

Computational Analysis of Medieval Pen Flourishing

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Introduction
Team



University of Applied Sciences St. Pölten

Center for Cultural Heritage Studies
Klosterneuburg Abbey



Florian Kibler
Computer Vision
Researcher



Victor Adriel de Jesus Oliveira
User Interface Researcher



Markus Seidl
Computer Vision Researcher
Project Lead, USTP



Max Theisen
Domain Expert



Martin Haltrich
Project Lead, Klosterneuburg Abbey



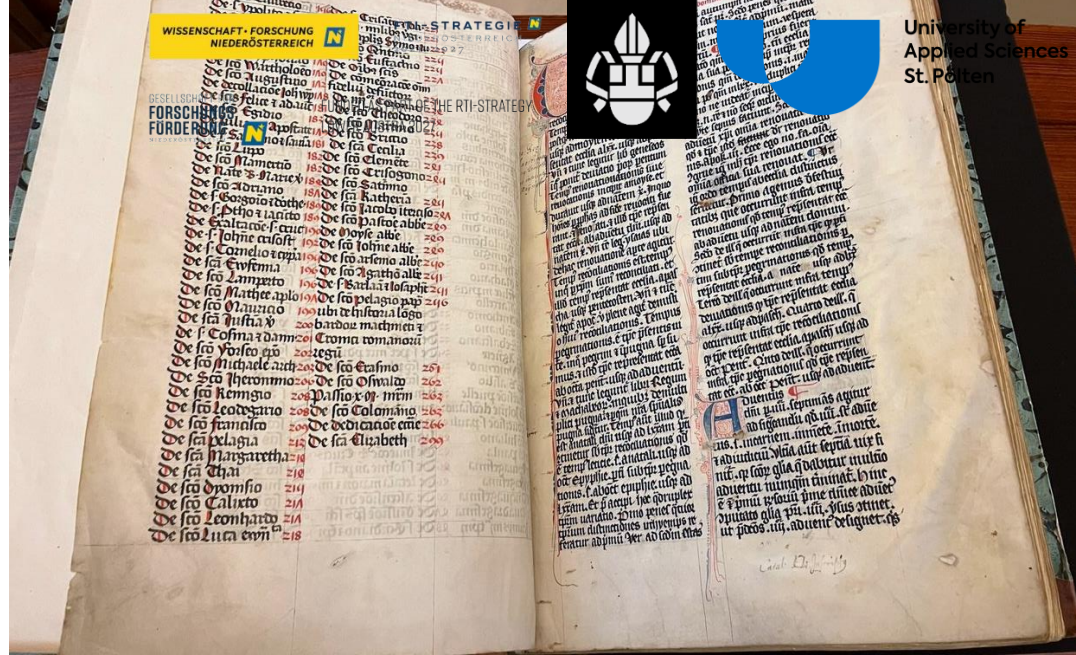
Research Context



Research Context

Medieval Manuscripts and Decoration

Image Source: Klosterneuburg Abbey



- Medieval manuscripts are central cultural assets that not only transmit texts but also communicate through their visual design
- Decorations acted as navigational and aesthetic markers, guiding reading and emphasizing hierarchy or meaning
- Decoration included *painted initials*, *miniatures*, *pen flourishing*, ...



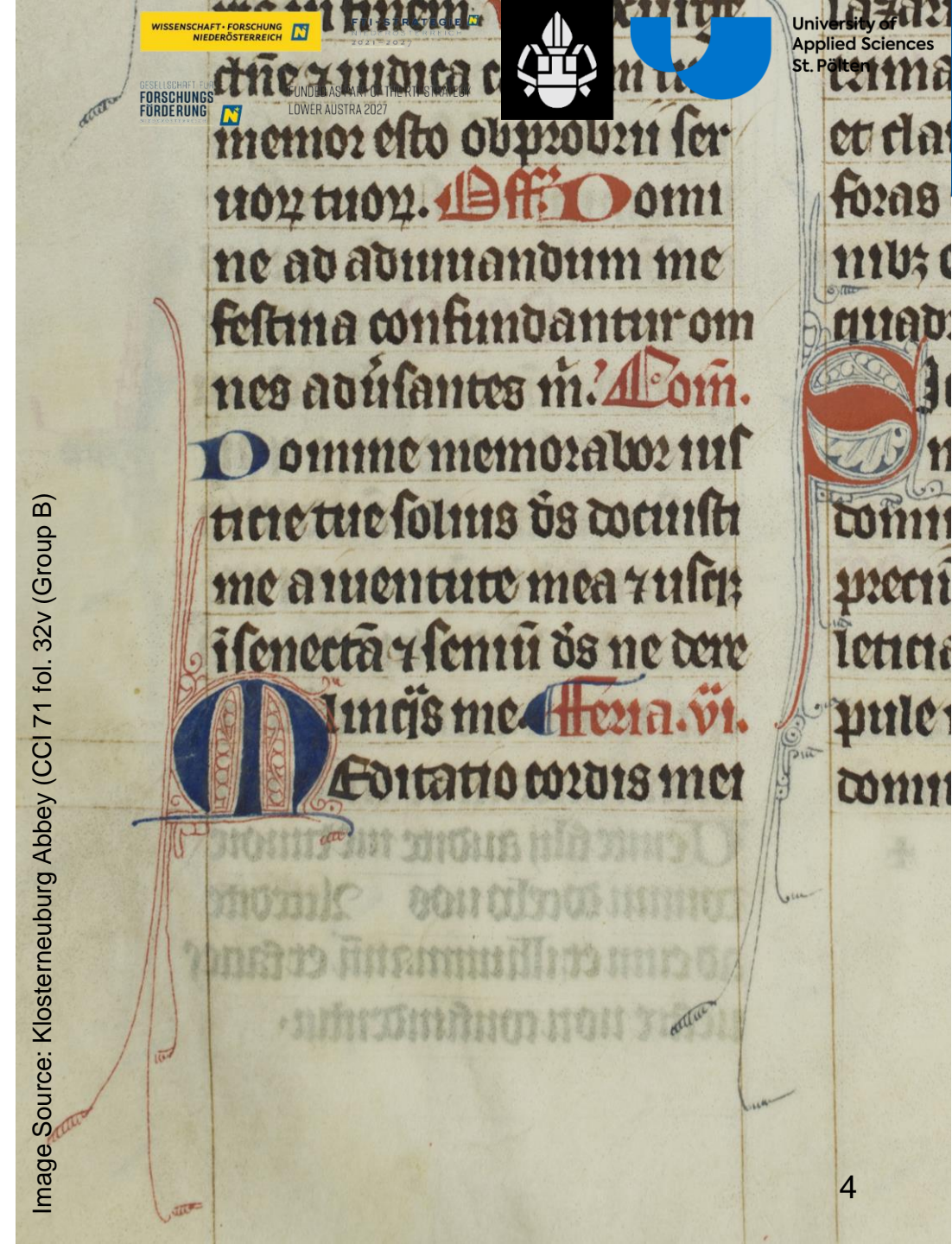
Source: Clementinae, and other text(s) von Clemens V. - Leiden University Libraries, Netherlands - Public Domain.



Source: Klosterneuburg Abbey

What is Pen Flourishing?

- Decorative, floral ornamentation executed in ink (often red/blue) added after text was written
- Pen flourishing can take on highly complex, interwoven shapes
- Carried no narrative meaning, but expressed stylistic identity and workshop practice
- Created by florators (specialized artists)
- Domain experts (art historians) analyze details of the execution to identify *florator groups*
- Identifying groups allows for insight into medieval social structures and monastic networks





Research Context

Challenges and Motivation

- Many manuscripts available, however ...
- Few labeled examples – little ground truth to learn from
- Limited amount of studies on individual florators
- Domain experts face too much data, need help exploring it
- A tool is needed that is **explorative**, **explainable** to foster trust in experts



Image Source: Klosterneuburg Abbey



PeuAFleu

- PeuAFleu is an interdisciplinary research project of the University of Applied Sciences St. Pölten in cooperation with Klosterneuburg Abbey
- Positioned at the Intersection of Digital Humanities and Computer Vision
- Objective: **AI-assisted stylistic analysis of pen flourishing in 13th- and 14th-century medieval manuscripts from the Abbey's library, aimed at grouping penwork stylistically**

Image Sources: Michael Zechany, Klosterneuburg Abbey; USTP



Research Context

Corpus

- Hundreds of Klosterneuburg manuscripts from this time with penwork, few of the ornamental decorations studied
- CCI 71 and 615
 - Missals with lavish decoration
 - Group B is found in both manuscripts
 - Several hundred images with training data
- CCI 73
 - Florator of numerous manuscripts also found in other collections
 - Every image was analyzed and labeled by hand → **Ground Truth!**

CCI 71 Group B



CCI 71 fol. 51r



CCI 71 fol. 67r



CCI 615 fol. 273v

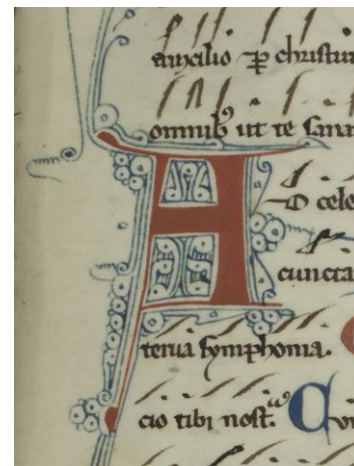
CCI 73 Group A



CCI 73 fol. 7r



CCI 73 fol. 67v



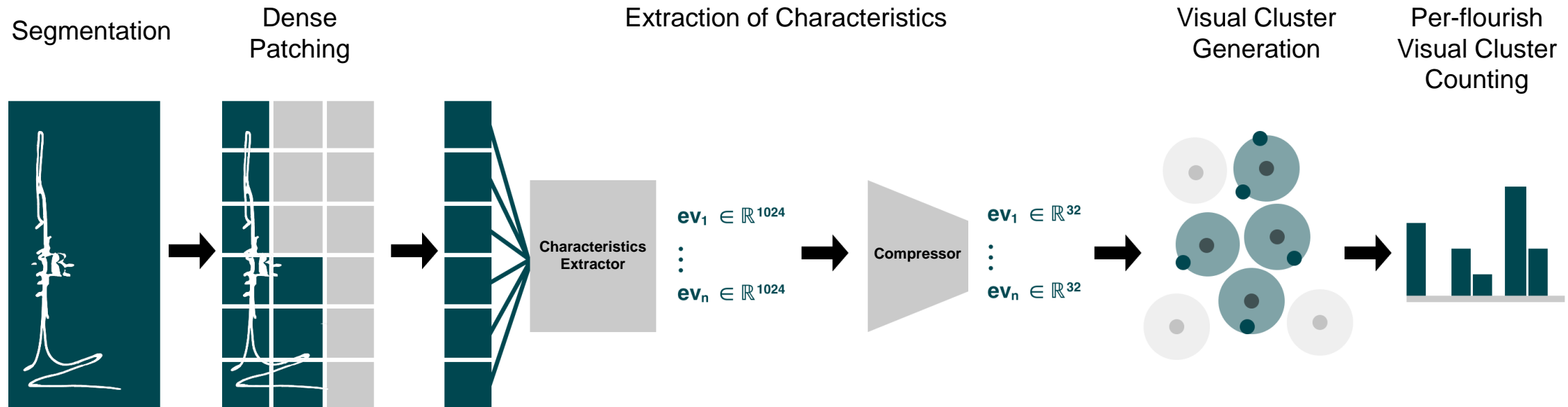
CCI 73 fol. 81r

Image Source: Klosterneuburg Abbey



Technical Approach

Architecture



Architecture

- Scanned in high-resolution (4435px × 5975px)
- Pen flourishing masks created by automated segmentation
- Blur applied to non-flourishing areas
- Pages are split by flourishes

CCI 71 fol. 17v3 (B)



Image Source: Klosterneuburg Abbey

Architecture

- Scanned in high-resolution (4435px × 5975px)
- Pen flourishing masks created by automated segmentation
- Blur applied to non-flourishing areas
- Pages are split by flourishes



Architecture

- Patches extracted from a regular overlapping grid
 - Every patch could represent an important characteristic
 - Accounts for every potentially relevant feature and focusses on local characteristics
- Patches with $>20\%$ pen flourishing foreground (masks) are retained



Patching



CCI 71 fol. 169r1 (71 B) CCI 73 fol. 143v2 (73 C)

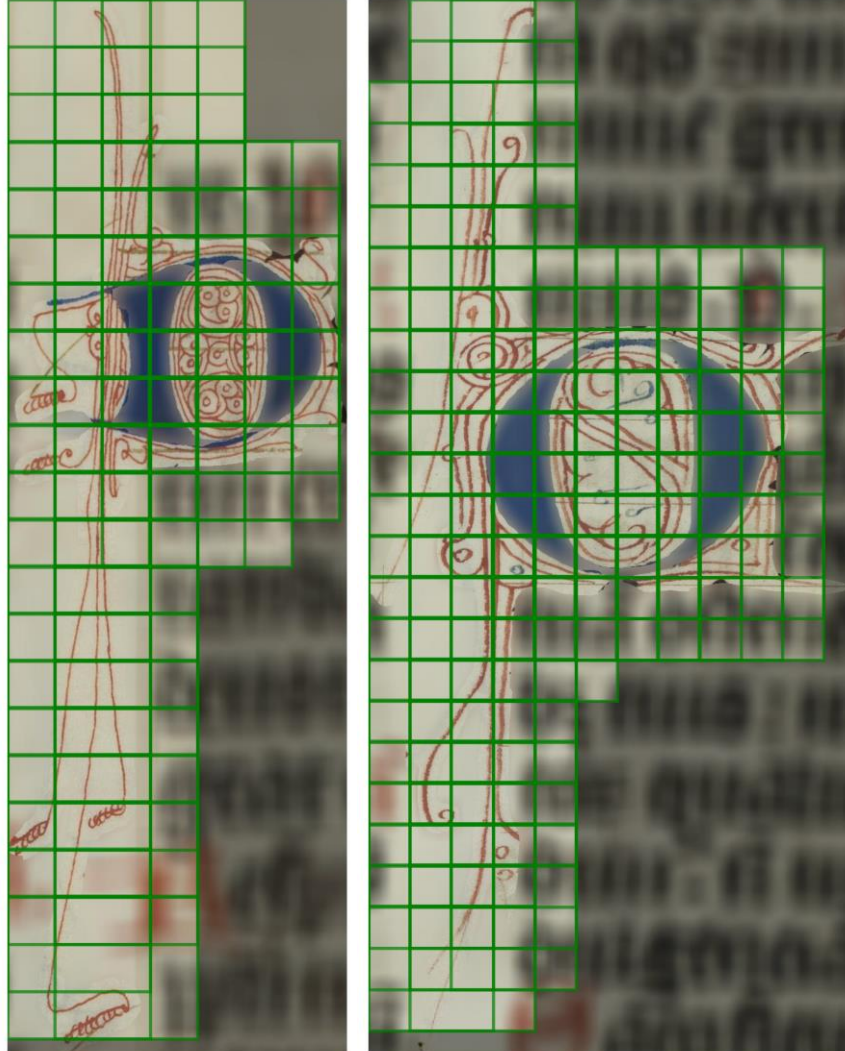


Image Source: Klosterneuburg Abbey

Architecture

- Patches extracted from a regular overlapping grid
 - Every patch could represent an important characteristic
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Approach

Architecture

- Extract characteristics of each patch (DenseNet-121) and compress (custom trained Autoencoder)
- Characteristics could include ...
 - Texture
 - Color
 - Curvature
 - ...
- Not an image anymore but a numerical representation of the characteristics
 - **Assumption: Similar characteristics have similar numerical representations**



$$ev_1 \in \mathbb{R}^{1024}$$

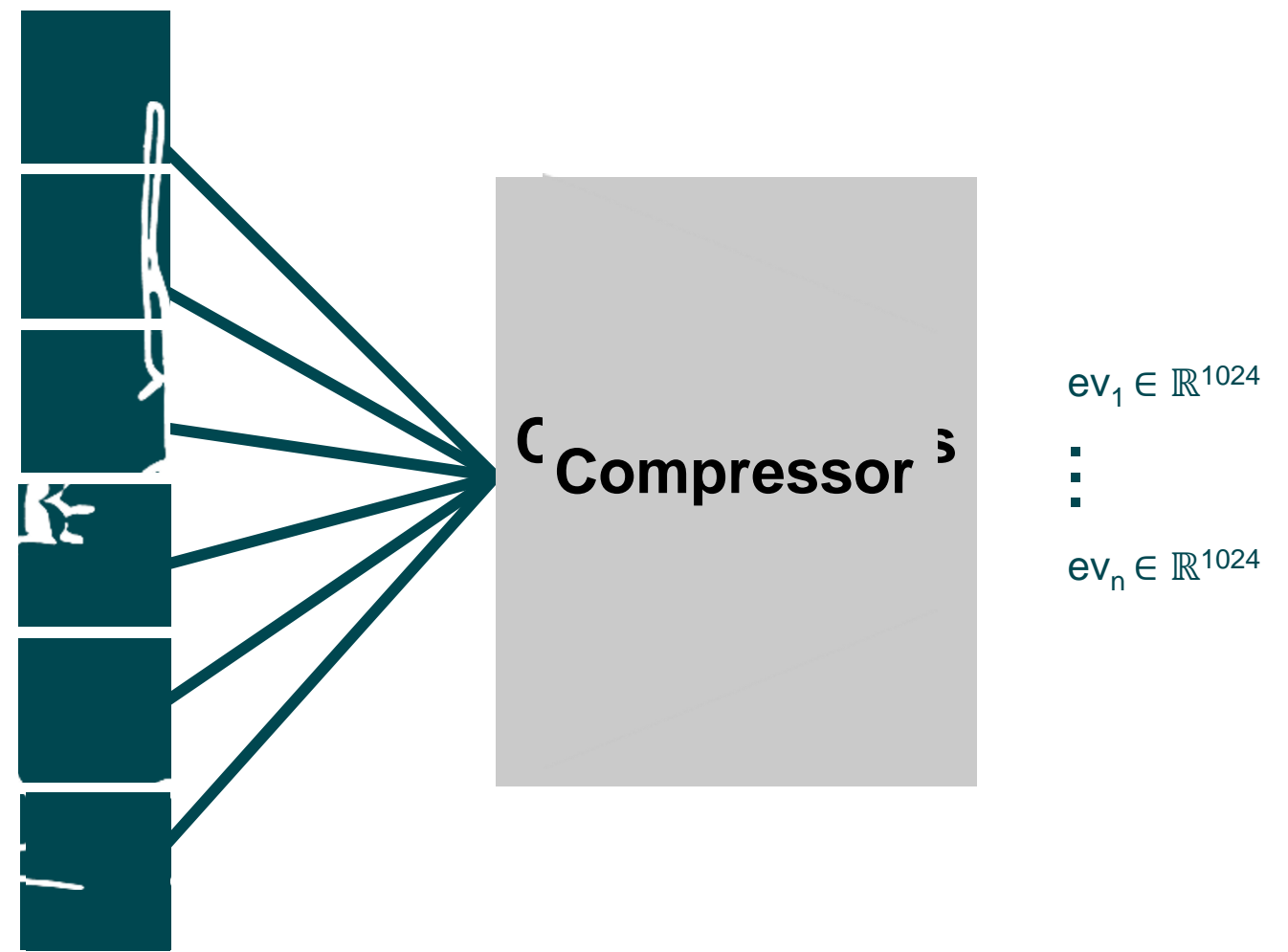
⋮

$$ev_n \in \mathbb{R}^{1024}$$

Approach

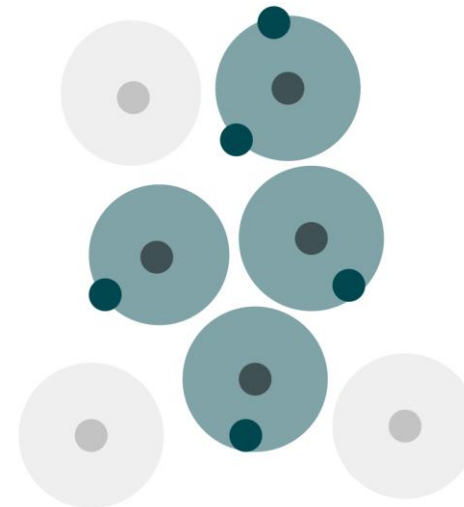
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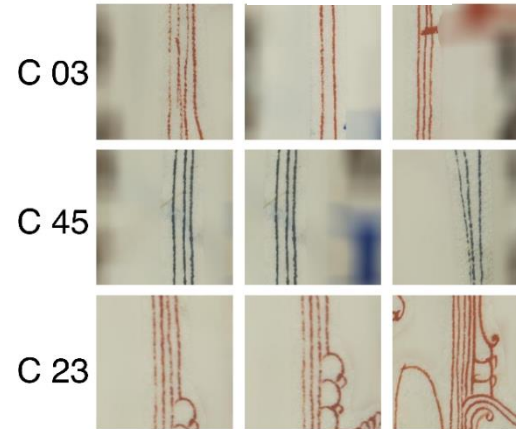
Architecture

- Cluster all patches of the dataset to identify **visual clusters**
- Assign each patch of a given flourish to one of the identified visual clusters
- Count occurrences of different visual clusters to go from many local to one global representation per flourish
- **Assumption: Flourishes with similar visual cluster counts are similar to each other**

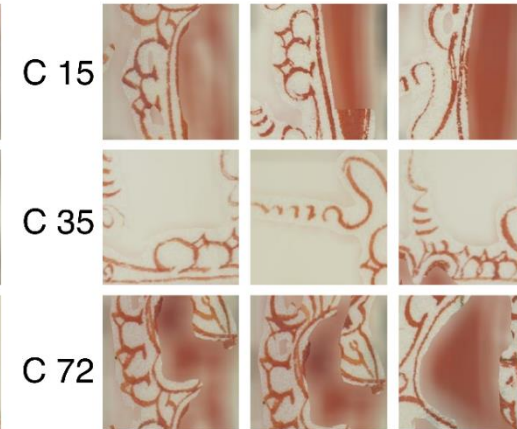


Most relevant visual clusters

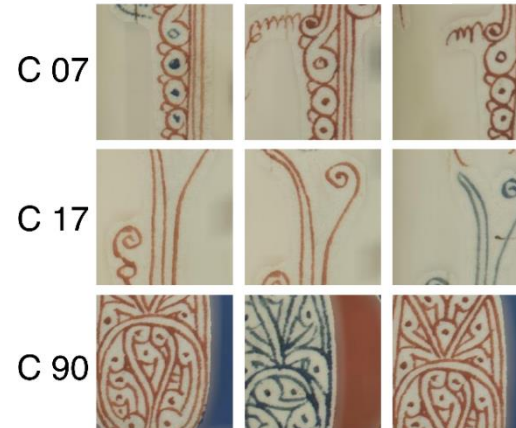
Group 71 B



Group 71 D



Group 73 A



Group 73 C

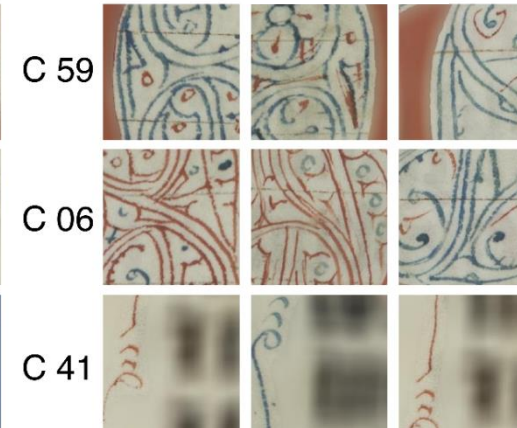


Image Source: Klosterneuburg Abbey

Most relevant visual clusters

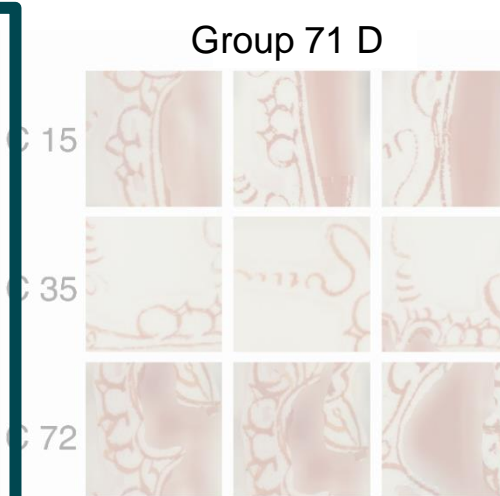
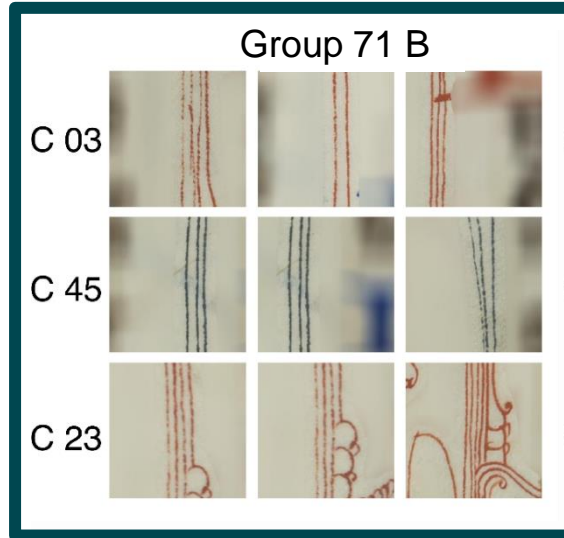
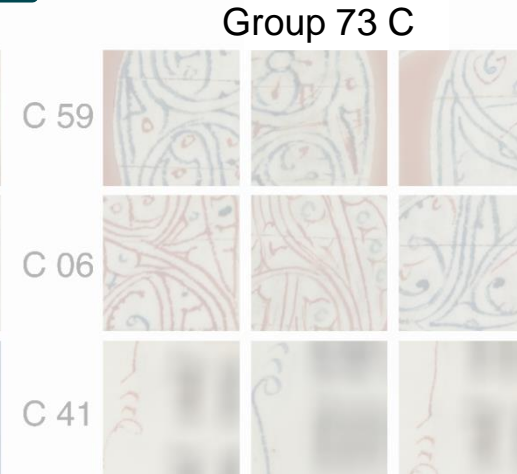


Image Source: Klosterneuburg Abbey



Most relevant visual clusters

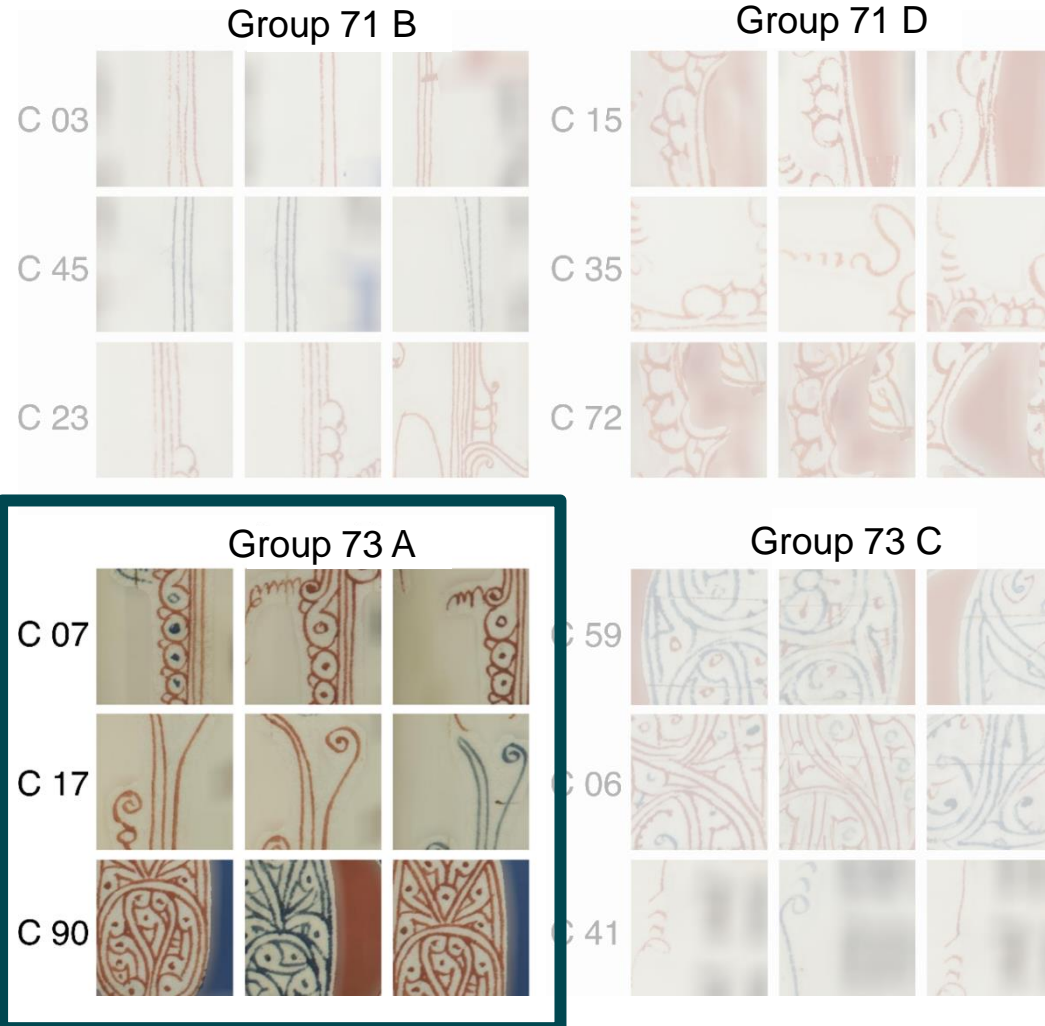
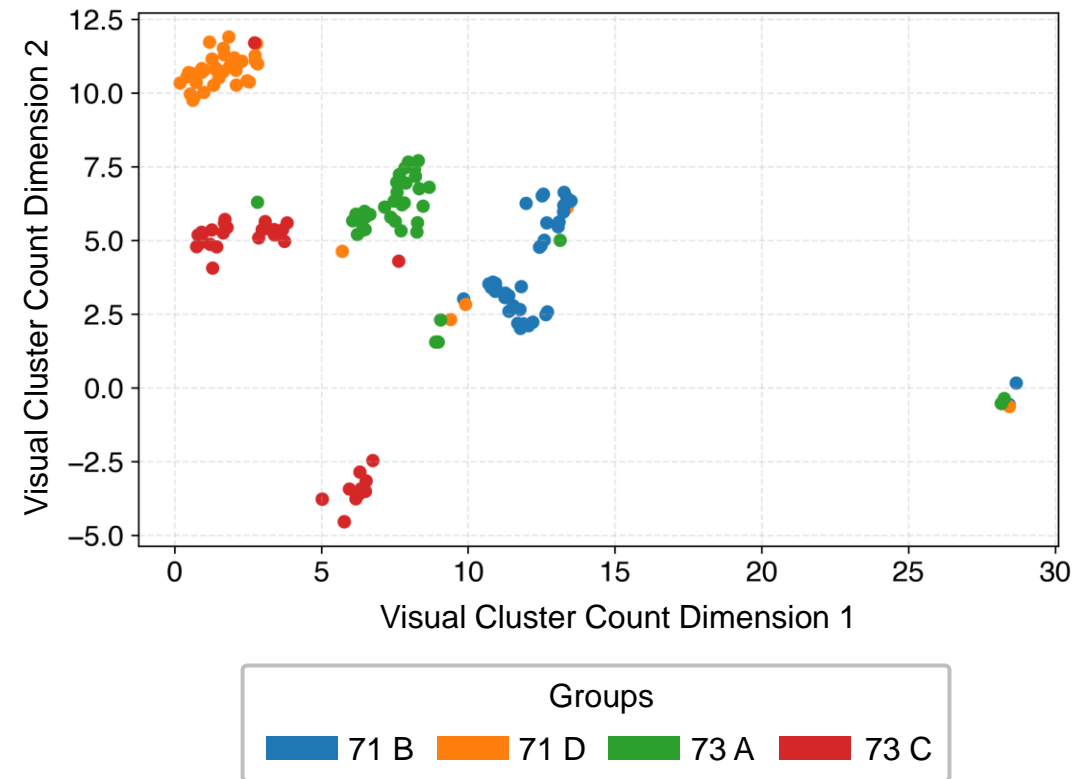


Image Source: Klosterneuburg Abbey

Similarity Visualization

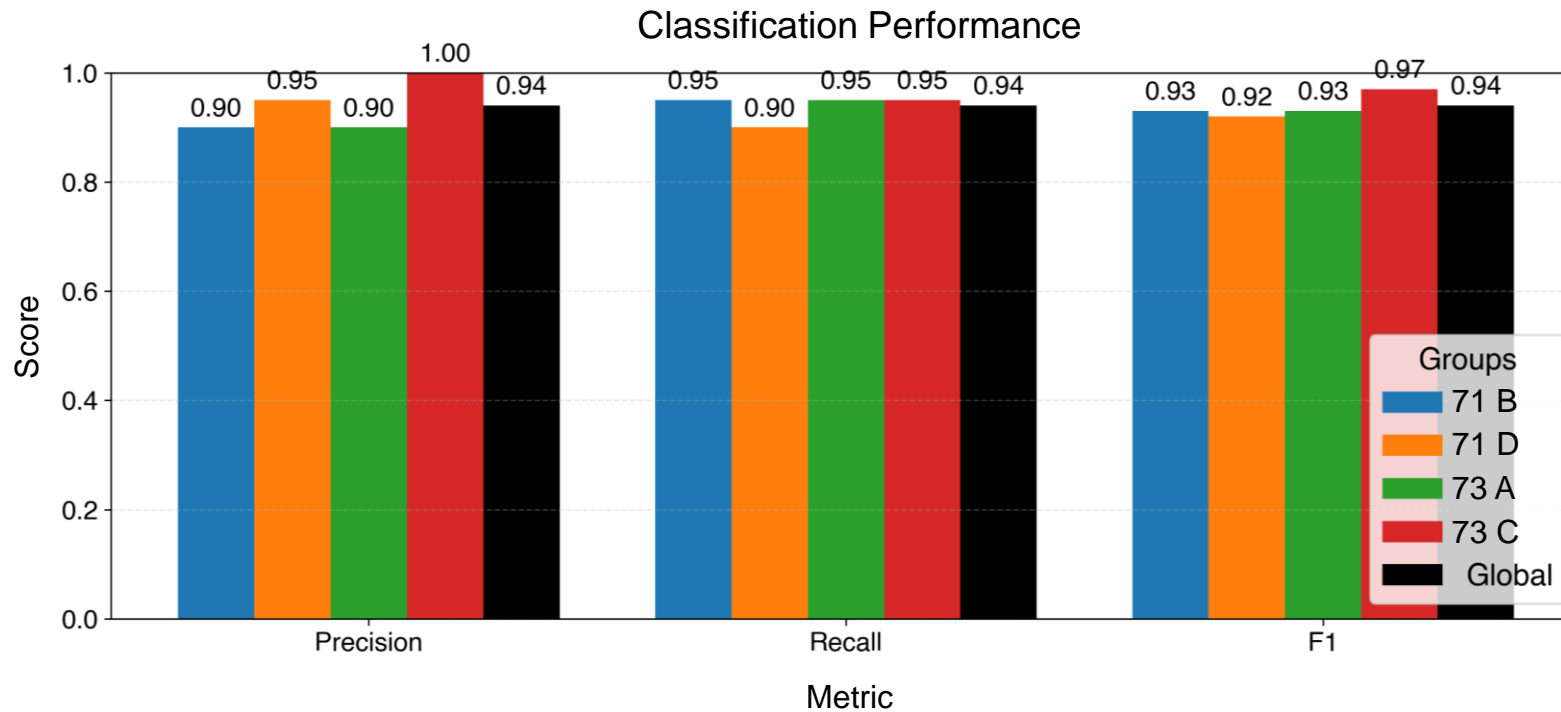
- Each point represents one flourish
- Color encodes the different florator groups

Projected Flourishes of Florator Groups from
CCI 71 and 73



Automated Classification

- Classification performance measured by a classifier trained on top of the global representations of the pen flourishing
- Leverages similarity of a given set of pen flourishes to assign them to the same or a different florator group

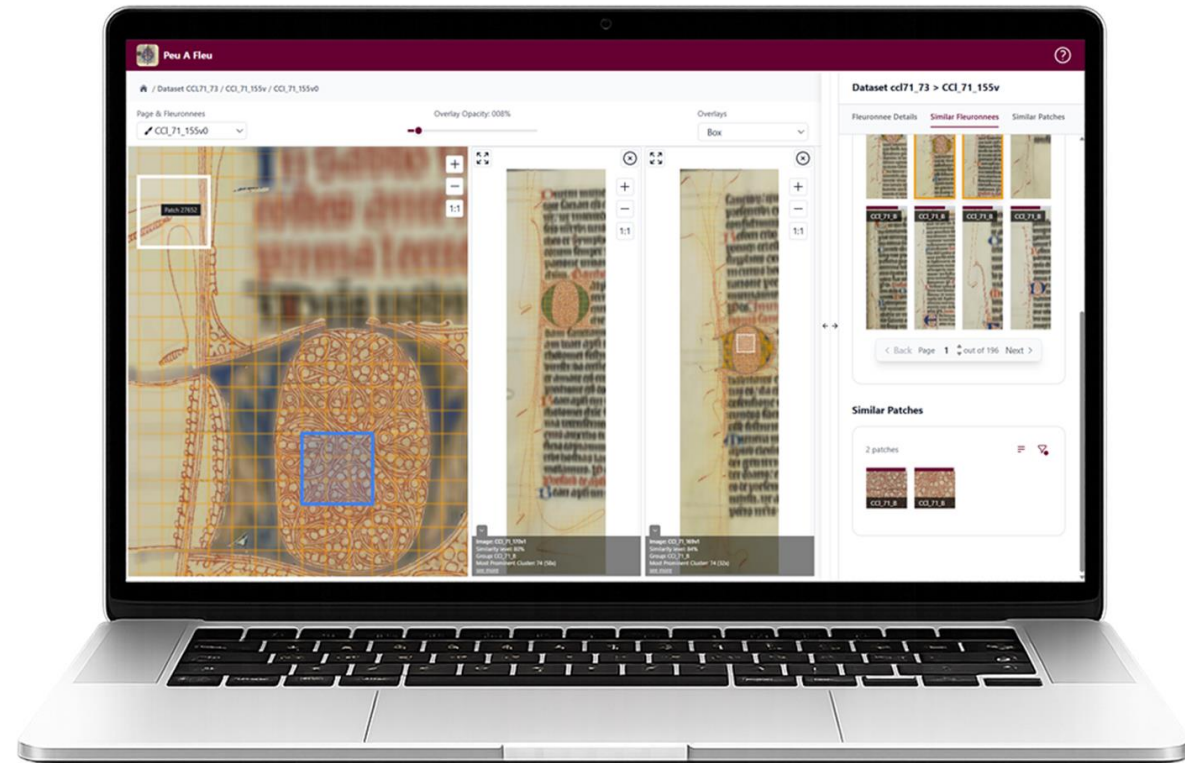




Prototype

Prototype Idea

- Uses our proposed method in a user-friendly tool for art-historical research
- Similarity measure used for pen flourishing retrieval and much more ...





Demonstration

Next Steps

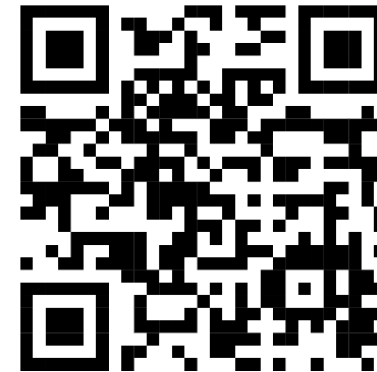


- 1 Scale up:** Extend dataset to more manuscripts, periods, and stylistic schools for broader validation
- 2 Qualitative Evaluation:** Conduct user study with art historians for the tool

Thank you!

Acknowledgements

We thank and acknowledge Gesellschaft für
Forschungsförderung Niederösterreich (GFF) for
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Research Project



Paper

Sources

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2. Otto Mazal, *Buchkunst der Gotik*, ger. Graz: Akademische Druck - und Verlagsanstalt, 1975, ISBN: 978-3-201-00949-2.
3. Christine Jakobi-Mirwald, “Flourish and blotts or how we name salient ornament features in manuscripts,” *Textes et Etudes du Moyen Âge*, vol. 94, pp. 183–205, 2019.
4. Wolfgang Augustyn, Christine Jakobi-Mirwald, Christine Sauer, and Martin Roland, “Fleuroné,” *Reallexikon zur Deutschen Kunstgeschichte*, vol. 9, pp. 1114–1196, 1997.
5. Evelyn Theresia Kubina, “Für recht und ordnung. fleuronée-initialen in handschriften und urkunden des vierten viertels des 13. jahrhunderts in wien und niederösterreich,” in *Europäische Bild- und Buchkultur im 13. Jahrhundert*, Wien, Köln, Weimar, 2020, pp. 167– 177.
6. Martin Roland, *Buchschmuck in Lilienfelder Handschriften. Von der Gründung des Stiftes bis zur Mitte des 14. Jahrhunderts (Studien und Forschungen aus dem Niederösterreichischen Institut für Landeskunde 22)*. Wien: NÖ Institut für Landeskunde, 1996.



Appendix



Pen Flourishing Data

Approach
Data

Total Number of
Florator Groups

8

Total Number of Pen
Flourishes

2,102

Total Number of
Florator Groups
(Used)

4

Total Number of Pen
Flourishes (Used)

788



Group A



Group B



Group C



Group D



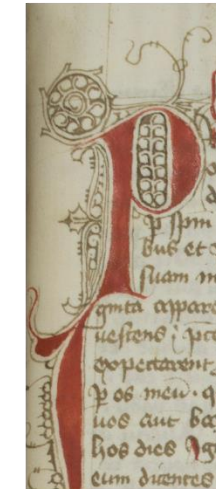
Group E



Group F



Group G

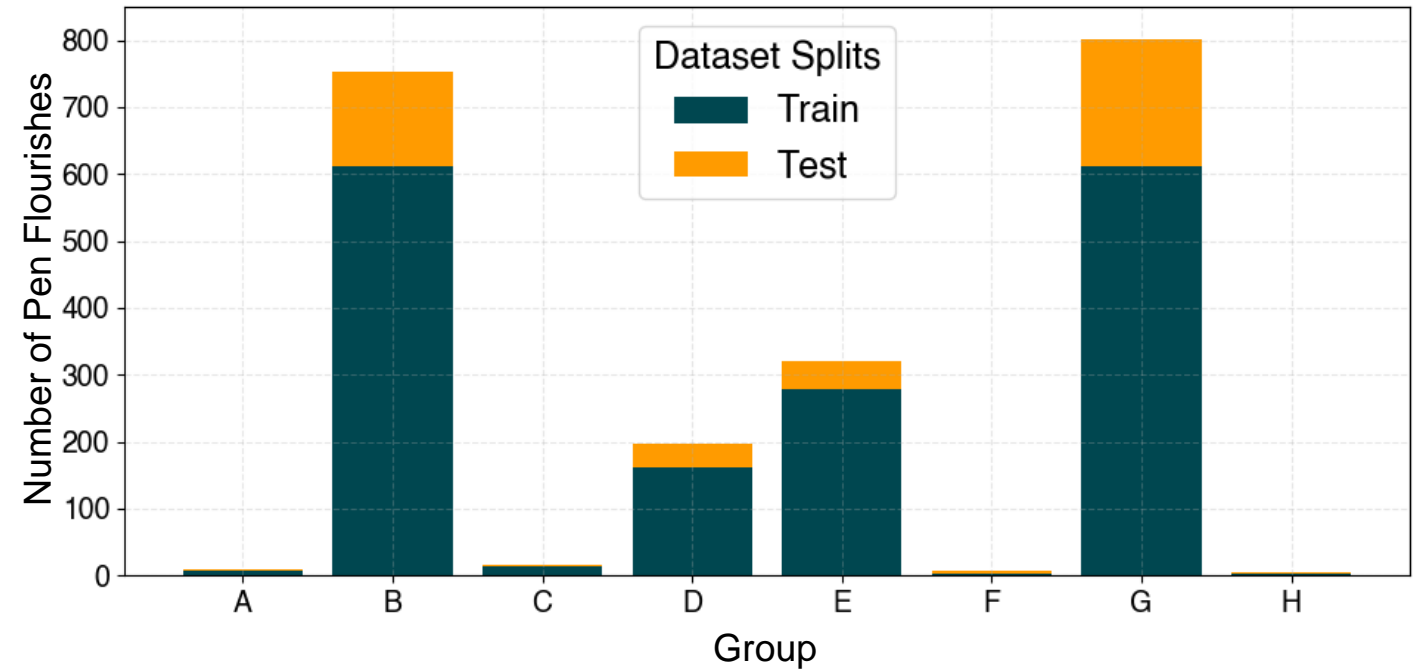


Group H

Image Source: Klosterneuburg Abbey

Approach
Data

Number of Pen Flourishing Samples per Group



Total Number of
Florator Groups

8

Total Number of Pen
Flourishes

2,102

Total Number of
Florator Groups
(Used)

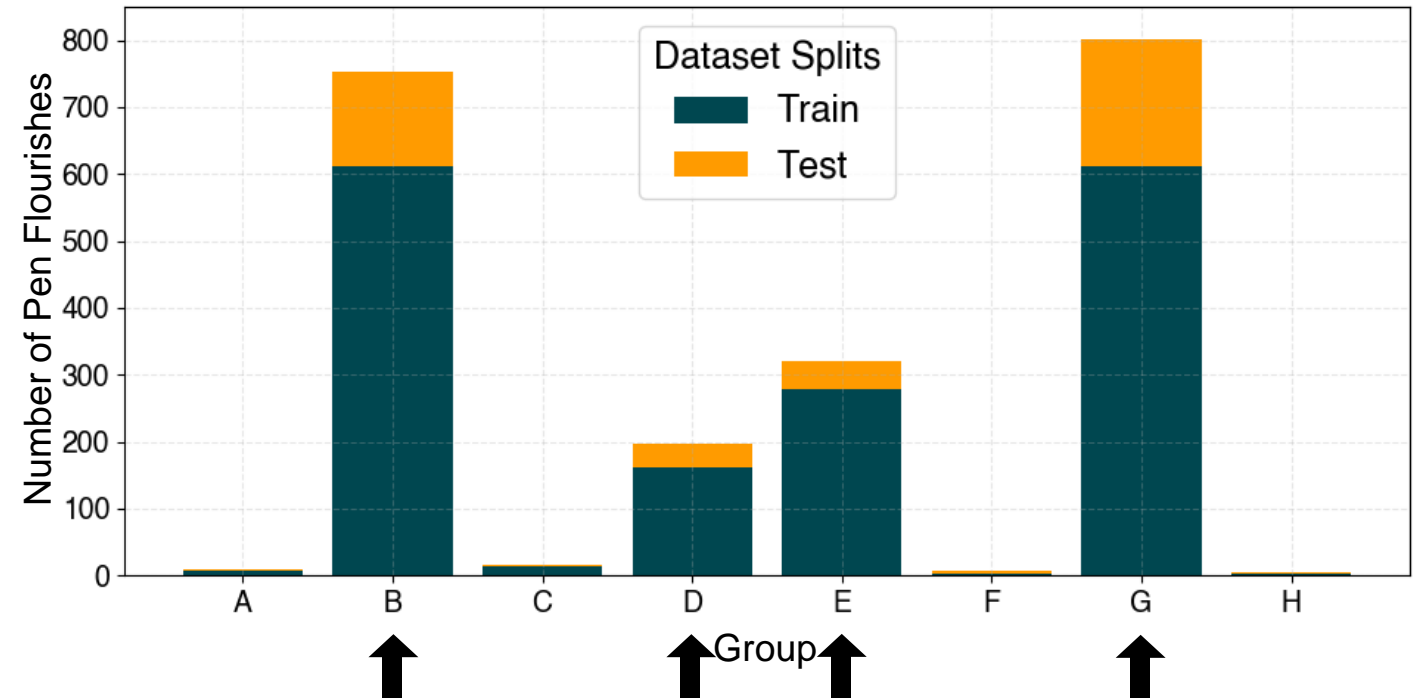
4

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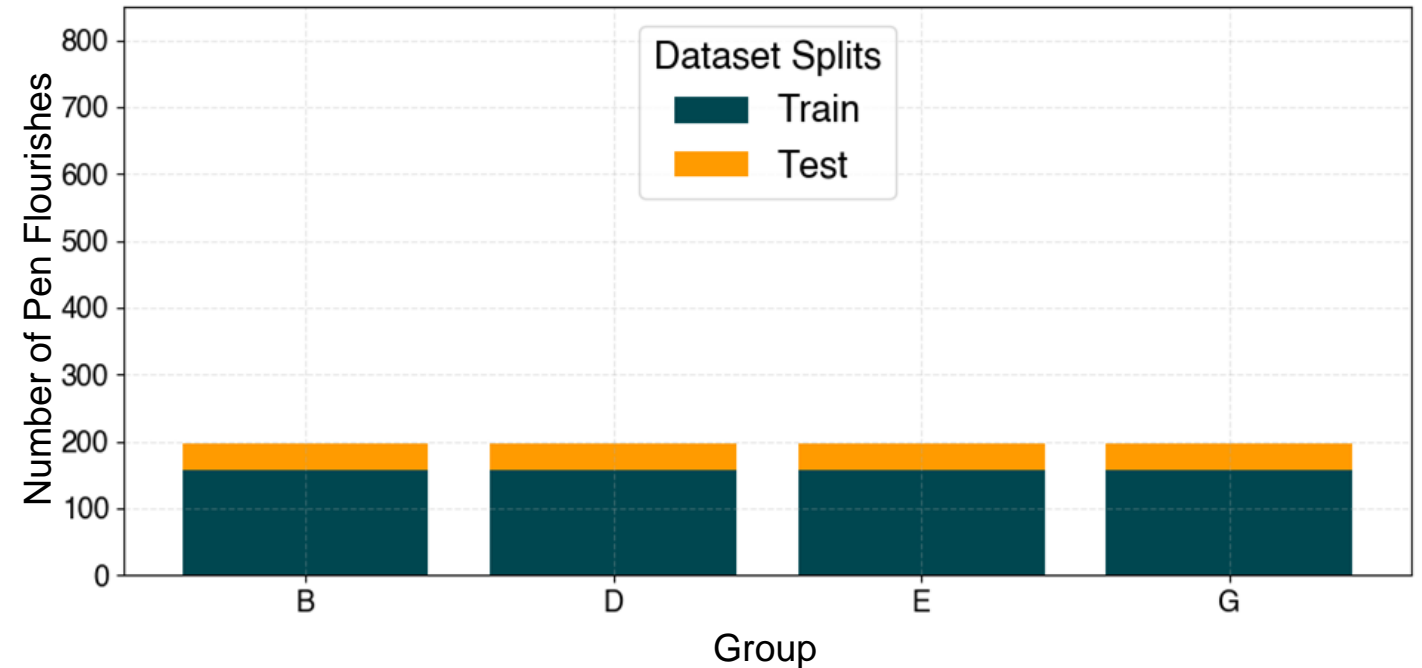
Total Number of Pen
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Approach
Data



Number of Pen Flourishing Samples per Group



Total Number of Florator Groups

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Total Number of Florator Groups (Used)

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788

Pen Flourishing Example per Group

Total Number of
Florator Groups

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4

Total Number of Pen
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788



Group B
CCI 71 fol. 23v3

Group D
CCI 71 fol. 226v1

Group E
CCI 73 fol. 43r2

Group G
CCI 73 fol. 158v3

Image Source: Klosterneuburg Abbey



Approach

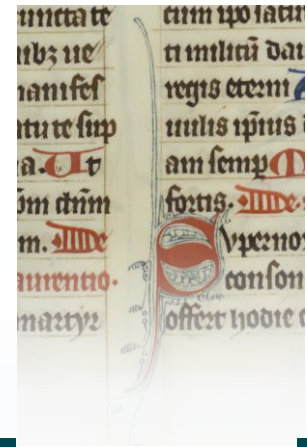
Approach

Model Transparency

1 Similarity-Level Transparency
Why are flourishes similar?

2 Cluster-Level Transparency
Which features are most characteristic for each group?

CCI 71 fol. 72v1 (B)



CCI 71 fol. 131v1 (B)

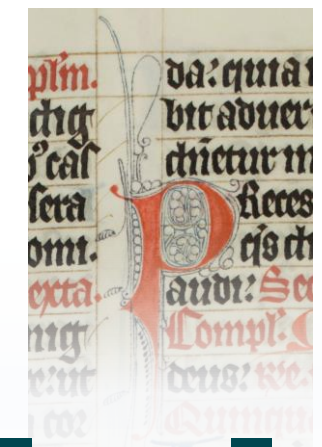
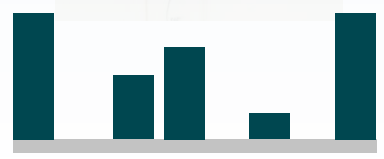
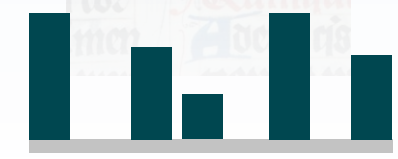
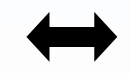


Image Source: Klosterneuburg Abbey



Histogram 1



Histogram 2

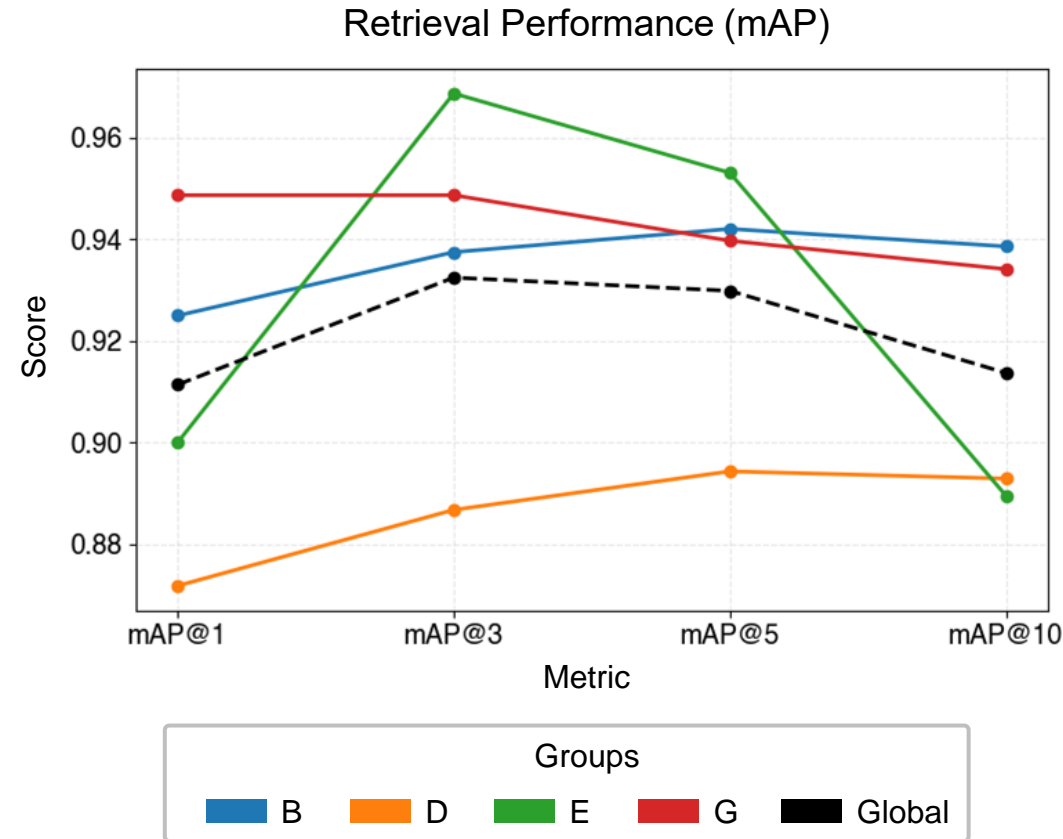


\sum [red square] [tan square] [tan square] [red square] ... [tan square] = Similarity Score
Contribution Scores



Evaluation

Retrieval Performance



Evaluation

Similarity-Level Transparency

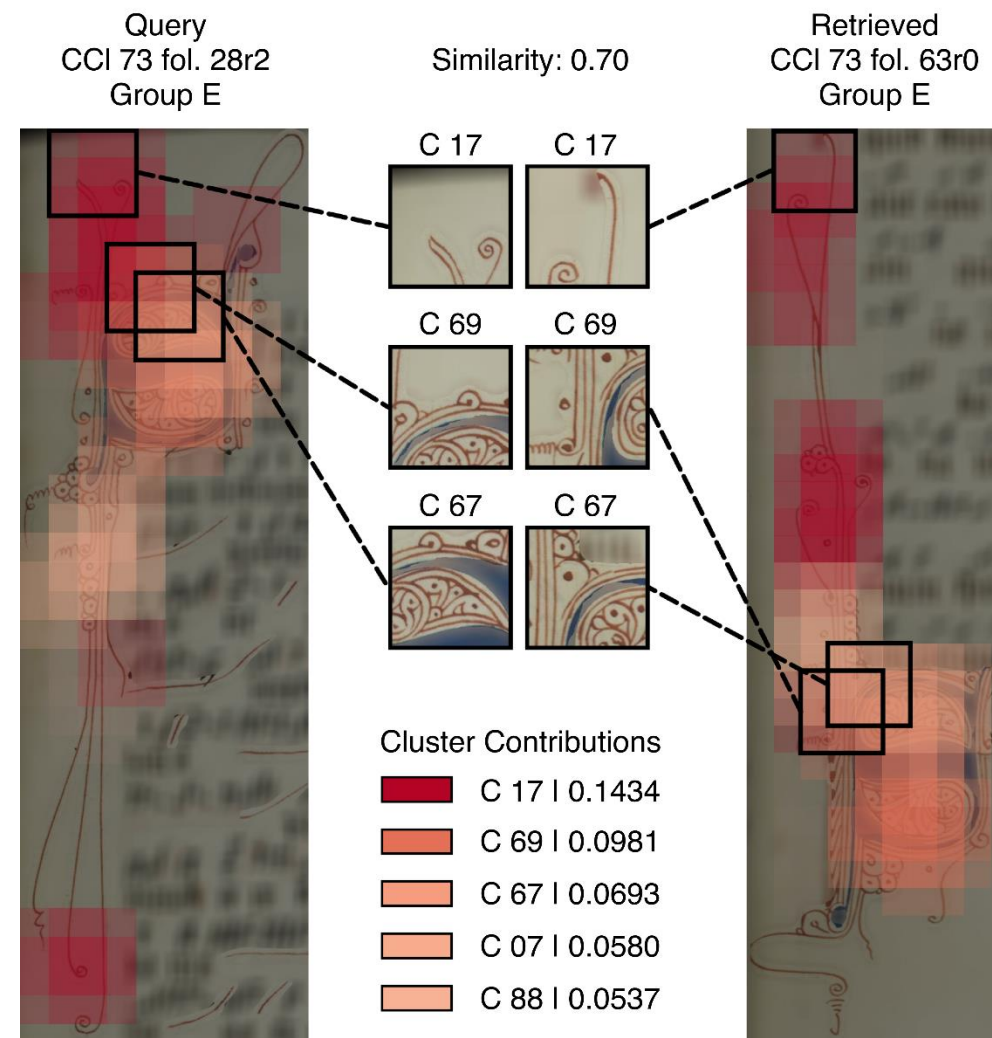
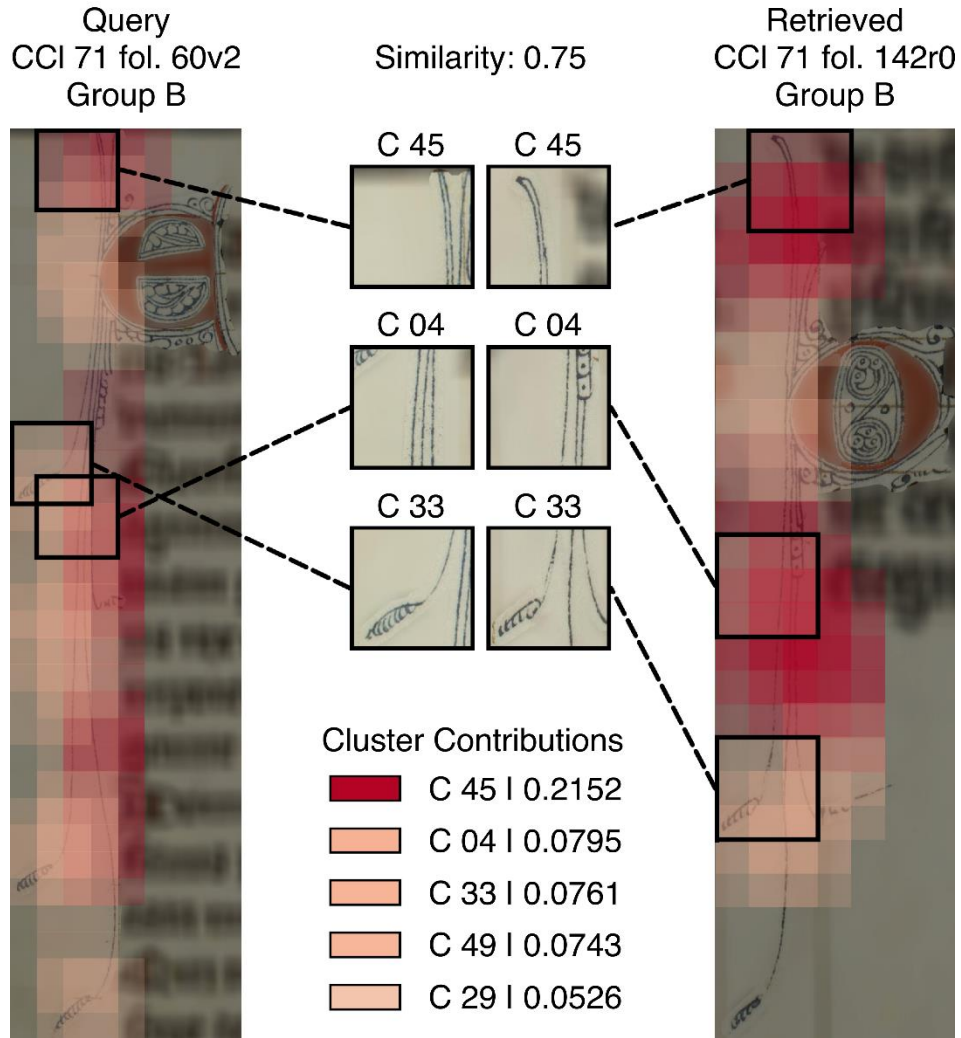


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Evaluation

Similarity-Level Transparency

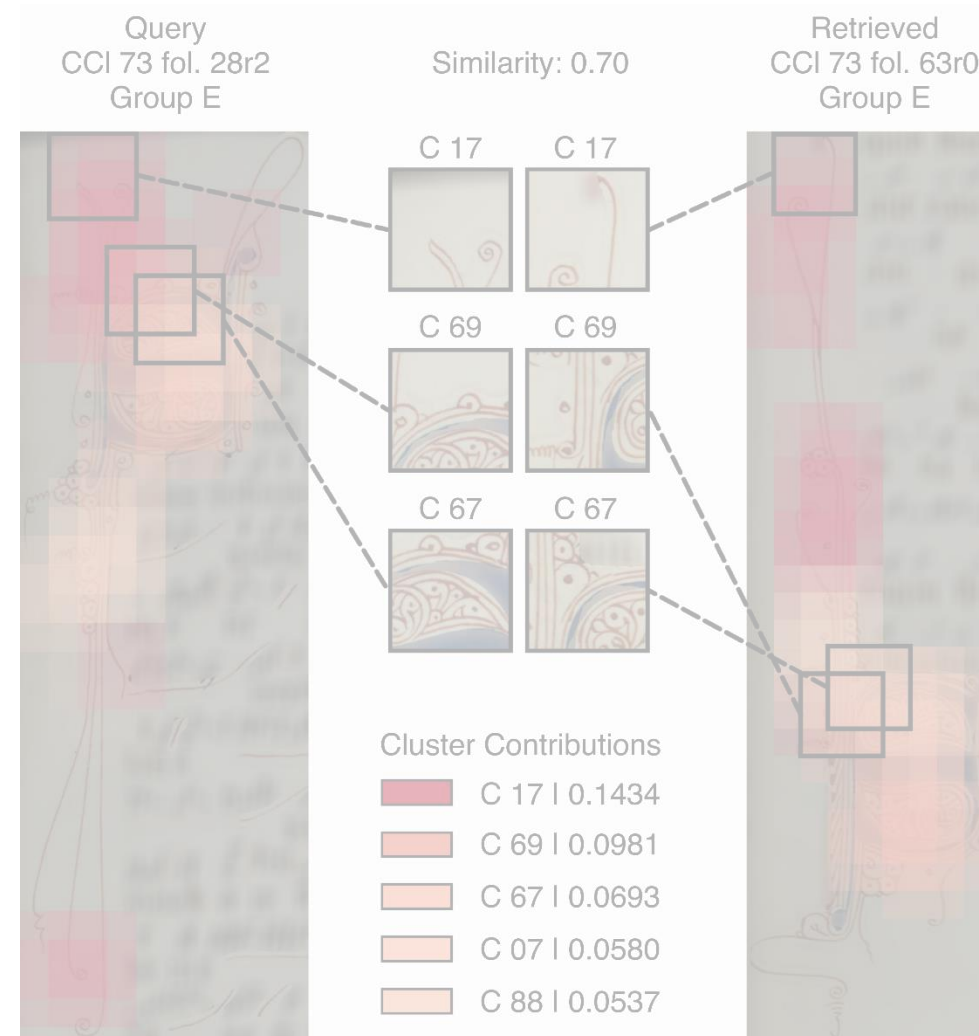
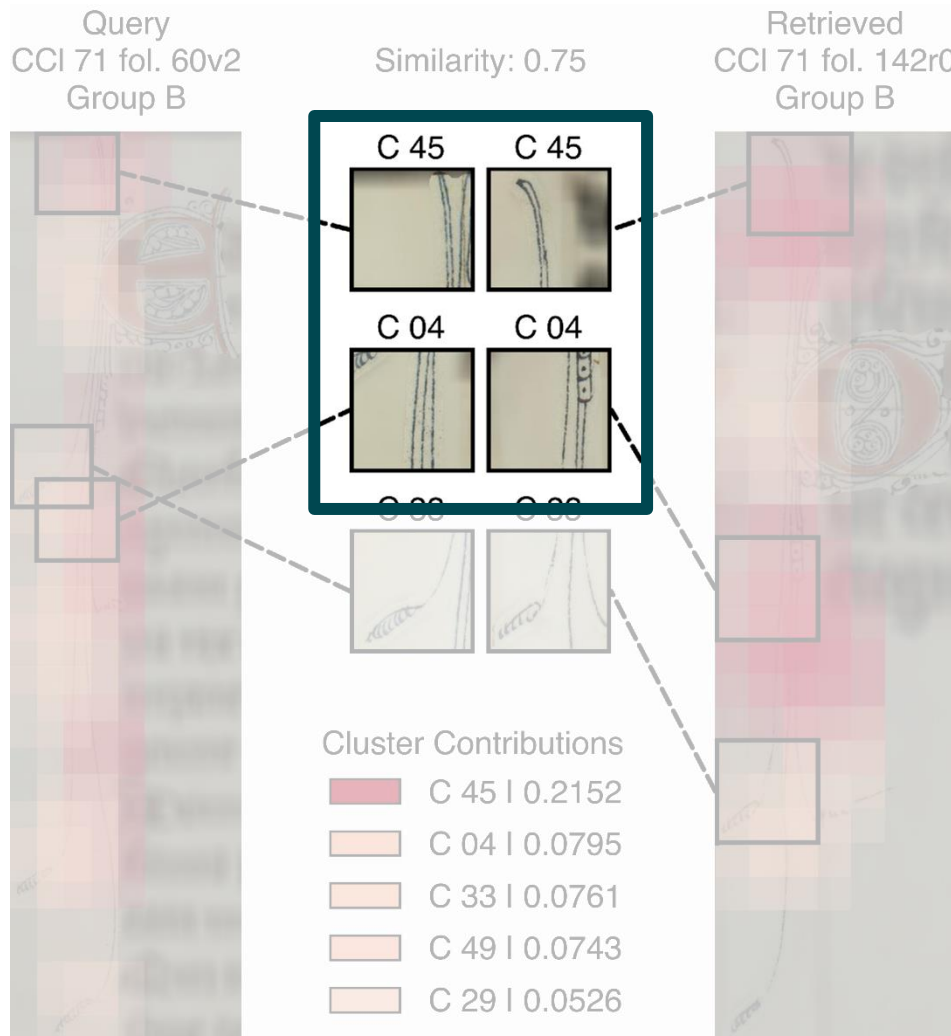


Image Source: Klosterneuburg Abbey

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Similarity-Level Transparency

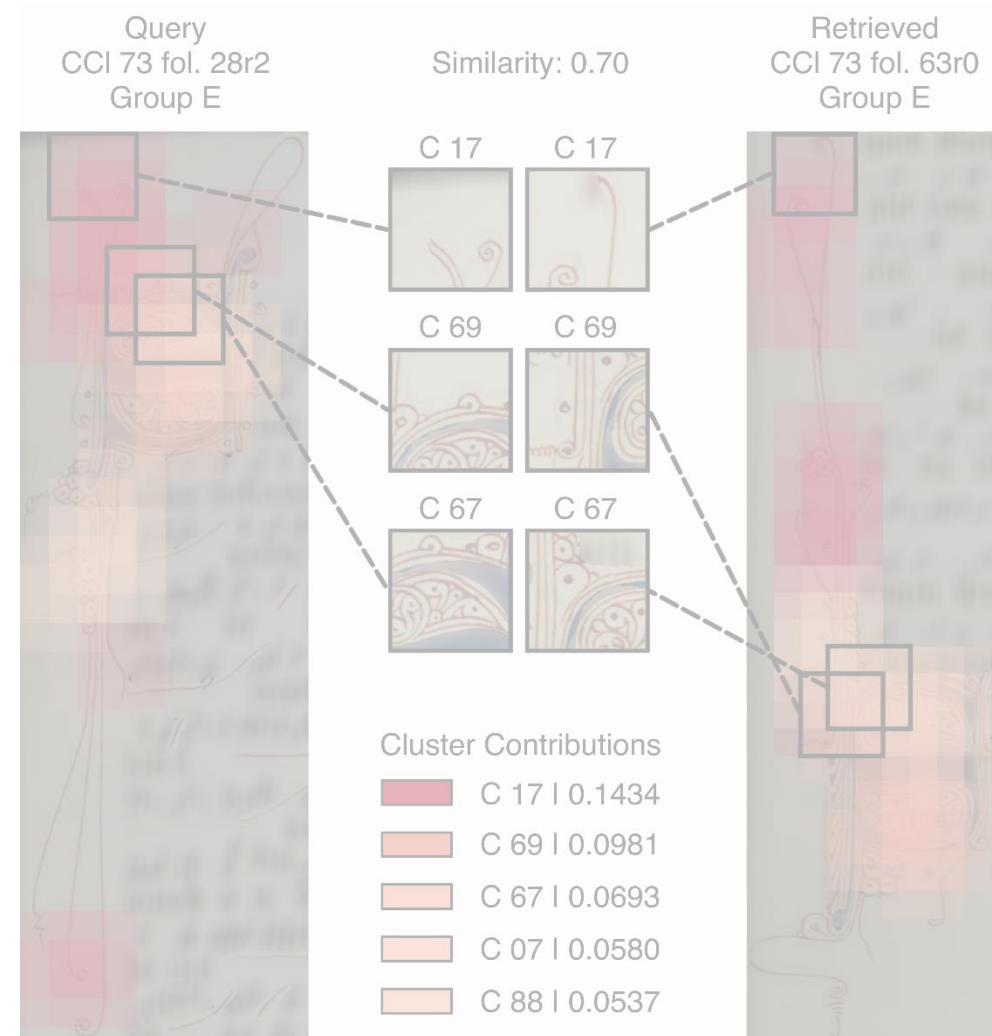
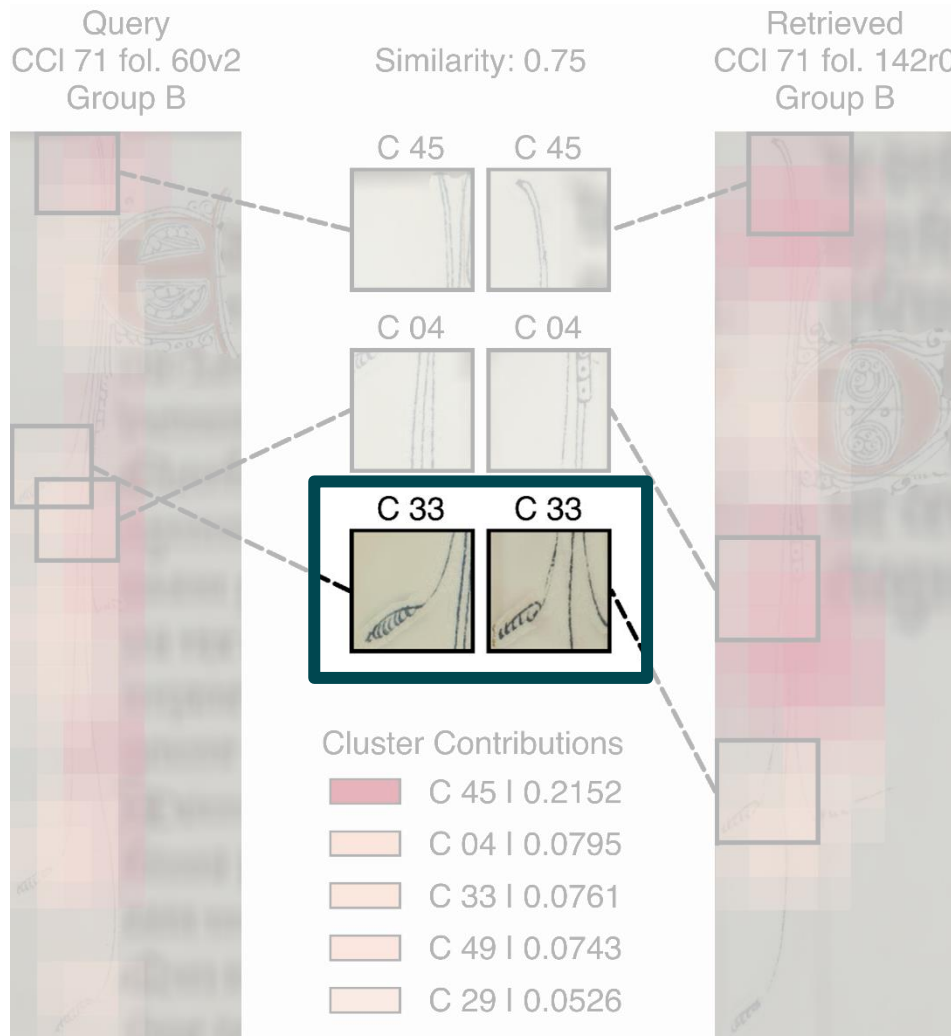


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Evaluation

Similarity-Level Transparency

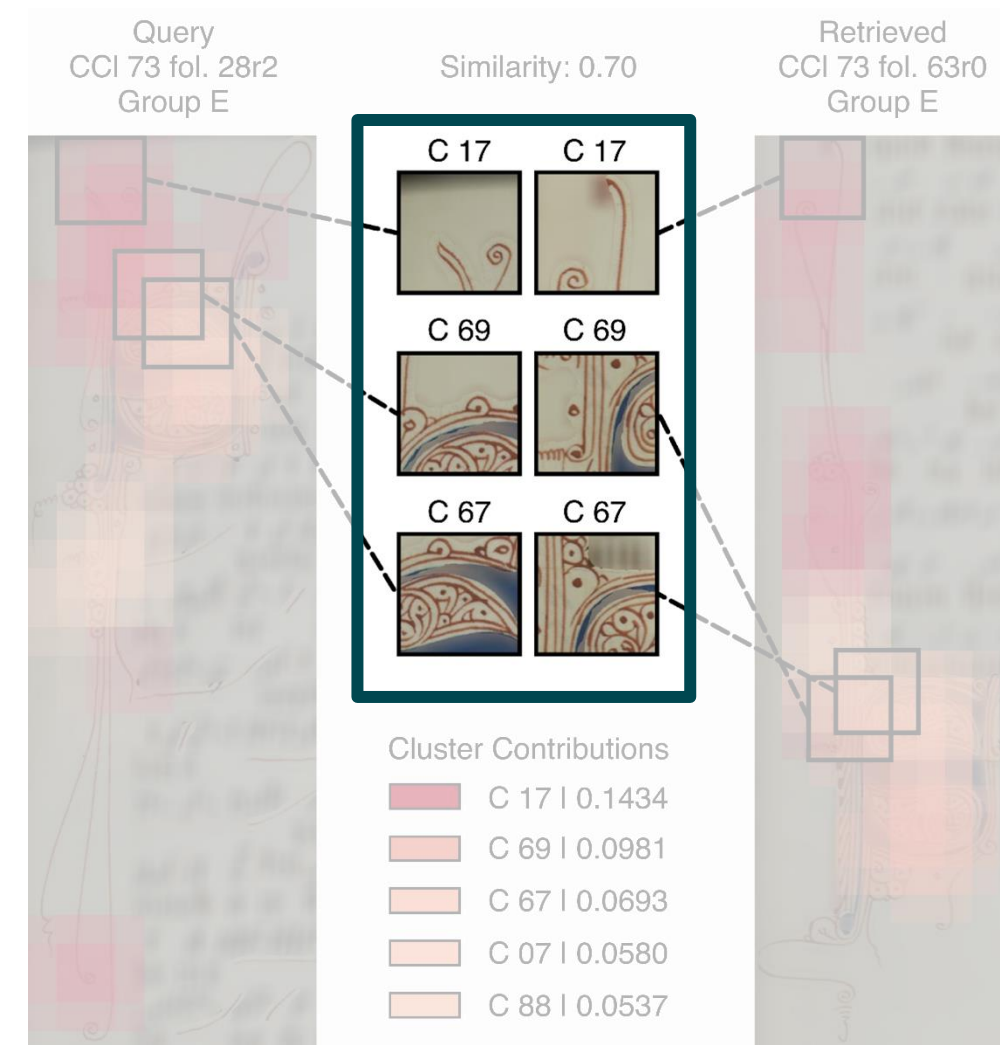
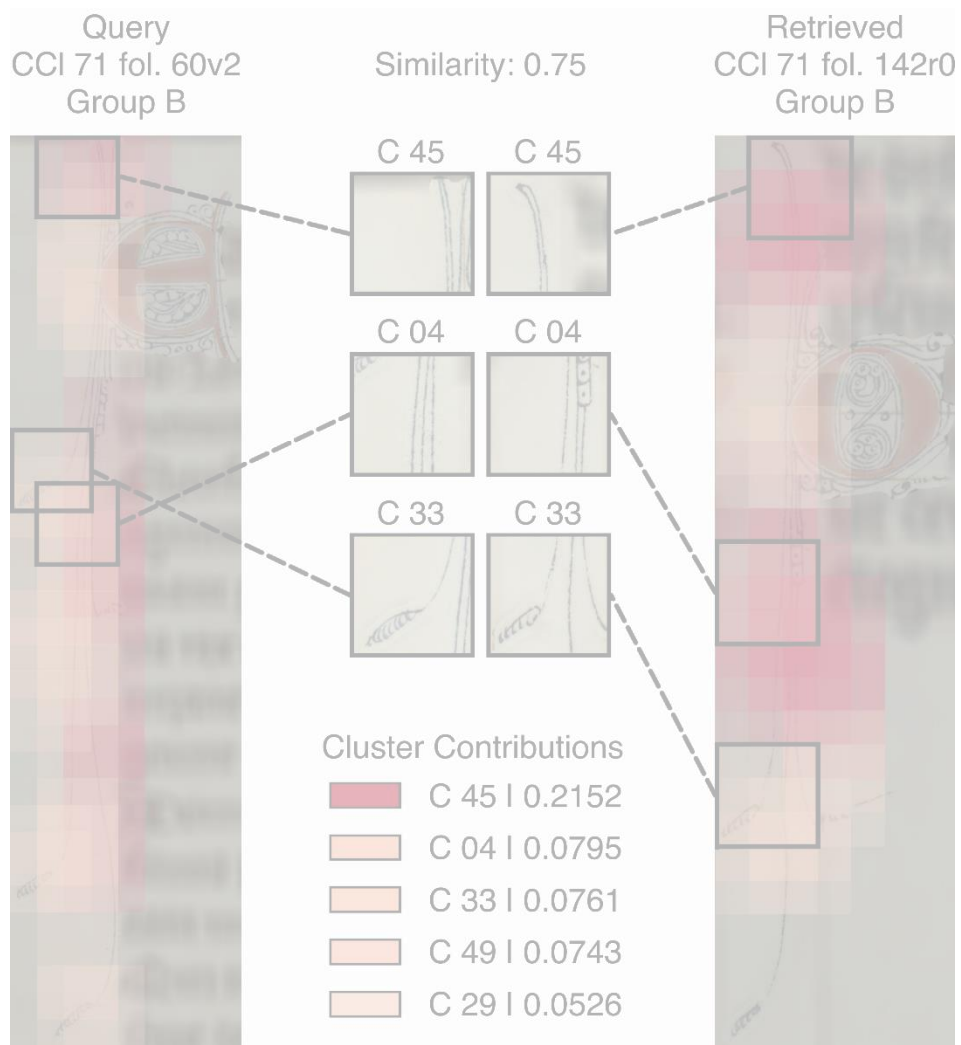
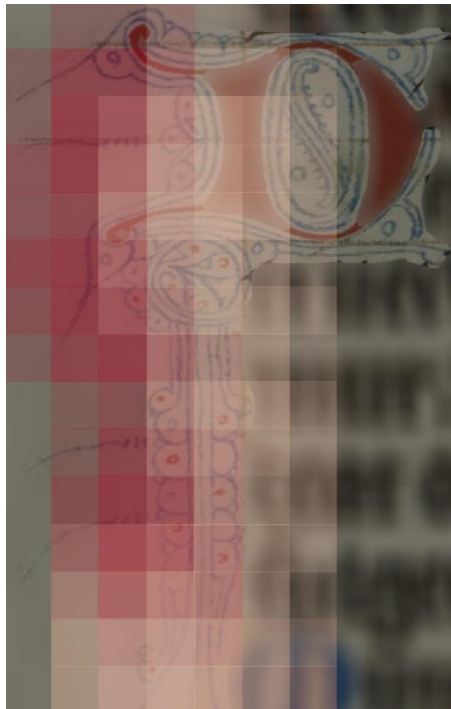


Image Source: Klosterneuburg Abbey

Domain Expert Annotations

Our Approach

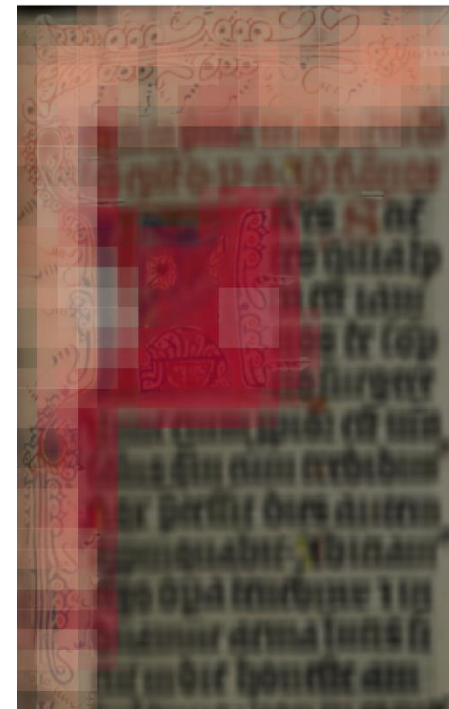


Expert Annotations



CCI 71 folio 120v0 (C)

Our Approach



Expert Annotations

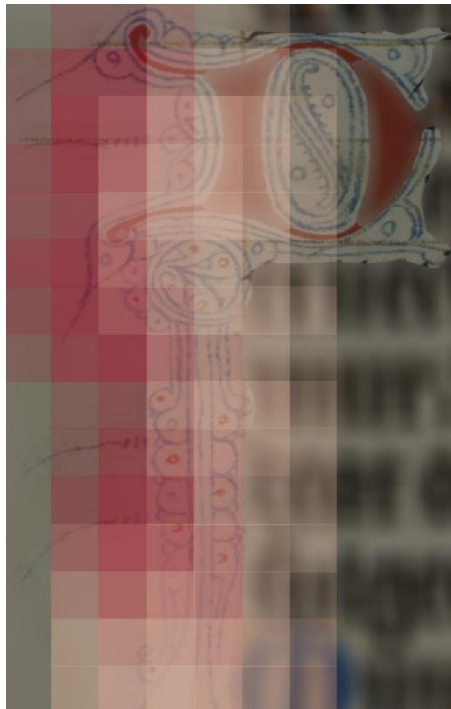


CCI 71 fol. 214r3 (E)

Image Source: Klosterneuburg Abbey

Domain Expert Annotations

Our Approach



Expert Annotations



CCI 71 folio 120v0 (C)

Our Approach



Expert Annotations

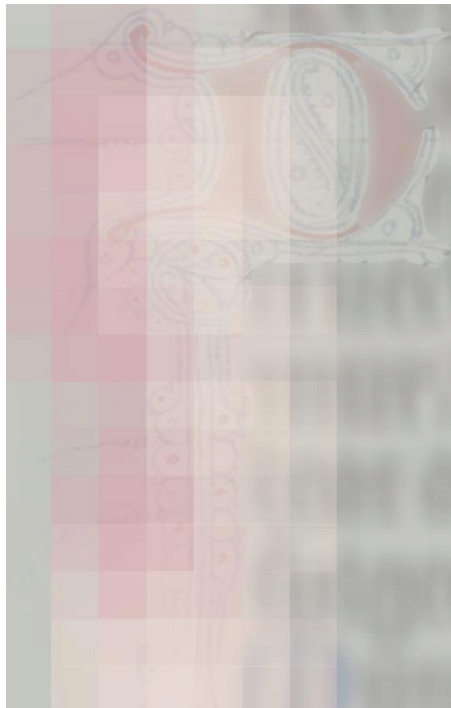


CCI 71 fol. 214r3 (E)

Image Source: Klosterneuburg Abbey

Domain Expert Annotations

Our Approach

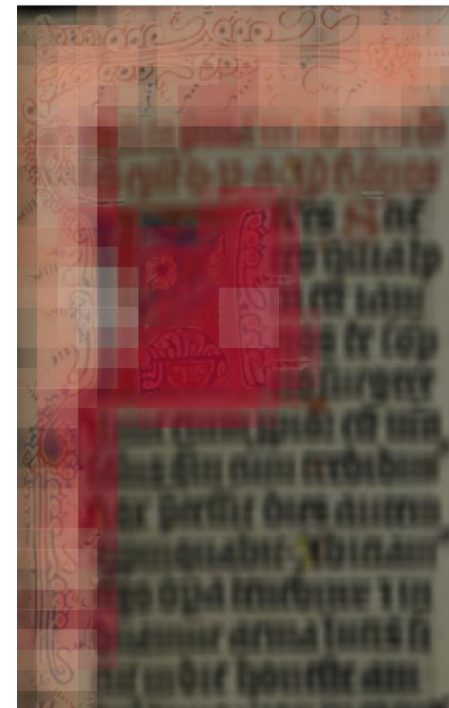


Expert Annotations



CCI 71 folio 120v0 (C)

Our Approach



Expert Annotations



CCI 71 fol. 214r3 (E)

Image Source: Klosterneuburg Abbey