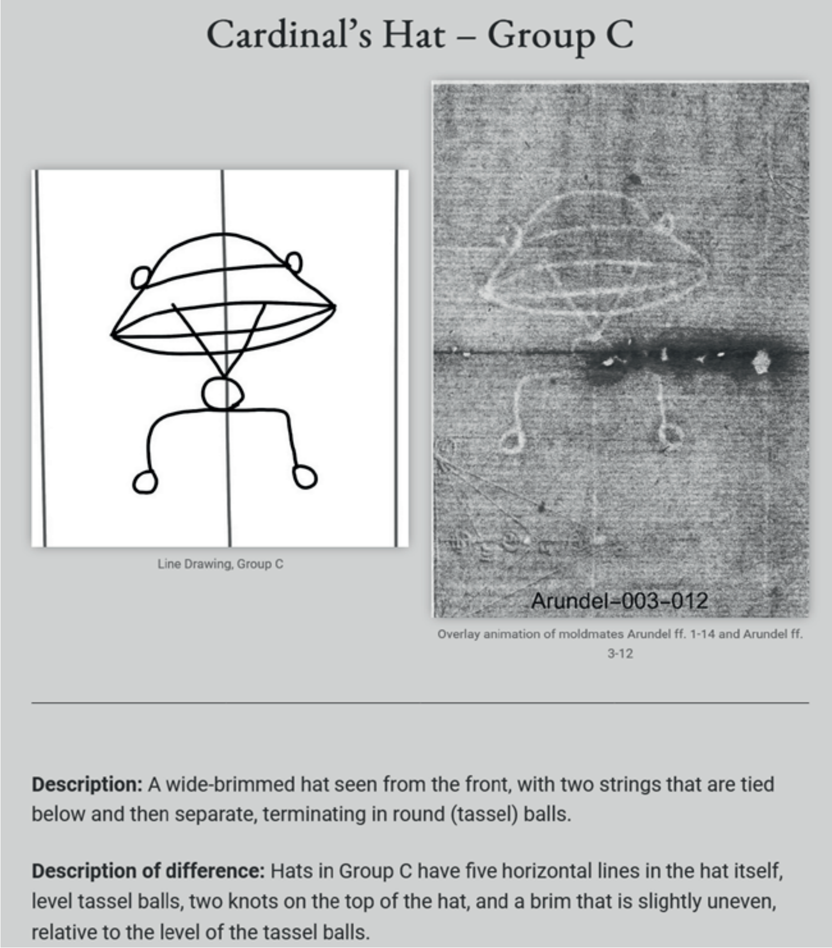

Fig. 1 Screenshots showing the introductory section of the mouldmate group page for Cardinal's Hat-Group C on LEOcode.org, featuring a line drawing for rapid recognition only, a representative animated overlay, and other information.

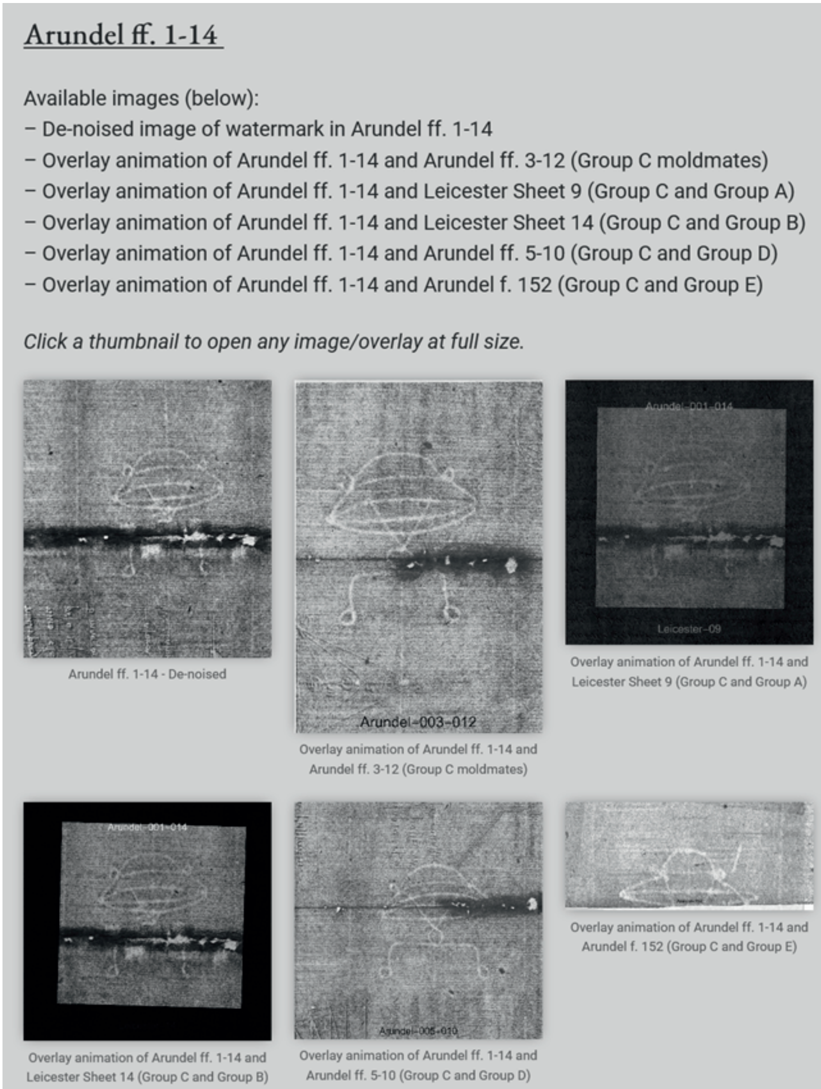

Fig. 2 An example of the individual bifolium section for Arundel ff. 1–14 on the Cardinal's Hat-Group C mouldmates page on LEOcode.org, featuring the de-noised watermark image, as well as overlay animations comparing both mouldmates and non-mouldmates.

The Codex Leicester

Codex Leicester Sheet	Watermark
Leicester Sheet 1	Eagle – Group A
Leicester Sheet 2	Eagle – Group A
Leicester Sheet 3	Eagle – Group B
Leicester Sheet 4	Eagle – Group A
Leicester Sheet 5	Lily, heraldry (see **Others**)
Leicester Sheet 6	Tulip – Group B
Leicester Sheet 7	Tulip – Group A
Leicester Sheet 8	Tulip – Group A
Leicester Sheet 9	Cardinal's Hat – Group A
Leicester Sheet 10	Cardinal's Hat – Group A
Leicester Sheet 11	Cardinal's Hat – Group A
Leicester Sheet 12	Cardinal's Hat – Group A
Leicester Sheet 13	Cardinal's Hat – Group A
Leicester Sheet 14	Cardinal's Hat – Group B
Leicester Sheet 15	Cardinal's Hat – Group B
Leicester Sheet 16	Cardinal's Hat – Group A
Leicester Sheet 17	Cardinal's Hat – Group B
Leicester Sheet 18	Cardinal's Hat – Group B

Fig. 3 The Codex Leicester's section on the Browse by Source page on LEOcode.org, featuring an ordered list of all watermarked bifolia, with corresponding links to their entries on LEOcode.org.

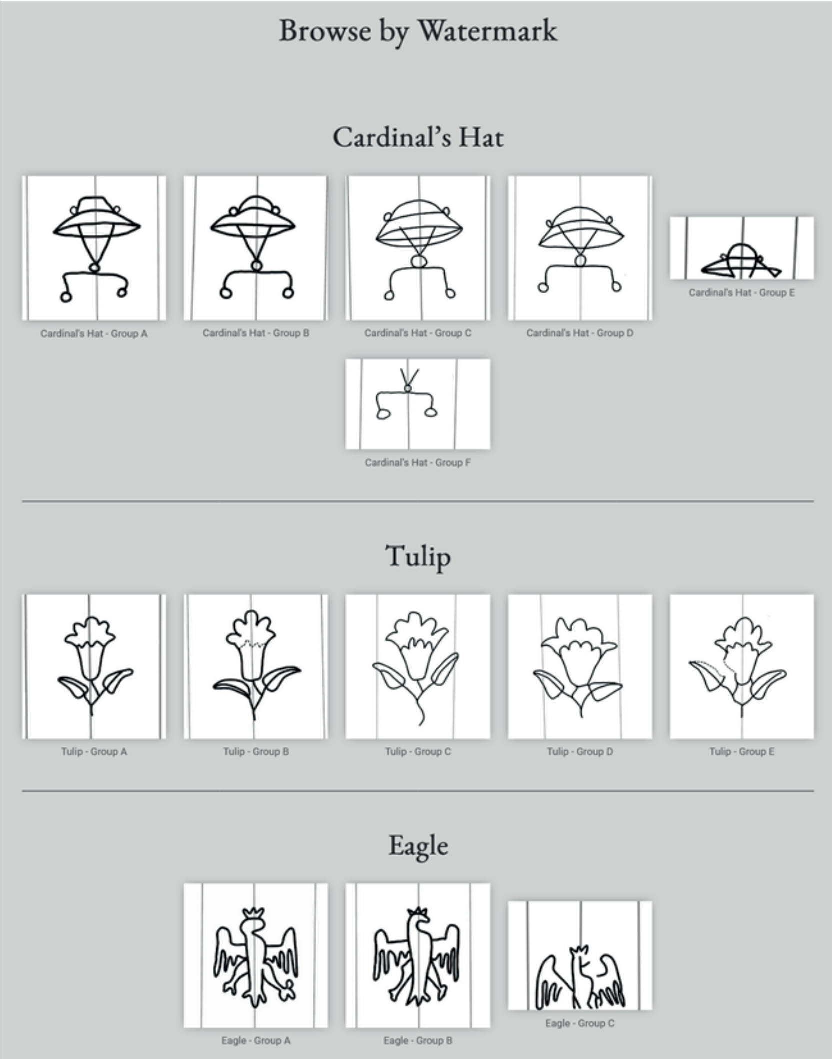

Fig. 4 The Browse by Watermark page on LEOcode.org, featuring rapid recognition line drawings of the most common mouldmate groups found in the Codex Arundel and Codex Leicester.

Finally, a crucial section of the website encourages collaboration with anyone in possession of transmitted light or radiographic images of historic papers. Under the menu option Help Build LEOcode, visitors can find a brief introduction to how the software coding tools may be useful, and different options for professional partnership. Any image with watermarks, chain lines, and laid lines in a sheet of historic paper can be analysed with the software independently of the LEOcode research team. The suite is available to download through a linked GitHub repository, which also contains User Guides for self-guided implementation.[10] When visitors have both standard and transmitted light images of historic papers and require the de-noising process to clarify structural features in the paper, they are encouraged to reach out to the team for tips and possible collaboration. Finally, the team especially welcomes caretakers of other notebooks by Leonardo to share images and work collaboratively to integrate results into LEOcode.[11]

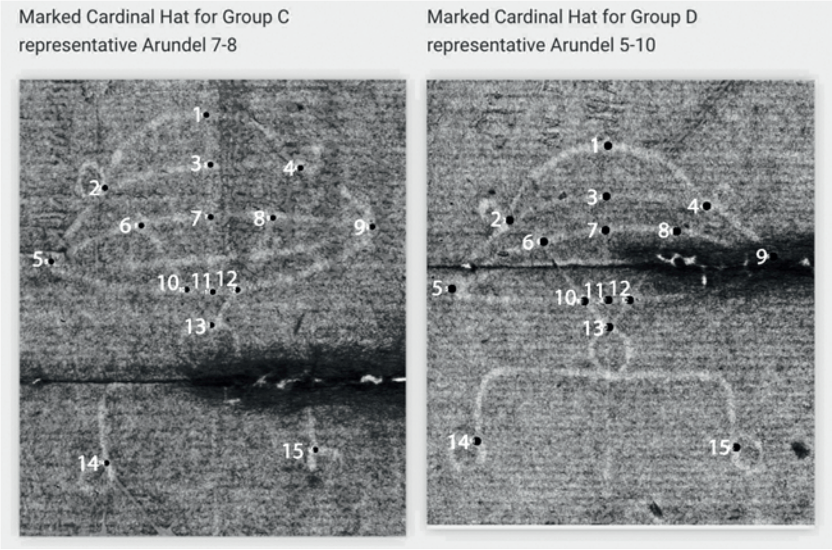

Fig. 5 The Help Build LEOcode section of the website details marking strategies for the six most common watermarks found in the Codex Arundel and Codex Leicester, including for cardinal's hats, as shown here.

10 Find the Github repository for the Paper Studies Suite of computational coding tools and user guides at the following URL: https://github.com/sethares B/PaperStudies.

11 Specific marking strategies are presented for the six watermark types presented on LEOcode.org, for example different cardinal's hat watermarks (Fig. 5). Inquiries for collaboration may be sent directly to contact@leocode.org.

5 Conclusion: New Digital Frontiers

LEOcode.org seeks to make widely available the results of applying a suite of software to characterize the physical properties of papers found the Codex Leicester and the Codex Arundel. The software developed for LEOcode is provided free of charge along with an offer of assistance from the LEOcode team. The project demonstrates the use of the software resources to fulfill two main goals: one, to inspire collaboration among scholars specializing in the study of Leonardo's papers; and two, to provide real-life examples of the usefulness of the software for paper historians, conservators, codicologists, and art historians in other fields. Its online format, which undergoes continuous edits and additions as studies of Leonardo's papers continue, is ideal for accommodating this growing body of work. The broader goal to connect cultural heritage assets through the digital realm represents a greater priority given to increased access and collaboration among institutions and researchers.

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Bibliography

Bambach (2019)	Bambach, Carmen C.: Leonardo da Vinci Rediscovered, 4 vols., New Haven and London 2019.
Baron (2019)	Leonardo da Vinci: A Mind in Motion, ed. by Juliana Barone (exh. cat.), London 2019.
Holben Ellis et al. (2021)	Holben Ellis, Margaret; Sethares, William A. and C. Richard Johnson, Jr.: A Powerful Tool for Paper Studies: The Computational Coding of Watermarked Papers in Leonardo's Codex Leicester and Codex Arundel, in: The Quarterly. The Journal of the British Association of Paper Historians, 119 (2021) July, pp. 1–18.
Johnson et al. (2015)	Johnson, Jr., C. Richard; Sethares, William A.; Holben Ellis, Margaret and Haqqi, Saira: Hunting for Paper Moldmates among Rembrandt's Prints. Chain-line pattern matching, in: IEEE Signal Processing Magazine. Art Investigation, 32 (2015) 4, pp. 28–37 – https://doi.org/10.1109/MSP.2015.2404931.
Johnson et al. (2017)	Johnson, Jr., C. Richard; Sethares, William A.; Holben Ellis, Margaret; Haqqi, Saira; Snyder, Reba; Hinterding, Erik; van Leeuwen, Idelette; Wallert, Arie; Christoforou, Dionysia; van der Lubbe, Jan; Orenstein, Nadine M.; Campbell, Angela and Dietz, George: Chain Line Pattern Matching and Rembrandt's Prints, in: Rembrandt and His Circle: Insights and Discoveries, ed. by Stephanie S. Dickey, Amsterdam 2017, pp. 319–334.
Johnson et al. (2021)	Johnson, Jr., C. Richard; Sethares, William A. and Holben Ellis, Margaret: Overlay Videos for Quick and Accurate Watermark Identification, Comparison, and Matching, in: Journal of Historians of Netherlandish Art, 13 (2021) 2 – https://doi.org/10.5092/jhna.2021.13.2.1.

Pedretti (1987)	Pedretti, Carlo: The Codex Hammer of Leonardo da Vinci, translated into English and annotated by Carlo Pedretti, Florence 1987.
Pedretti/Vecce (1998)	Pedretti, Carlo and Vecce, Carlo: Apparati IV, V, Filigrane, in: Il Codice Arundel 263, nella British Library: edizione in facsimile nel riordinamento cronologico dei suoi fascicoli, Florence 1998, pp. 58–61.
Sethares et al. (2020)	Sethares, William A.; Holben Ellis, Margaret and Johnson Jr., C. Richard: Computational Watermark Enhancement in Leonardo's Codex Leicester, in: Journal of the American Institute for Conservation, 59 (2020) 2, pp. 87–96 – https://doi.org/10.1080/01971360.2019.1703483.
van Staalduinen et al. (2006)	van Staalduinen, Mark; van der Lubbe, Jan C. A.; Laurentius, Frans; Dietz, Georg and Laurentius, Theo: Comparing X-ray and Backlight Imaging for Paper Structure Visualization, in: EVA-Electronic Imaging & Visual Arts, (2006) 4, pp. 108–113.