Historical Documents in Focus:

Visual and Computational Analysis from Papyri to Inscriptions

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ICDAR2025

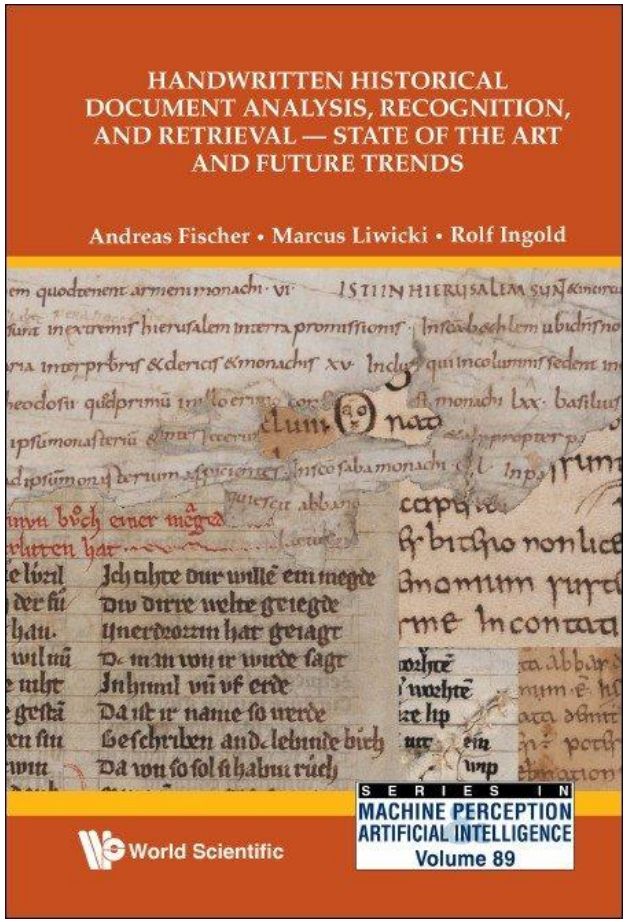
Swiss National Science Foundation

Universität Basel

Program of the Tutorial

- Introduction to Ancient Document Analysis
  A brief introduction to what historical document analysis is and what the challenges and opportunities it offers.
- Break
- Example of Application
  We will program in Python a model for the Detection and Recognition of Ancient Greek characters on papyrus from Egypt.

An Interesting Read

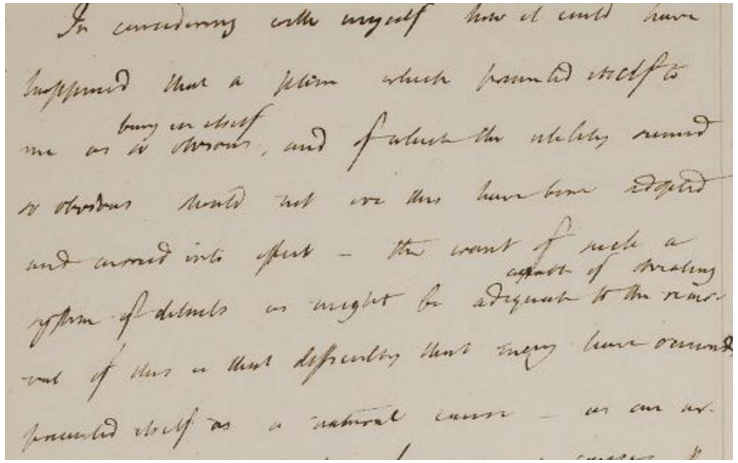


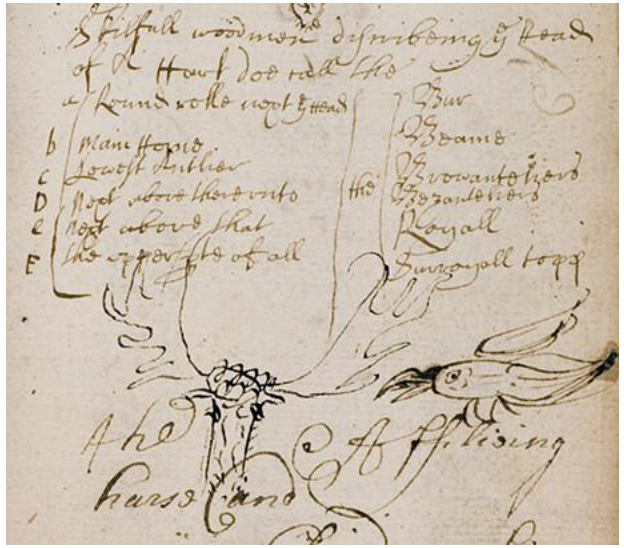
Handwritten Historical Document Analysis, Recognition, and Retrieval — State of the Art and Future Trends
Ed. Andreas Fischer, Marcus Liwicki and Rolf Ingold

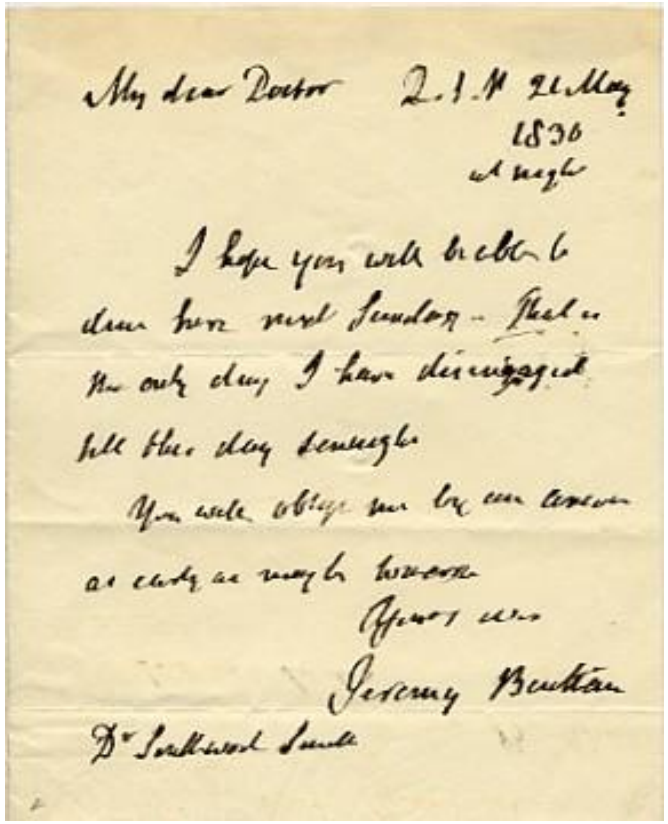
https://doi.org/10.1142/11353

What are Historical Documents?

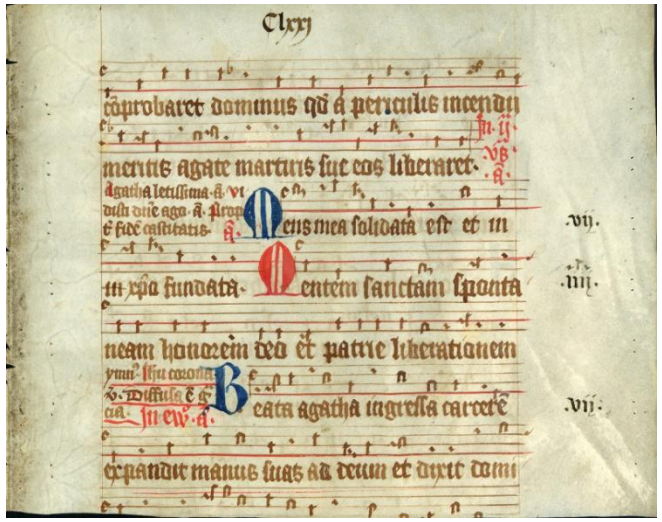
Early Modern Manuscript

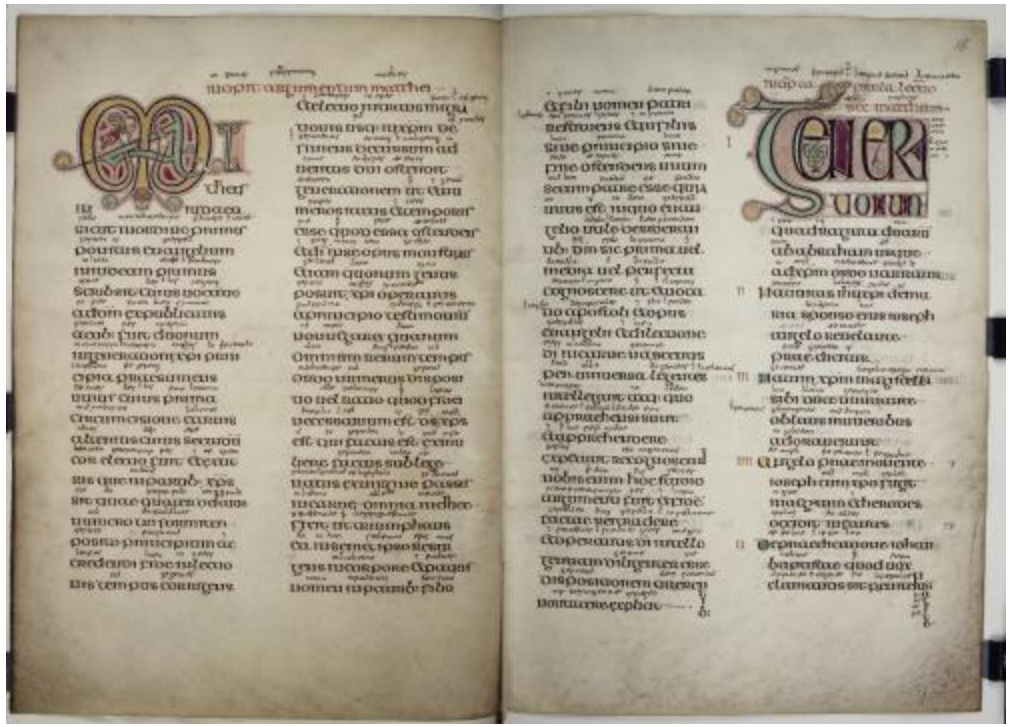




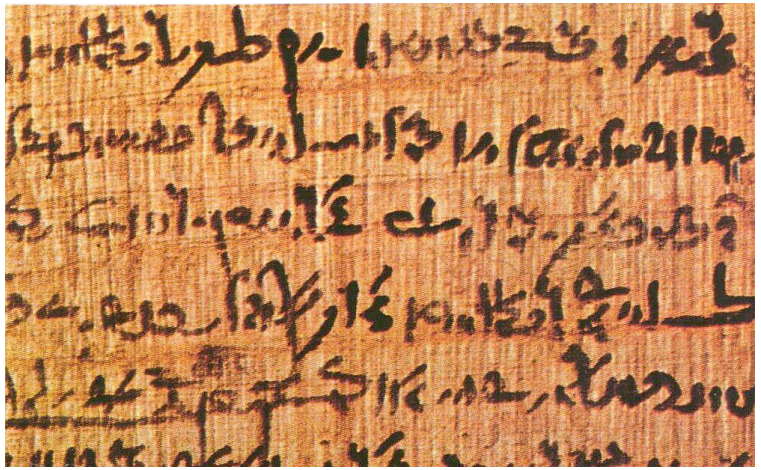


Medieval Manuscripts

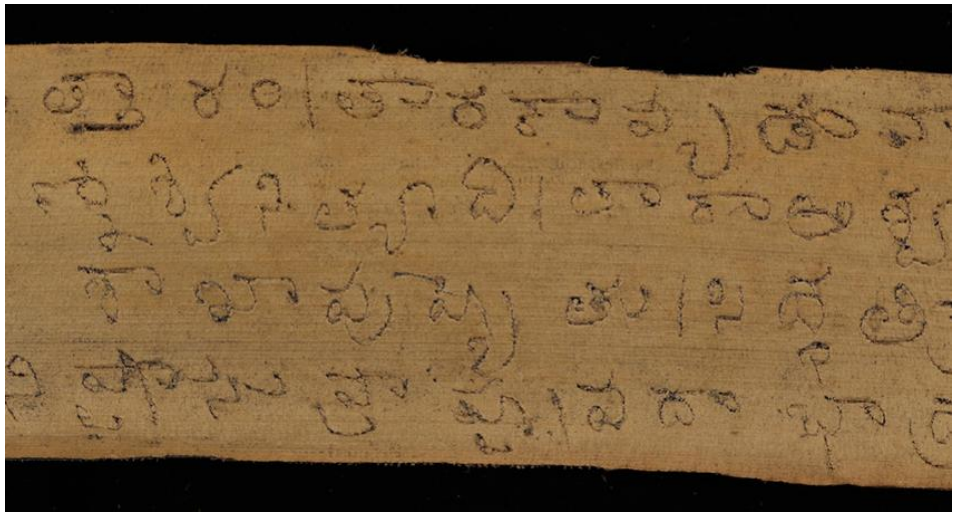




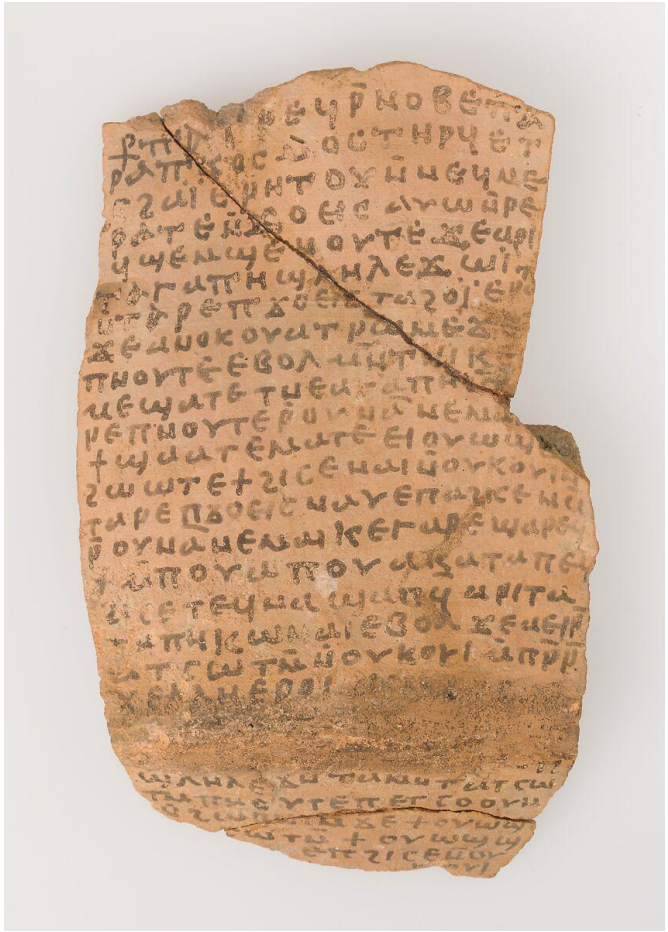
Ancient Papyri



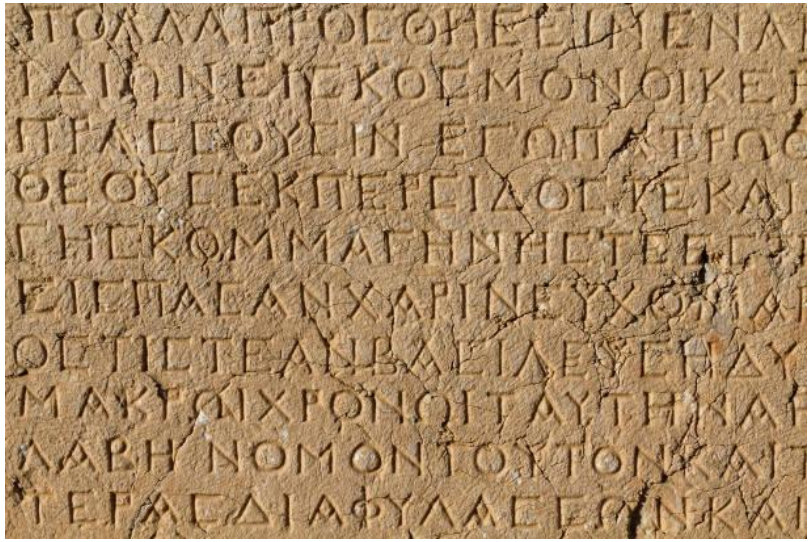
Ancient Leaf Document

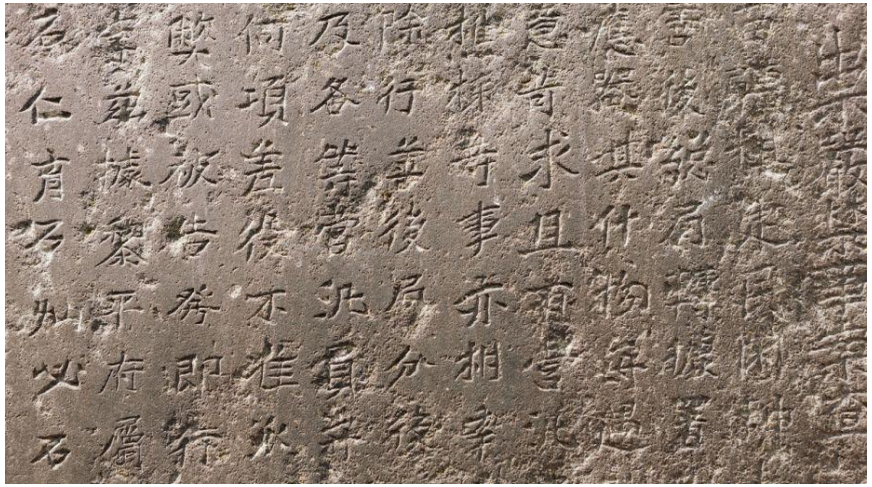


Ostraca



Inscriptions





What are Historical Documents?

A historical document is not just "*an old book*" but **any medium** through which human beings have expressed meaning and recorded information, often using **very different materials** and **techniques**.

Applications of Artificial Intelligence to Historical Documents

Pipeline of Historical Document Processing

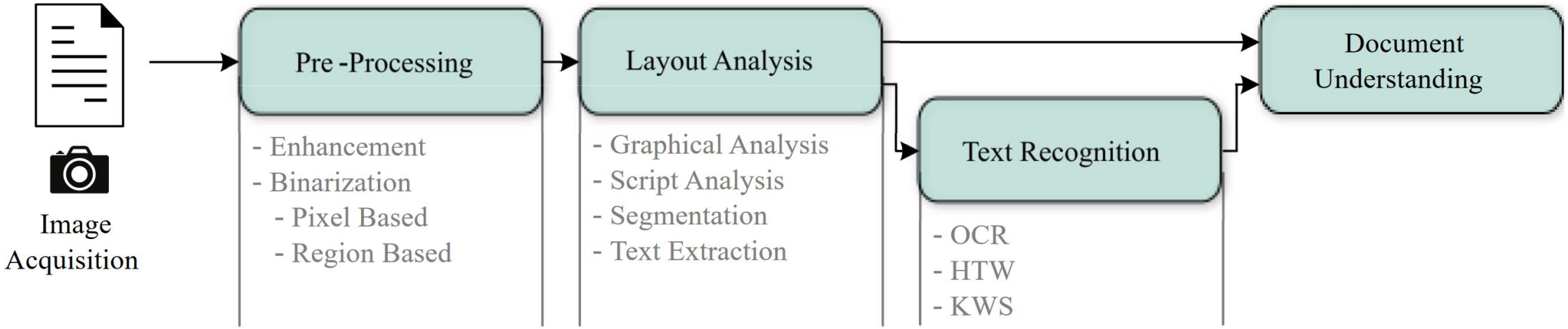
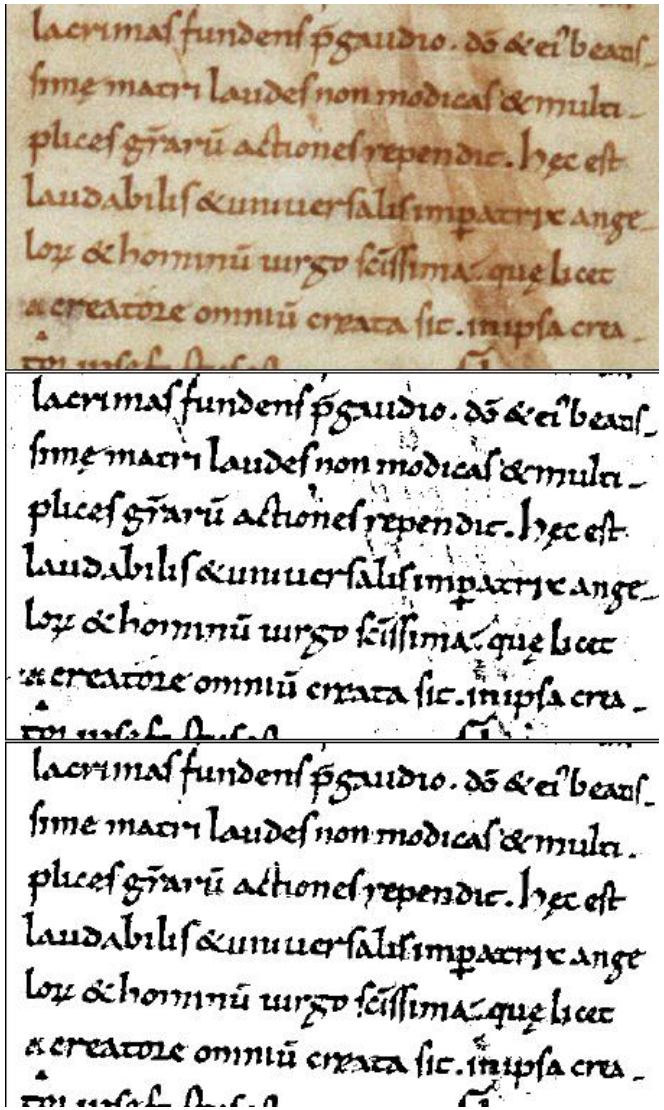
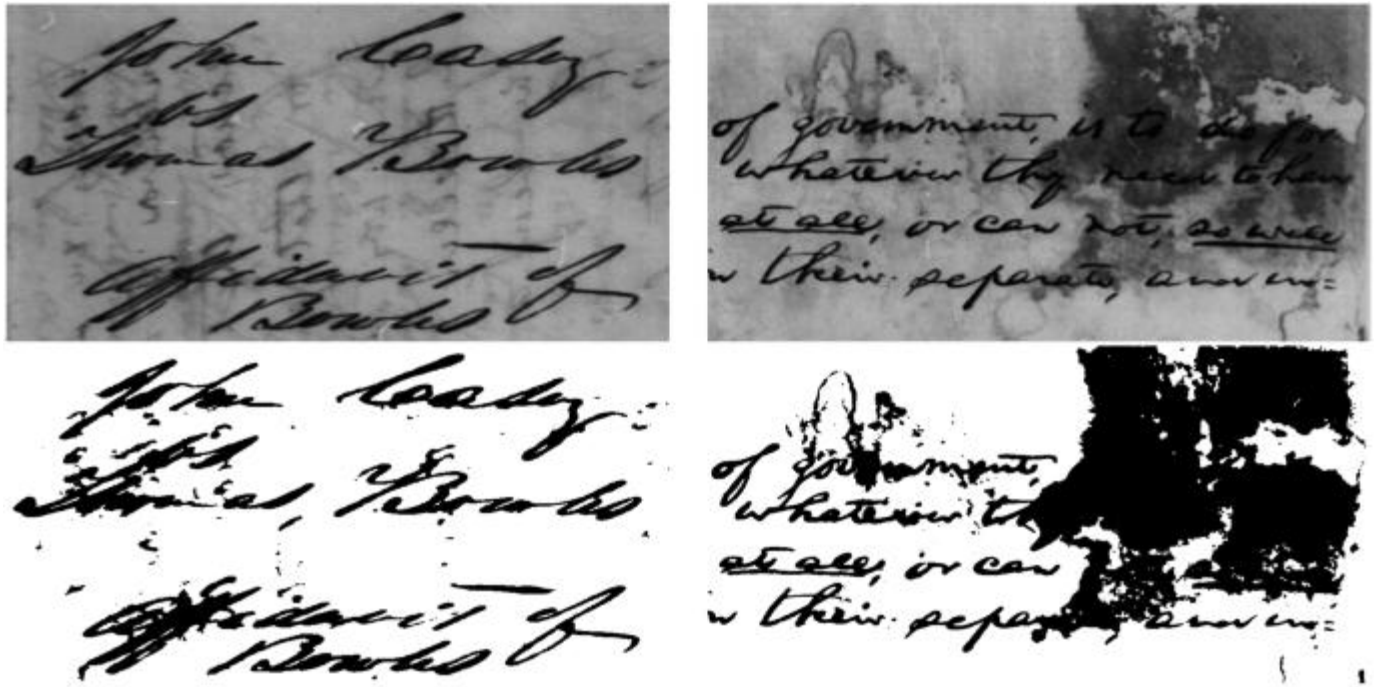


Figure 2.5: Typical Historical Document Processing Workflow.

Pre-Processing - Binarization



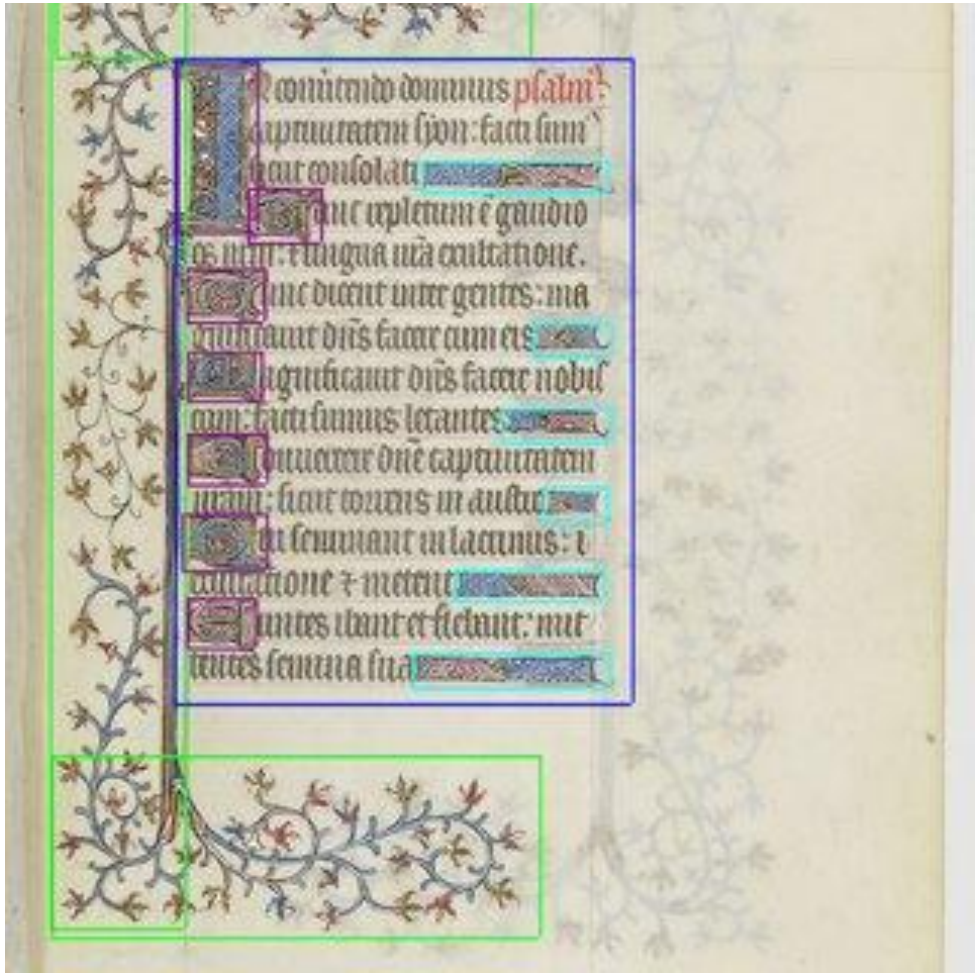


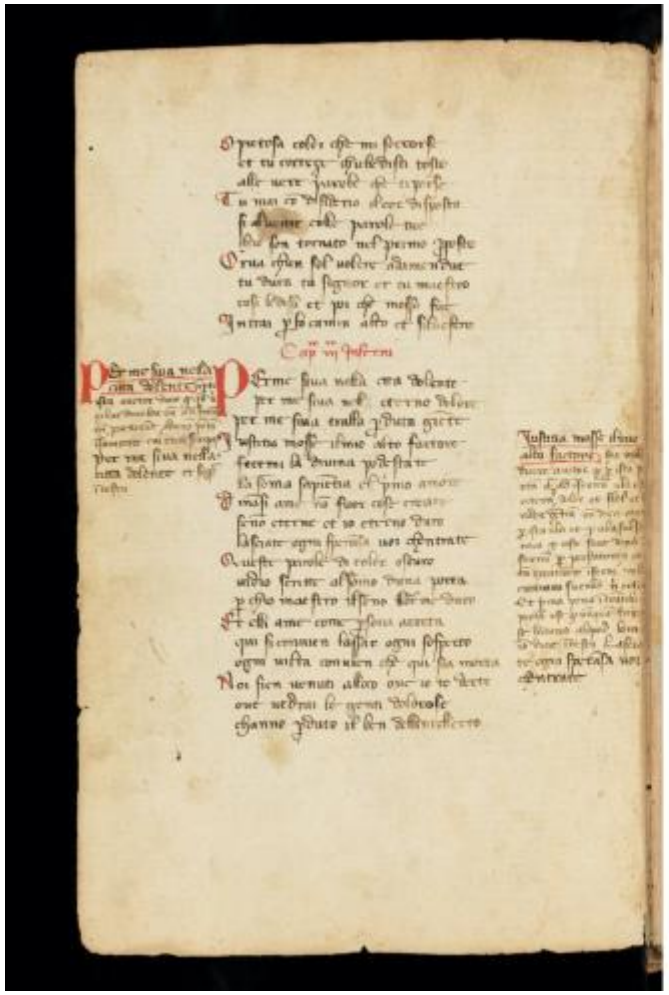
Pre-Processing - Binarization

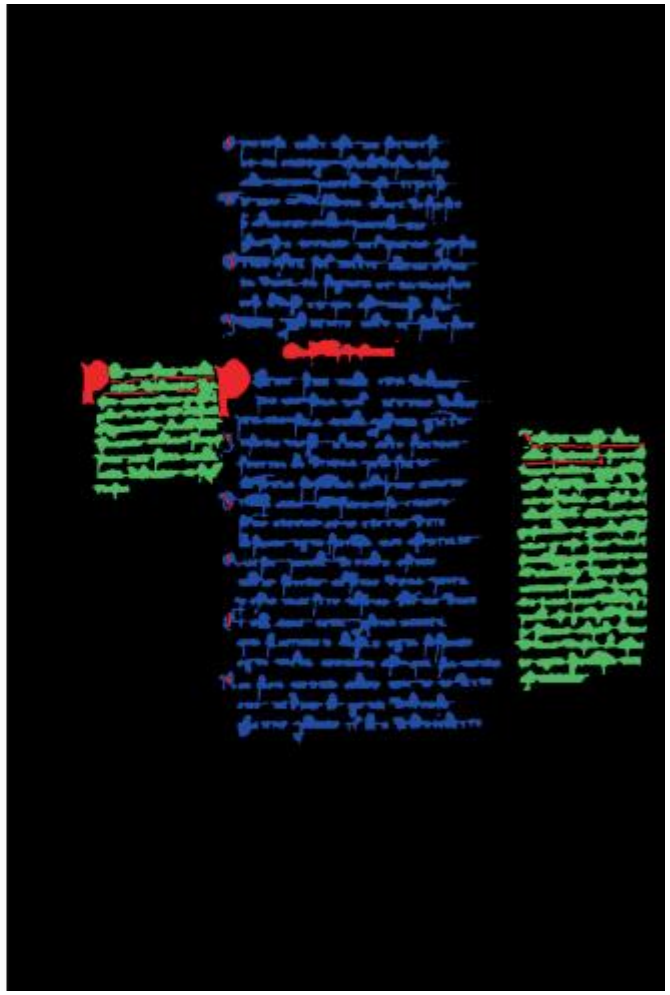
Deep Learning-Based Approaches (End-to-End)

- **U-Net** and variants: Encoder–decoder convolutional networks that learn to distinguish text from background. Widely used because they can capture both fine details and global context.
- **GANs** (Generative Adversarial Networks): Trained to "translate" the degraded image into a cleaner binarized version, reducing noise, speckles, and bleed-through.
- **Transformer-based** models: Some recent work explores Vision Transformers or Hybrid CNN–Transformer architectures to learn robust representations even with small datasets.
- **Self-supervised learning**: Useful when the ground truth is scarce (a typical problem in ancient documents). The networks first learn with pretext tasks (restoration, denoising) and then adapt to binarization.

Layout Analysis – Page Segmentation







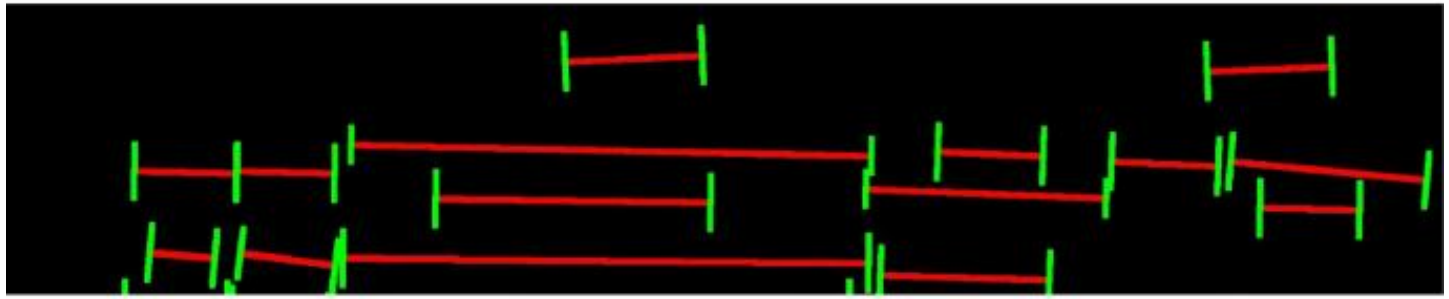
Layout Analysis – Page Segmentation

1. **CNN-based semantic segmentation**
   - **U-Net e variants (U-Net++, Attention U-Net)** → widely used to distinguish text, decorations, margins and background.
   - **Fully Convolutional Networks (FCN)** → treat the page as a pixel classification problem.
2. **Object Detection & Instance Segmentation**
   - **Faster R-CNN, Mask R-CNN, YOLOv5/YOLOv8** → used to segment blocks of text, figure boxes, lines, or even individual words.
3. **Transformer-based models**
   - **DETR (Detection Transformer)** → They exploit global attention to locate textual and graphic regions in historical documents.
4. **Graph-based approaches**
   - **Graph Neural Networks (GNN)** to model the logical structure of the document: nodes = regions, arcs = spatial relationships.
5. **Self-supervised approaches**
   - **Self-supervised pretraining** (autoencoder, contrastive learning) → useful sor small datasets.

Layout Analysis – Line Segmentation

Layout Analysis – Baseline Detection

(a) Baseline ground truth – The baselines are defined by the red dots. Dots of the same baseline are connected.

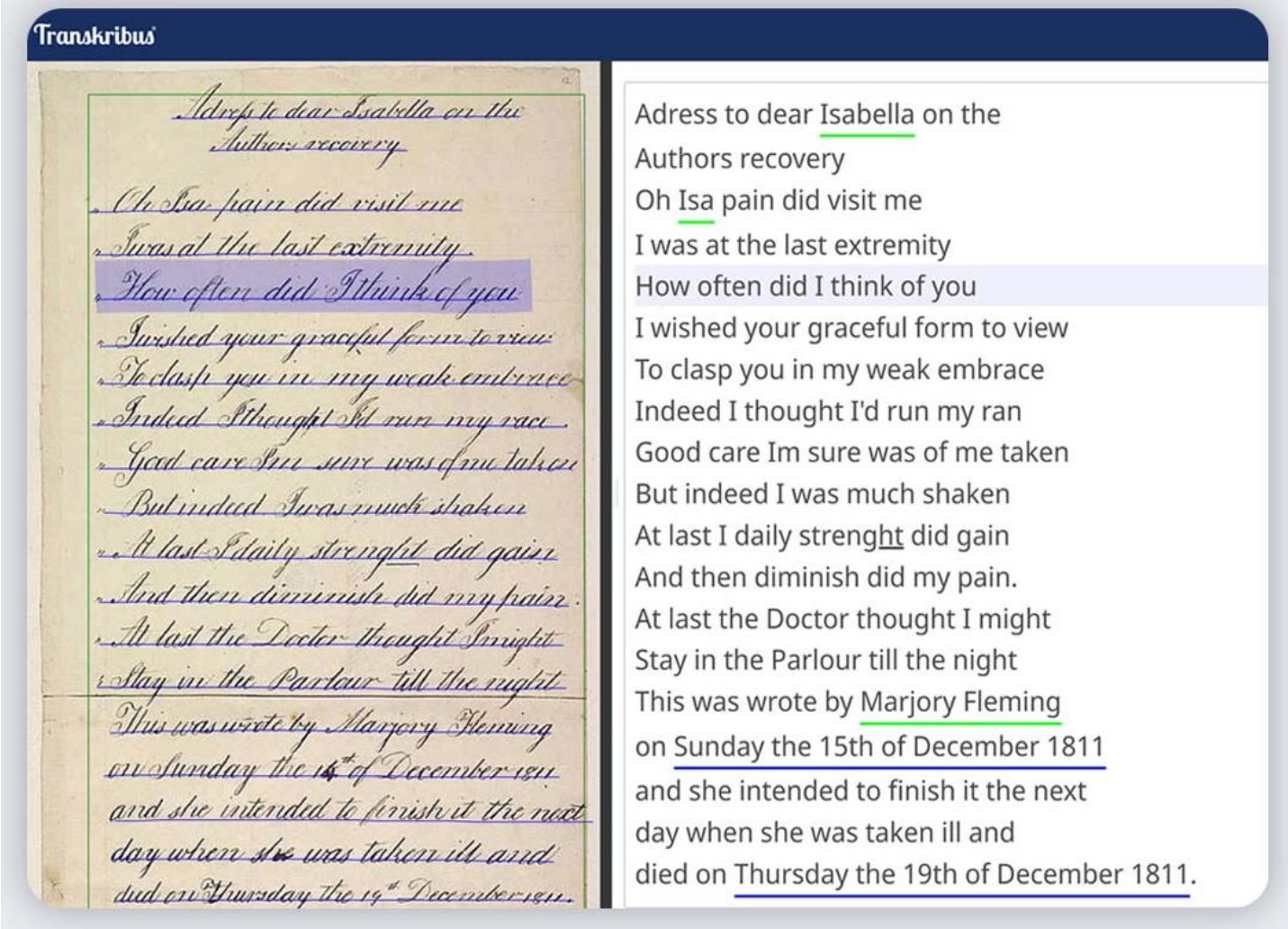


(b) Pixel ground truth – Green encodes the separator class, red the baseline class and black the "other" class. See supplements for an algorithm to automatically generate such GT.

Layout Analysis – Line Segmentation

1. **CNN-based semantic segmentation**
   - **FCN / U-Net segmentation**: semantic segmentation networks classifying pixels as “baseline” vs. “background.”.
2. **Object Detection & Instance Segmentation**
   - **Object Detection models (YOLO, Faster R-CNN, Mask R-CNN)** → detect bounding boxes or masks for text lines.
3. **Transformer-based models**
   - **DETR (Detection Transformer) adapted for lines** → directly detects baselines as segments..
4. **Skeletonization & contour-based methods**
   - Use CNNs or morphological algorithms to extract the “skeleton” of the writing → baseline curves can be extracted even in degraded manuscripts.

Text Recognition and Transcription

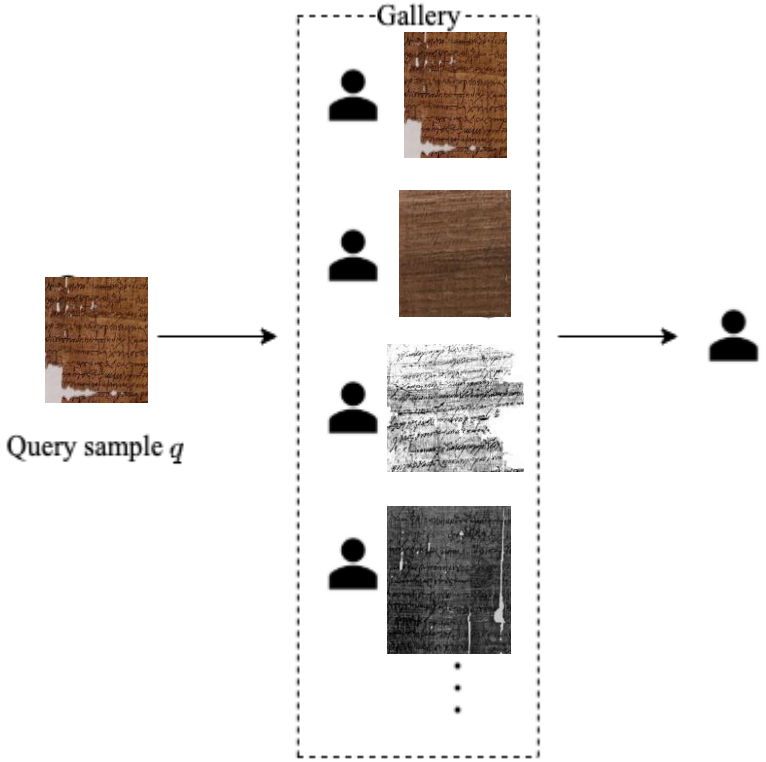


Text Recognition and Transcription

1. **Historical OCR**
   - Based on the possibility of subdividing words into characters and the following **classification** for their recognition.
2. **Handwritten Text Recognition (HTR)**
   - **CNN–LSTM** hybrids trained with **CTC loss**
   - **Transformer-based** models
3. **Visual Encoding – Textual Decoding**
   - Transformer-based OCR. Combines a Vision Transformer (ViT) encoder with a Transformer-based text decoder, trained end-to-end in a sequence-to-sequence fashion.
4. **Vision Language Models**
   - such as **Donut** or **BLIP-2**, are increasingly adapted to historical scripts, enabling in-context or few-shot transcription without large amounts of training data

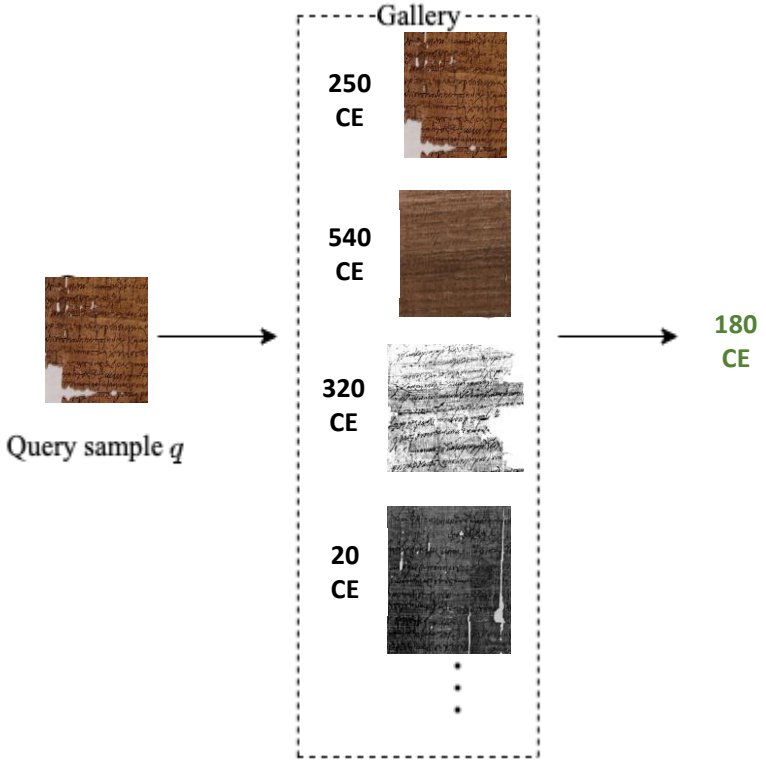
Classification and Attribution – Writer Identification

- Identify the hand of a particular scribe

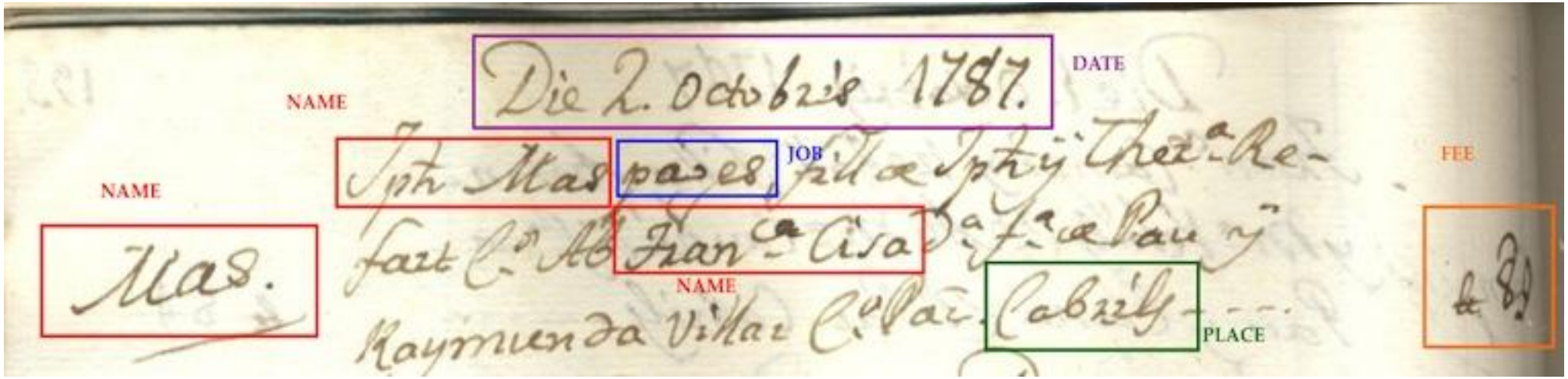


Classification and Attribution – Dating

- Estimate the creation date of a document



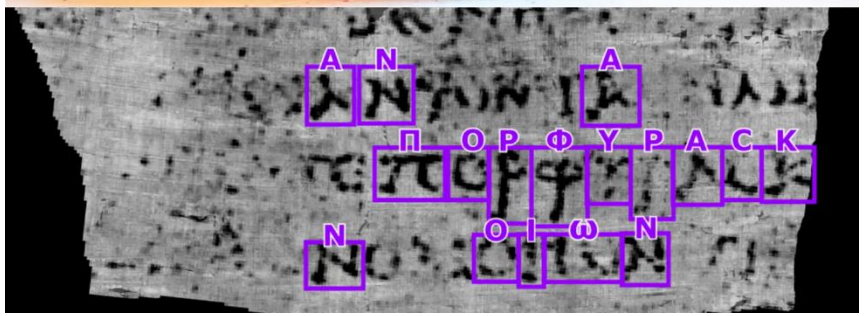
Linguistic and Semantic Analysis

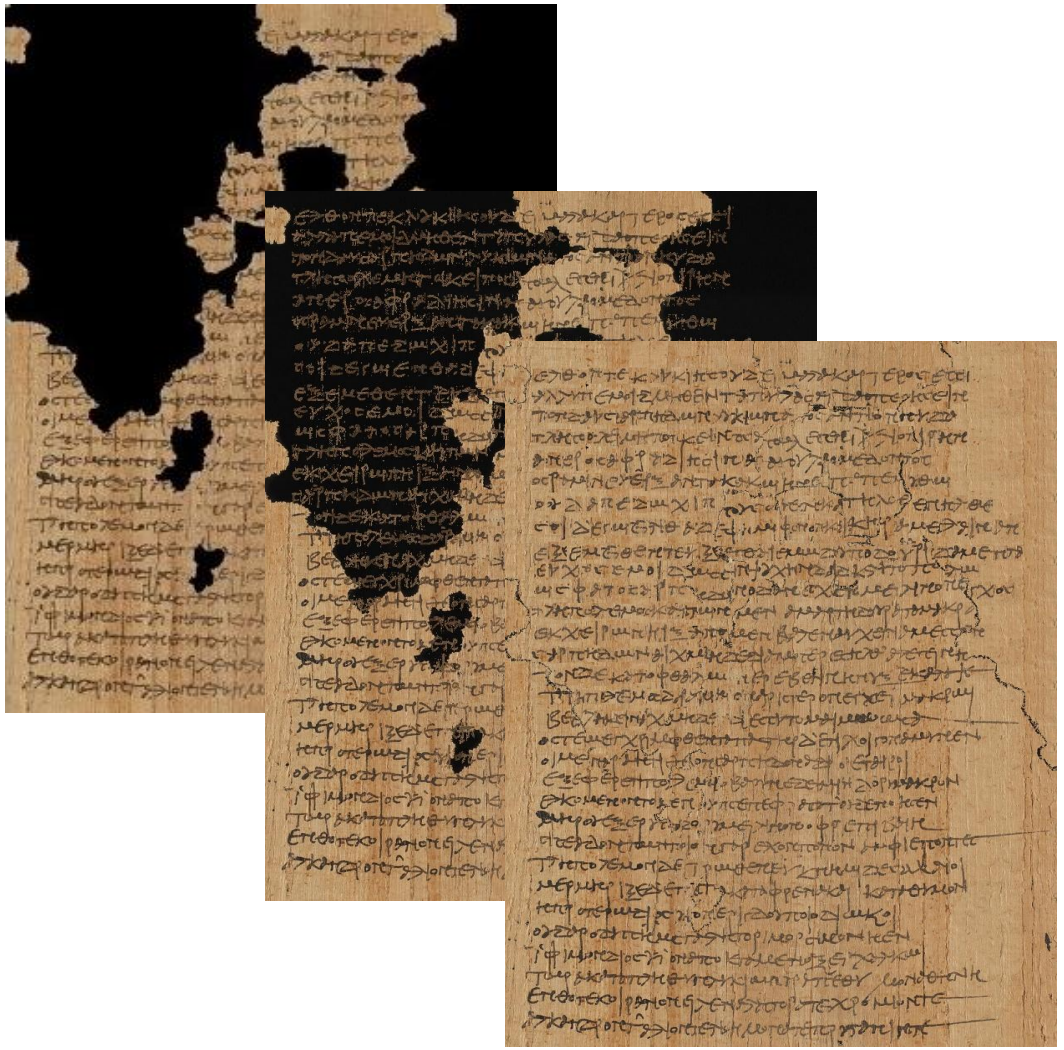


Linguistic and Semantic Analysis

1. **Named Entity Recognition (NER)**
   - Detecting **people, places, institutions, dates** in historical texts.
   - Often trained with **domain-adapted models** (e.g., spaCy/BERT fine-tuned on historical corpora).
2. **Information Extraction**
   - **Relation extraction**: linking names, events, and places (e.g., in charters or contracts).
   - **Event detection**: identifying historical events from chronicles or administrative records.
3. **Cross-lingual & Diachronic Analysis**
   - **Cross-lingual embeddings** → align different languages (e.g., Latin and Greek corpora).
   - **Diachronic embeddings** → track semantic change across time.
4. **Knowledge Graphs & Linked Data**
   - Converting extracted entities into **knowledge graphs** (e.g., people, places, events connected).
   - Enables integration with other historical datasets (archaeology, prosopography, epigraphy).

Restoration





Restoration

1. **Inpainting & Hole Filling**
   - **GAN-based inpainting**: learns to reconstruct plausible text patterns or parchment texture.
   - Used for **fragmented or damaged manuscripts**.
2. **3D Imaging & Tomographic Reconstruction**
   - **X-ray phase-contrast tomography** or micro-CT scans → used to "virtually unroll" scrolls (e.g., carbonized papyri from Herculaneum – Vesuvius Challenge).
3. **Deep Learning Restoration Models**
   - **Autoencoders** for denoising and reconstruction of missing text.
   - **GANs (pix2pix, CycleGAN)** → learn to translate degraded images into restored ones.
   - **Diffusion models** (emerging trend) for generative restoration with uncertainty estimation.

Some Datasets

IMPACT

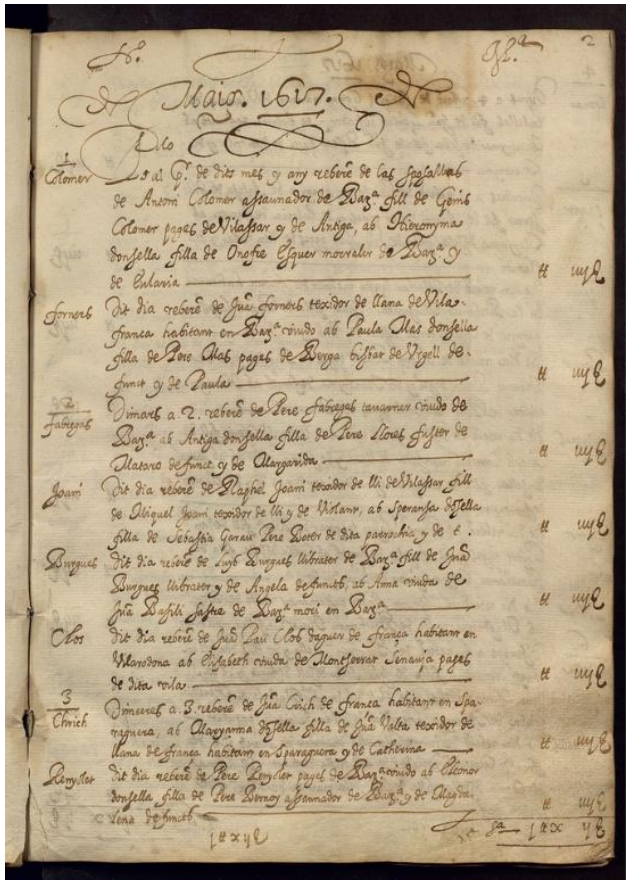
Early Modern to 20th Century - Layout Analysis - Different European languages

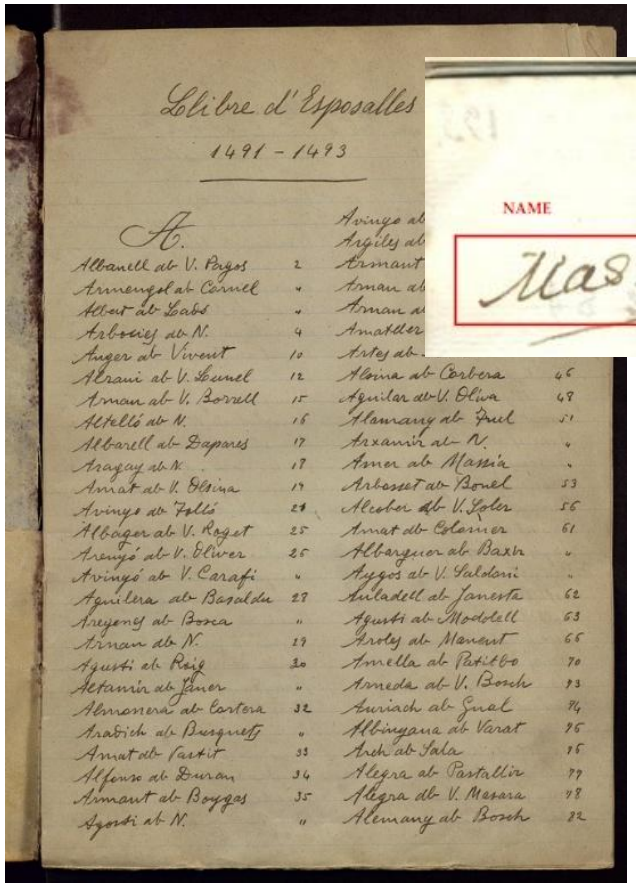
https://www.digitisation.eu/impact-dataset/

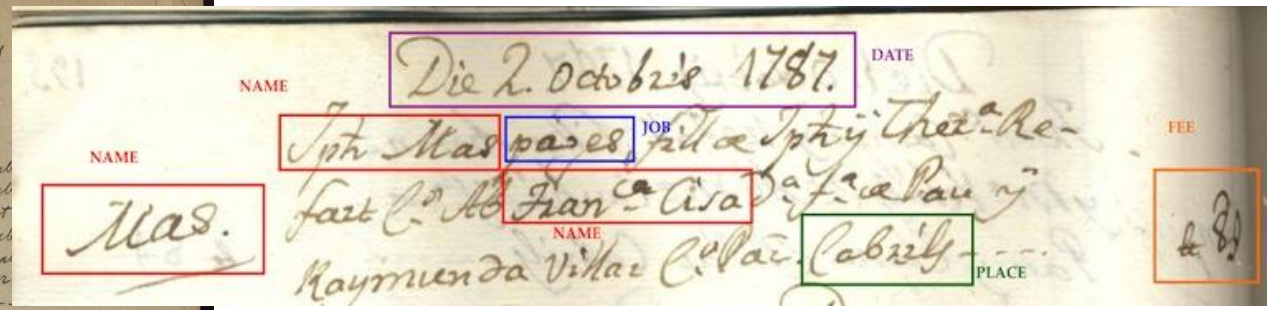
Esposalles

14th to 20th Century - Semantic Analysis - Spanish

https://dag.cvc.uab.es/dataset/the-esposalles-database/



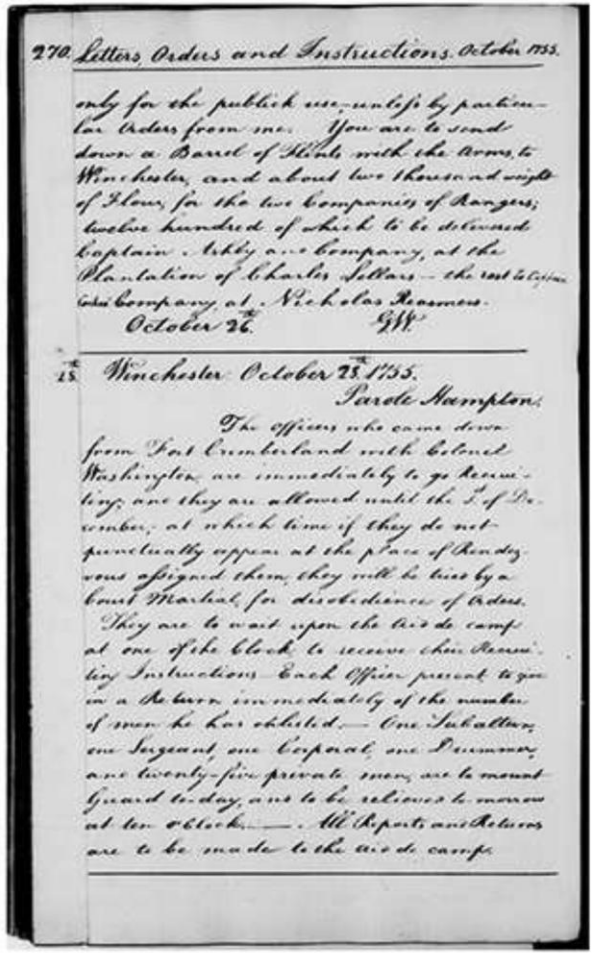




Washington

18th Century - Keyword Spotting / HTR - English

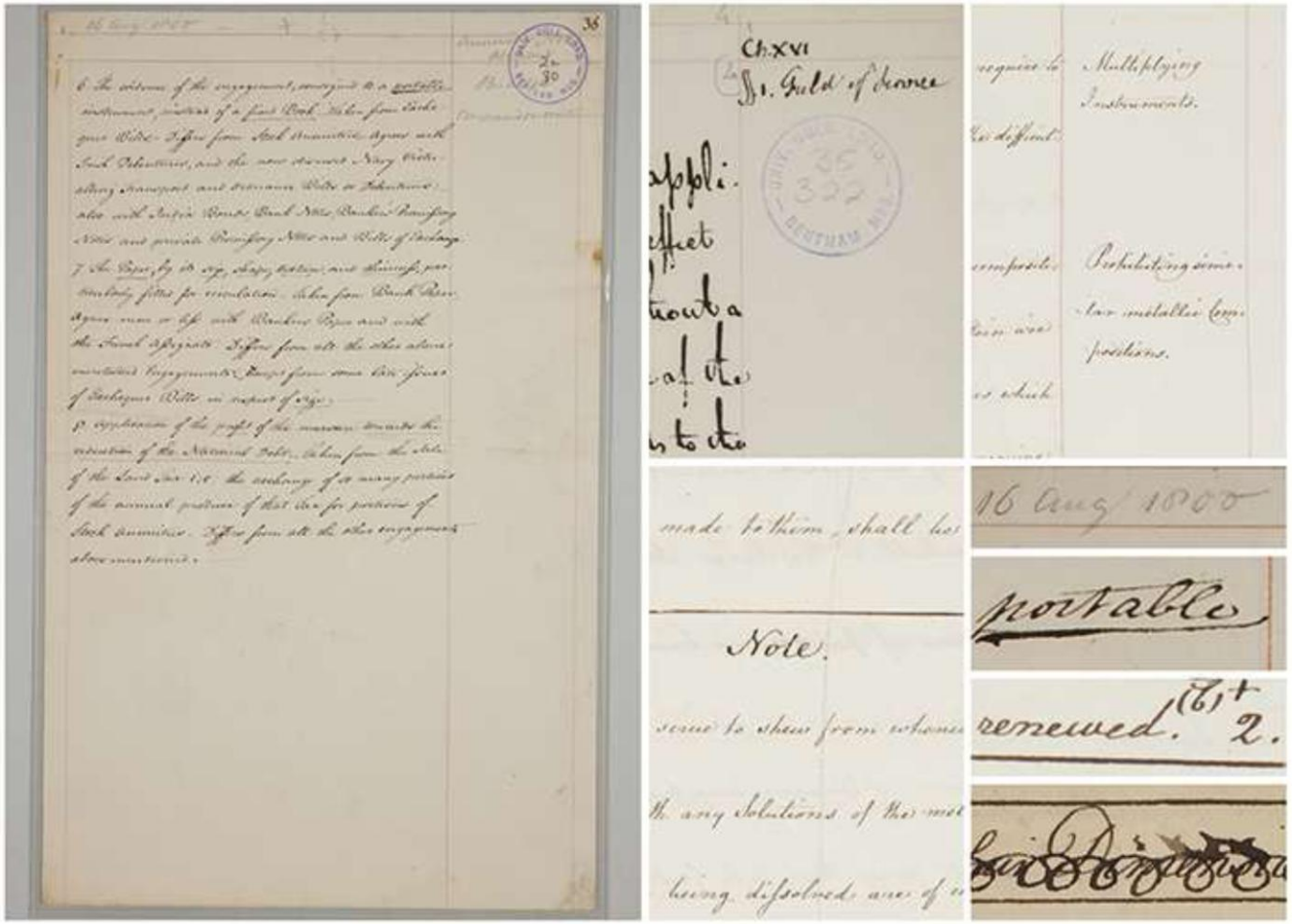
https://fki.tic.heia-fr.ch/databases/washington-database



Bentham Collection

18th Century - HTR - English

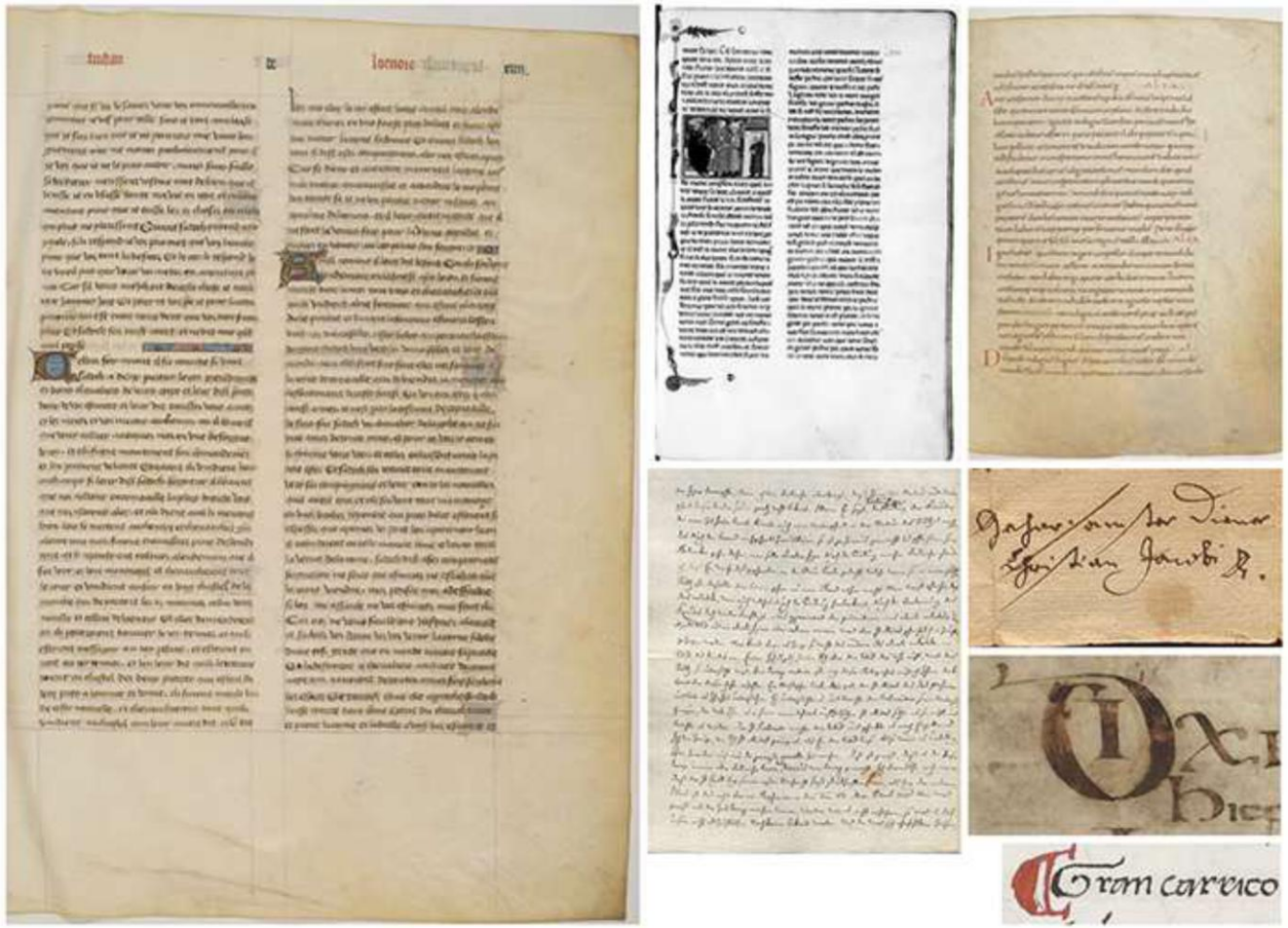
https://zenodo.org/records/44519



HisIR19

Medieval (9th to 15th) - Image Retrieval - Different European languages

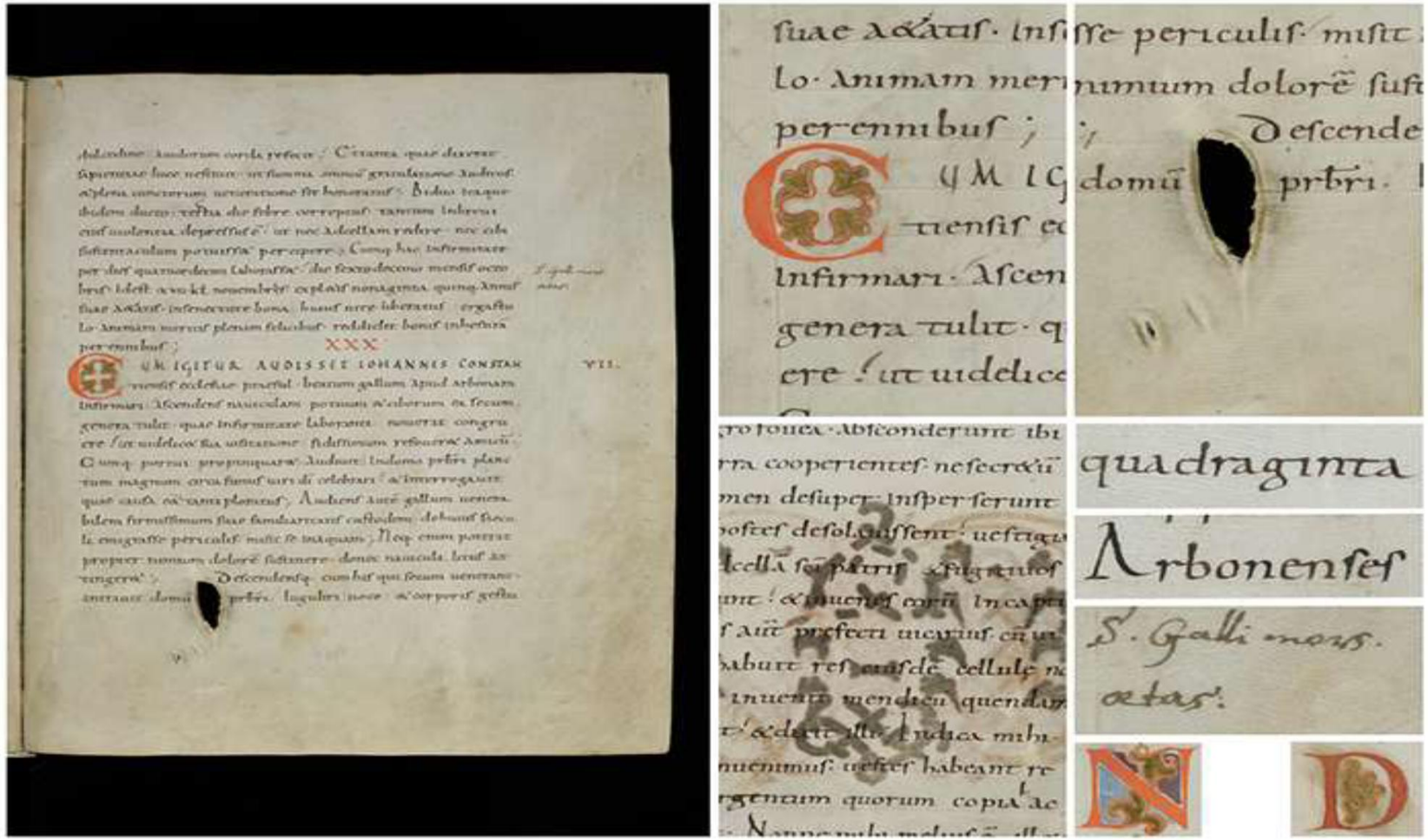
https://tc11.cvc.uab.es/datasets/HisIR19_1



Saint Gall

9th century - HTR / Line segmentation - Latin

https://fki.tic.heia-fr.ch/databases/saint-gall-database



Parzival

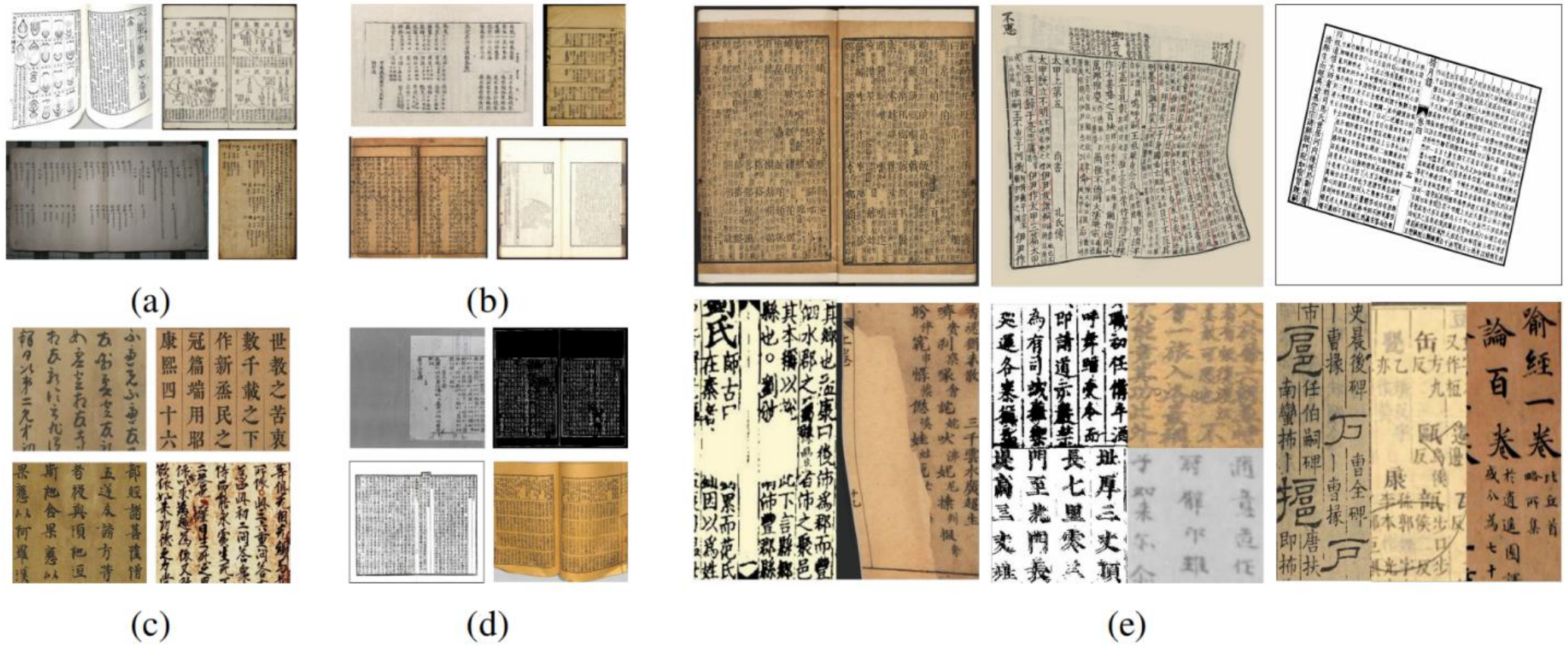
13th to 15th century - HTR - Old German

https://fki.tic.heia-fr.ch/databases/parzival-database

M5HisDoc

13th to 15th century - HTR - Chinese

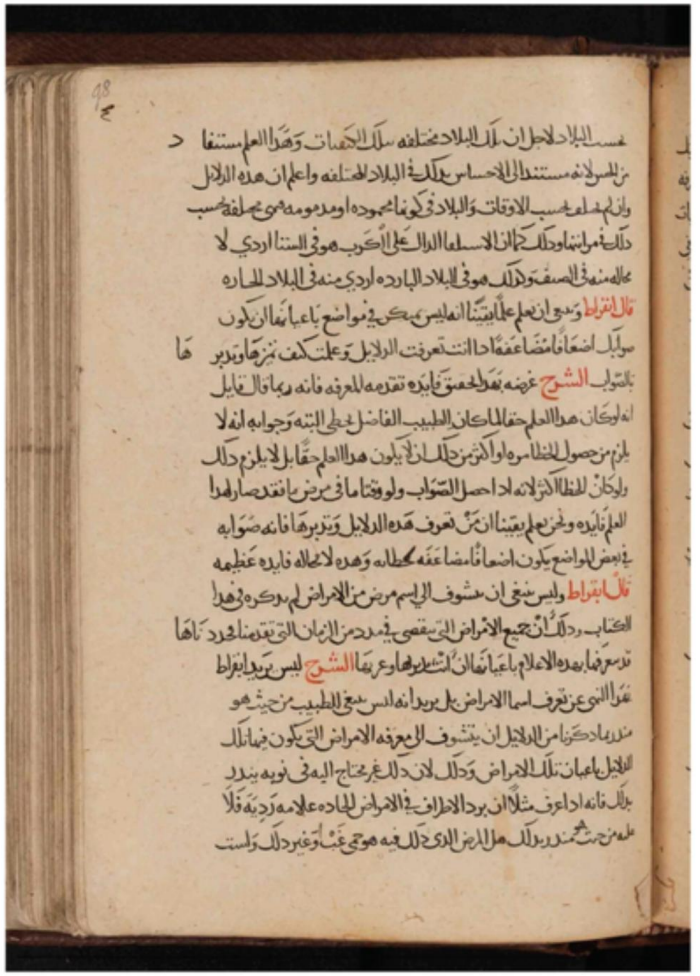
https://github.com/HCIILAB/M5HisDoc



KERTAS

1st to 14th century - HTR / Dating - Arab

https://qspace.qu.edu.qa/handle/10576/12024



GRK-Papyri

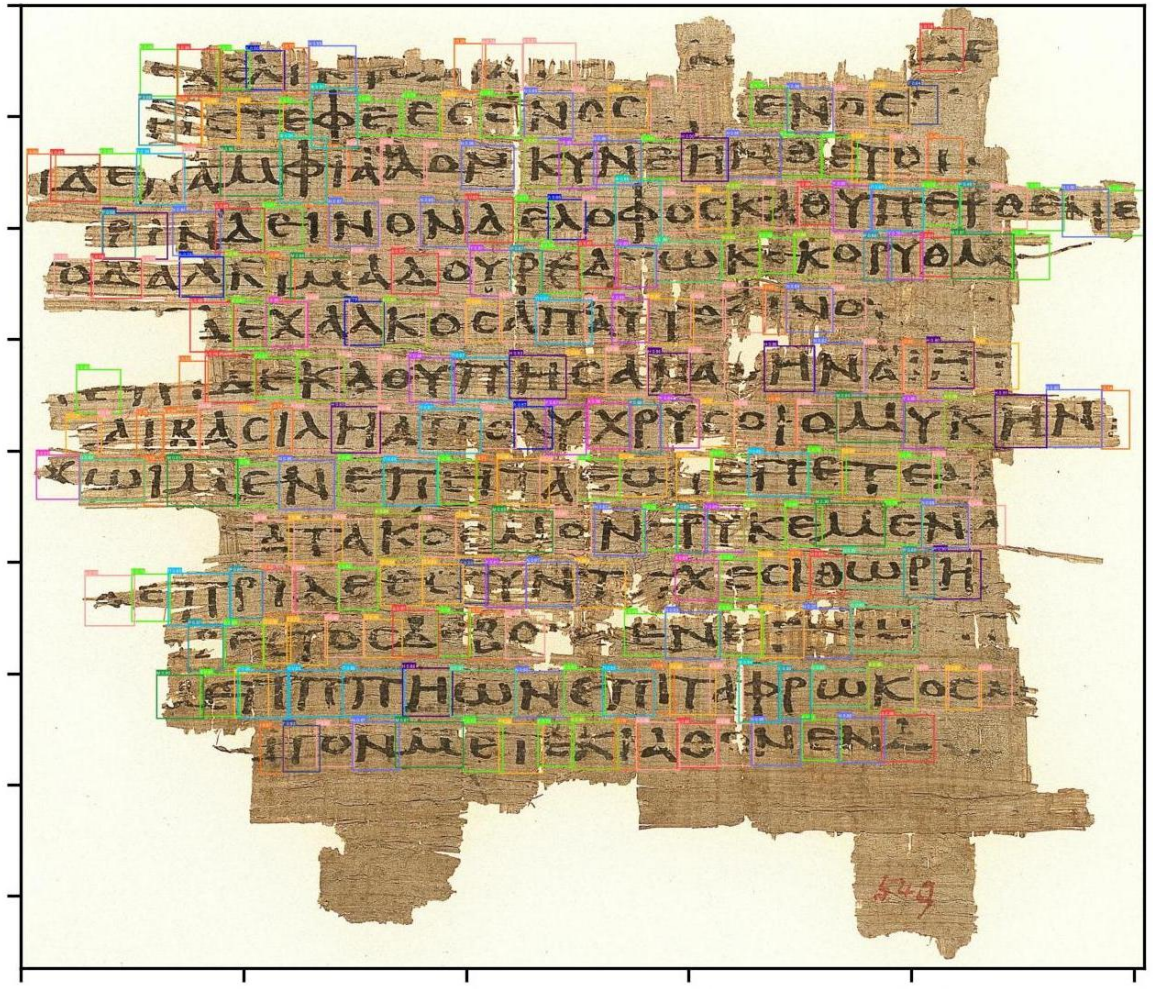
6th century - Writer Identification - Ancient Greek

https://d-scribes.philhist.unibas.ch/en/gkr-papyri/

DROGLOP

1st to 4th century - Character Detection - Ancient Greek

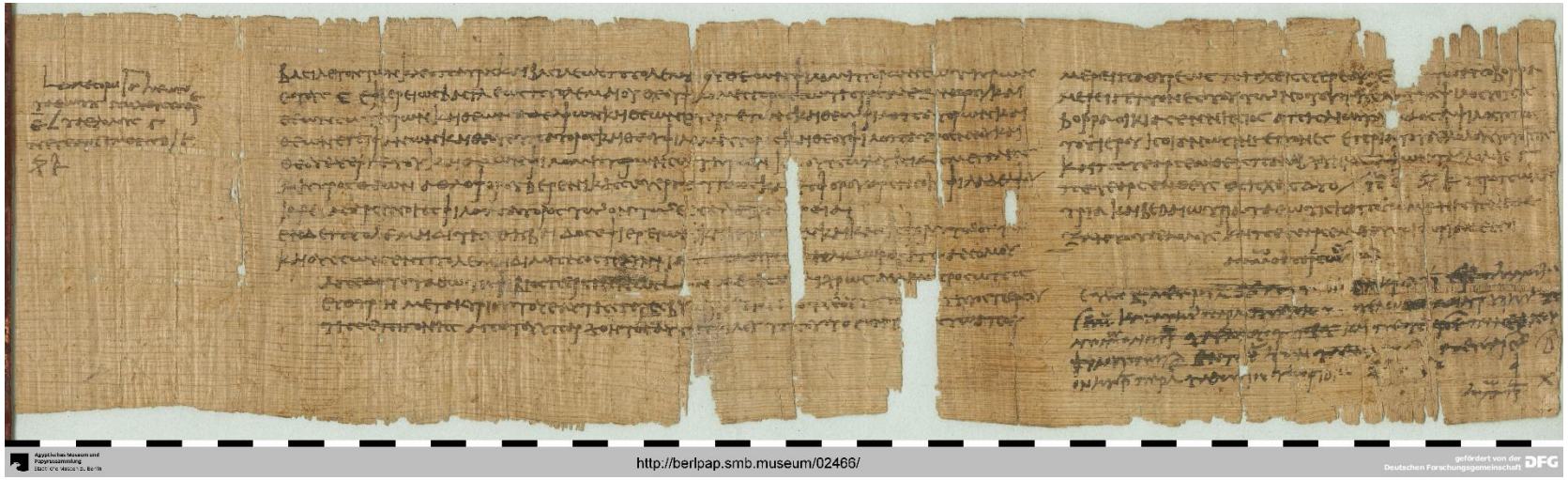
https://qspace.qu.edu.qa/handle/10576/12024

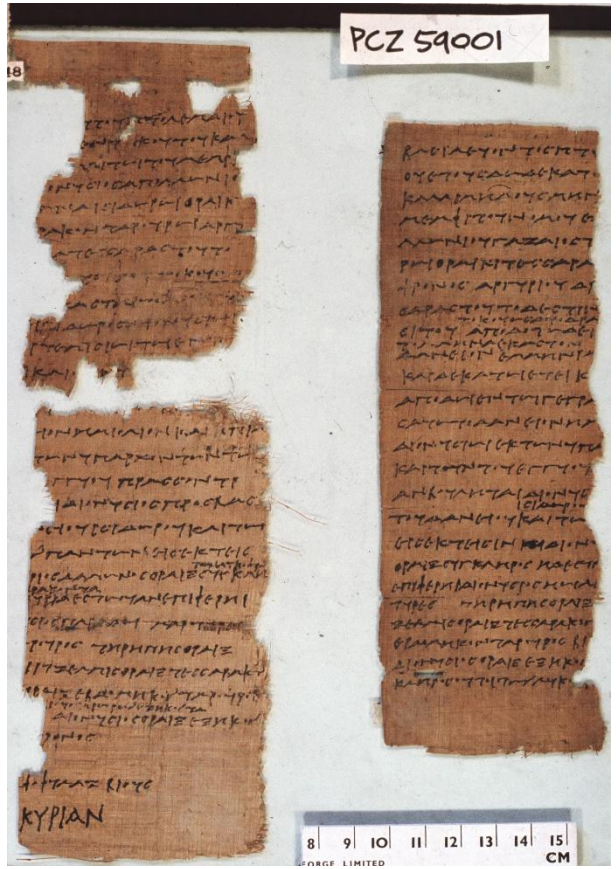


HellDate

3rd to 1st century BCE - Dating - Ancient Greek

https://zenodo.org/records/15830980





Other Datasets

- New datasets are constantly being published.
- ICDAR competitions are often organized about historical documents.
- Online archives of historical documents are available.

Online Archives - Be careful

https://papyri.info/

Papyri.info

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Ἀπλονοῦς Θερ[μουθ]ᾶτι
τῇ μητρὶ πλεῖσ[τ]α χα[ίρε]ιν·
πρὸ μὲν πάντων εὐχόμεθά σε
3,ms ⸢αρα
ὑγενιν(*) σὺν Ἀπλοναρίῳ. θέλω [σ]ε γι-
νώσκιν(*) ὅτι ἤκουσα παρὰ τῶν {ο} ἡ-
κώτων(*) μοι ὅτι ἠσθένηκος(*),
ἐχάρην δὲ ἀκούσασ[α] ὅτι κωμ-
σῶς(*) ἔσχηκος(*). ἐρωτῶ σε μεγά-
λως καὶ παρακαλῶ, ἐπιμέλου
ἑατῆς(*) ἅμα καὶ τῆς μικρᾶς ὡς
παρέλθ[η]τε τὸν χιμῶνα(*), εἵ-
να(*) εὕρομον(*) ἡμᾶς(*) υἱένωντος(*).
καὶ εἰμῖς(*) γὰρ πάντος(*) ὑγε[ν]ωμον(*).
καὶ περὶ τῆς Συρίας ἕ[ω]ς ἄρτι οὐδ[ὲ]ν
κακόν. ἐρωτῶ σε ἐὰν ἀκούσῃς πε-
ρὶ ⟦Τ⟧ Θερμουθᾶτος πέμψον μοι φάσ[ι]ν.
ἐρωτῶ σε, οὐ πρᾶγμά ἐστιν, ἐάν
τινα εὕρηται(*) καταβαί⟦ ⟧νωντα(*),
ἀποστῖλε(*) ὑμῖν(*) φάσιν περὶ τῆς
ὑγείας(*) ἡμῶν(*) καὶ τῆς μικρᾶς.

Image [open in new window]

Online Archives - Be careful

The Sigma Case

Σ

According to some analysis:

«*the letter sigma (Σ) results in being very rare in the Hellenistic-Roman period…*»

Online Archives - Be careful

The Sigma Case

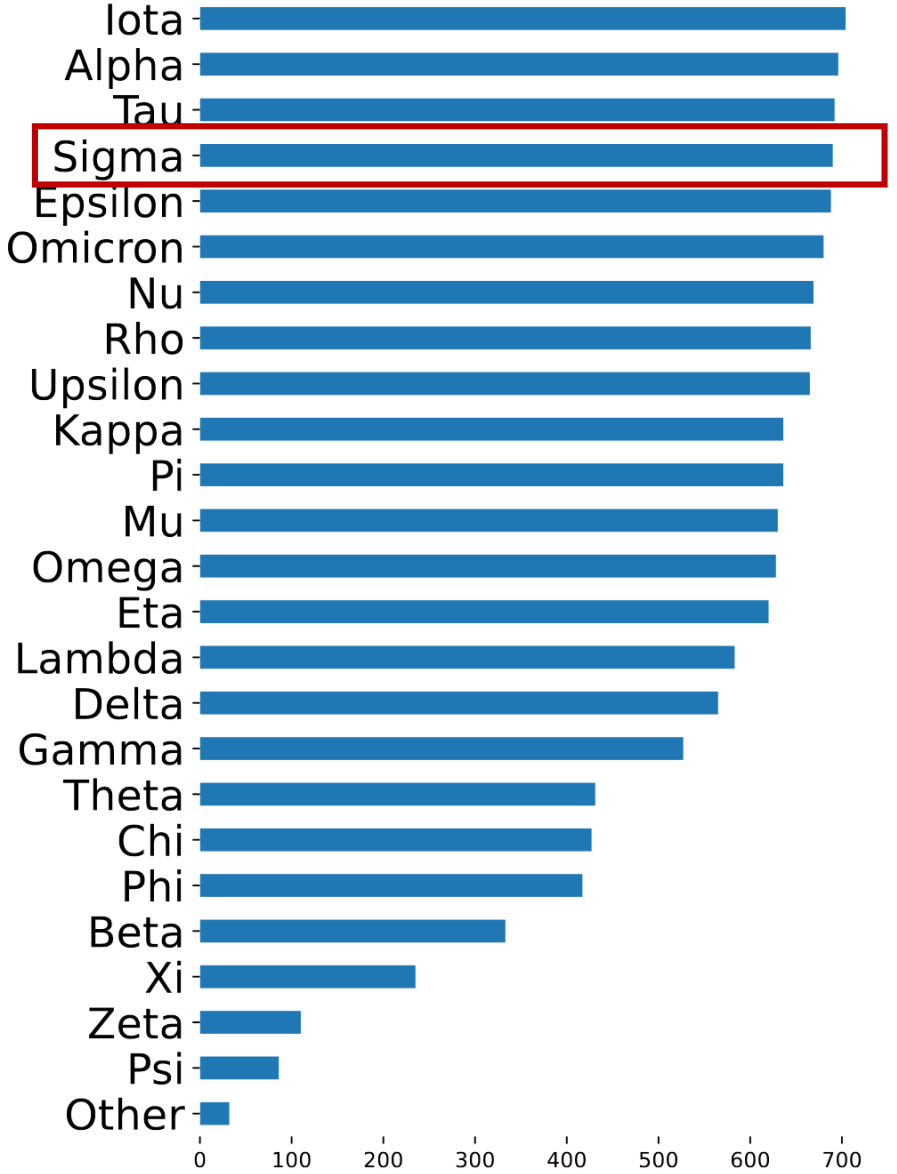

Figure 1. Letter frequency in our Hell-Char dataset

GitHub Tutorial:

https://github.com/giuseppedeg/ICDAR25---Tutorial-Historical-Documents-in-Focus

GliFix Tool:

https://glyfix.scicore.unibas.ch/