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Distant-Viewing Alchemical Laboratory Apparatus in Early Modern Print

Computer Vision approaches to detecting scientific illustrations in metallurgical texts

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Illustrations in Early Modern Technical Literature

- The **'New Historiography of Alchemy'** (Principe and Newman 2001) has transformed the history of science, resulting in an 'alchemical revolution' (Reardon 2011) which rehabilitates the tradition from its previous bad reputation as pseudo-science.
- The rise of the **Experimental History of Science** (Fors, Principe, and Sibum 2016, p. 85) leads scholars to embrace experimental 'RRR' methods: reconstruction, replication, and re-enactment (Hendriksen 2020, p. 314) which are now the standard in history of science (Martinón-Torres 2011)

→ growing interest in crafts knowledge and everyday practices linked to the foundations of modern natural sciences and chemistry (P. H. Smith 2006, p. 292).

A prime example for this trend is *The Making and Knowing* Project

...which focuses on recreating historical craft recipes (P. Smith 2020).

First (Al-)Chemical Laboratories

1. Transition from multi-purpose spaces to professional chemical laboratories in the 17th century (Morris 2015, p. 19–20).
2. Coincides with the boom of metallurgical technical treatises (Morris 2021).
3. Empirical evidence of early laboratories is scarce (Lang 2023).

Early Modern Technical Tracts as Sources

Such handbooks...

1. contain rich illustrations in handbooks on distillation, metallurgy, and mining.
2. provide invaluable insights into the laboratories, processes, and practices of the *artes technicae*.
3. remain relatively understudied despite their significance for the history of technology.

Depicting Mining, Metallurgy, and Distillation

- Chymistry, metallurgy and mining flourish during the proto-industrial revolution.
- Emergence of encyclopedic compendia detailing technological apparatus and processes & metallurgical technical treatises with technical illustrations
- Key montanist works include...
    1. Agricola's *De re metallica libri XII* (Agricola 1557),
    2. Biringucci's *De la pirotechnia Libri X* (Biringuccio 1550),
    3. Ercker's *Aula subterranea* (Ercker 1672), and
    4. della Porta's *De distillatione libri IX* (Porta 1609).
- Accessibility of knowledge in books replaces travel & in-person exchanges with experts (Giesecke 1991).
- Importance of illustrations and indices as finding aids within those compendia.

Distillation Treatises in the 16th Century

Emergence of Distillation Treatises

- Rise in popularity of distillation-focused literature (Laube 2022).
- Influential works:
  1. Brunschwig's *Liber der Arte Distillandi* (Brunschwig 1512) and
  2. Ryff's *Distillierbuch* (Ryff 1545).

Hieronymous Brunschwig

- Numerous versions, translations, and re-editions of Brunschwig's works testify to their popularity and influence (Laube 2022, p. 284–287).
- Transition from the 'small distillation book' to the more extensive 'large distillation book' (Brunschwig 1512).

Research Agenda & the Case for Automatic Object Detection i

- Reuse of illustrations in early modern prints, like modern stock photography (Götzelmann 2022) leads to the separation of images from their original contexts.
- Images don’t always illustrate the exact content of the text passages.
- Richly illustrated works in medical, herbiary, and distillation books are only possible due to illustration reuse.

Lazarus Ercker's *Aula Subterranea*

- Ercker's handbook is detailed enough for process replication.

$\rightarrow$ can be used to check how faithful representations in other books of the genre are.

Proposed Solution

- Application of computer vision for automatic detection of illustrations, specifically object detection.
- Aiming at a quantitative analysis of apparatus within chymical literature focusing on mining, metallurgy, and distillation in 16th-17th century print-

Detecting Alchemical Apparatus

Related Work in Computer Vision and Early Modern Illustrations

- Previous works focusing on whole illustrations in 15th/16th century print (Malaspina and Zhong 2017; Dutta, Bergel, and Zisserman 2021; Götzelmann 2022).
- Classifying illustrations as woodcut or copperplate engravings (Cormier, Park, and Beck 2020).
- Comparative systems for analyzing print copies and different states (Pflüger et al. 2020).
- Empirical studies on visual similarity in early modern scientific illustrations (Valleriani et al. 2023).
- Large-scale studies on image collation in manuscripts (Kaoua et al. 2021).

Adapting Existing Methods to the Specific Use Case

- Need for detecting singular objects in complex illustration scenes.
- Absence of existing methods for object detection in 16th/17th century book illustrations.

First Experiments with Out-of-the-box Methods

- Testing with out-of-the-box methods like the *Distant Viewing Toolkit*, *Segment Anything*, and OWL-ViT.
- The challenge probably lies in labeling and differentiating specific early modern objects (classification), not so much detecting and segmenting them.
- Does the etching style pose issues to the algorithms?

Segment Anything example output

Compiling Training and Evaluation Corpus

- Compilation of training data from books on mining, metallurgy, and distillation.
- Use of standard works with varying illustrations across editions and print shops.
- Evaluation corpus includes books from broader alchemy-related topics.
- **Objective:** evaluate detection of laboratory equipment and specific objects in illustrations.

Testing with OWL-ViT

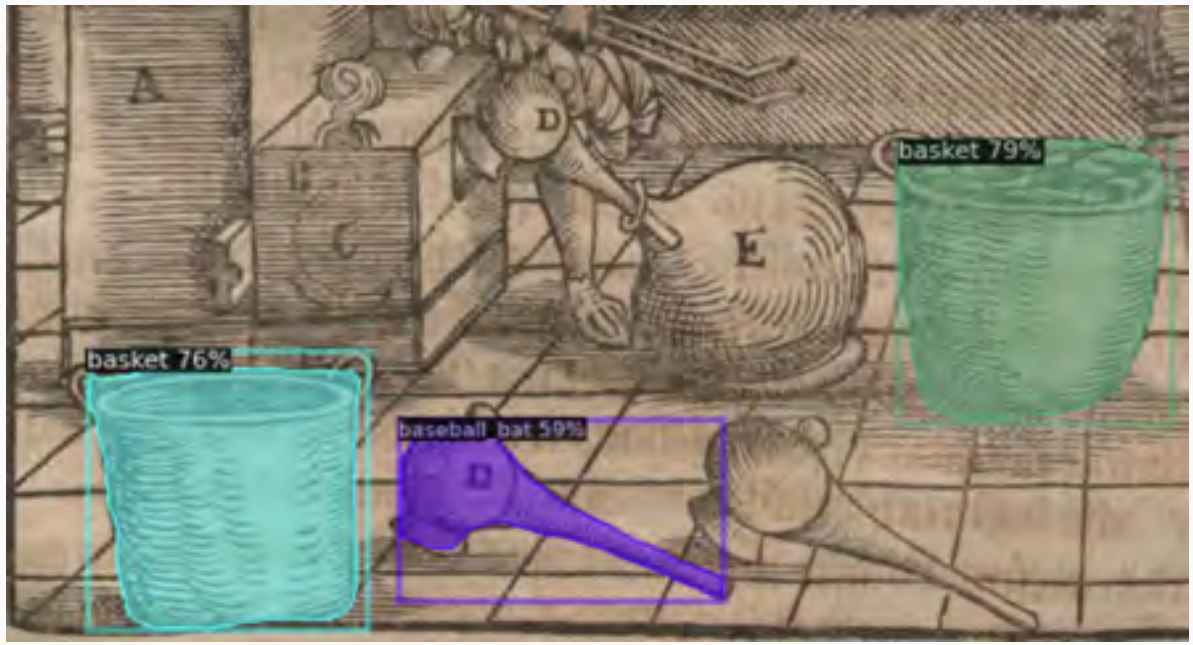
- OWL-ViT's has difficulty distinguishing alchemical from non-alchemical apparatus.
- probably due to training on benchmark corpora of modern, very distinct objects.
- Need for approaches that can handle stylistically similar and overlapping nature of early modern illustrations.

OWL-ViT visual query results on Ercker's *Aula subterranea*.

Distant Viewing Toolkit: Zebras & baseball bats

Distant Viewing Toolkit Challenges

- correctly labeling allegorical images.
- **Example:** Mislabeling an allegorical alembic as a zebra.
- labeling biased towards unrelated modern objects like baseball bats.



(Arnold and Tilton 2019).

The Alchemy of Annotation

The Alchemy of Annotation

- Semi-automatic annotation of images using the Supervisely platform.
- Goal: Improve model training with detailed annotations.
- Result: Creation of pixel-level labels for components of alchemical apparatus.

Alchemistic Equipment Classification

Based on the work at Herzog August Bibliothek Wolfenbüttel (Frietsch 2017):

- Use of IconClass classification for alchemy.
- Focus on relevant and frequent categories in the corpus.
- Introduction of additional classes like *ambices*.

49E3931 alchemistic vessels
- **49E39311** bottles (*ampullae*)
  - philosophical egg (*ovum philosophicum*)
  - pelican
  - phial
  - receiver (*receptaculum*)
- **49E39312** flasks (*cucurbitae*)
  - alembic
  - Moor's head
  - *operculum*
  - retort
  - rosenhut
- **49E39313** pots, jars (*ollae*)
  - aludel
  - chalice
  - crucible
  - cupel

49E3932 alchemistic furnace
- assay furnace
- athanor
- carburizing furnace
- 'slow Harry' (*piger henricus*)
- reverberatory furnace
- smelting furnace

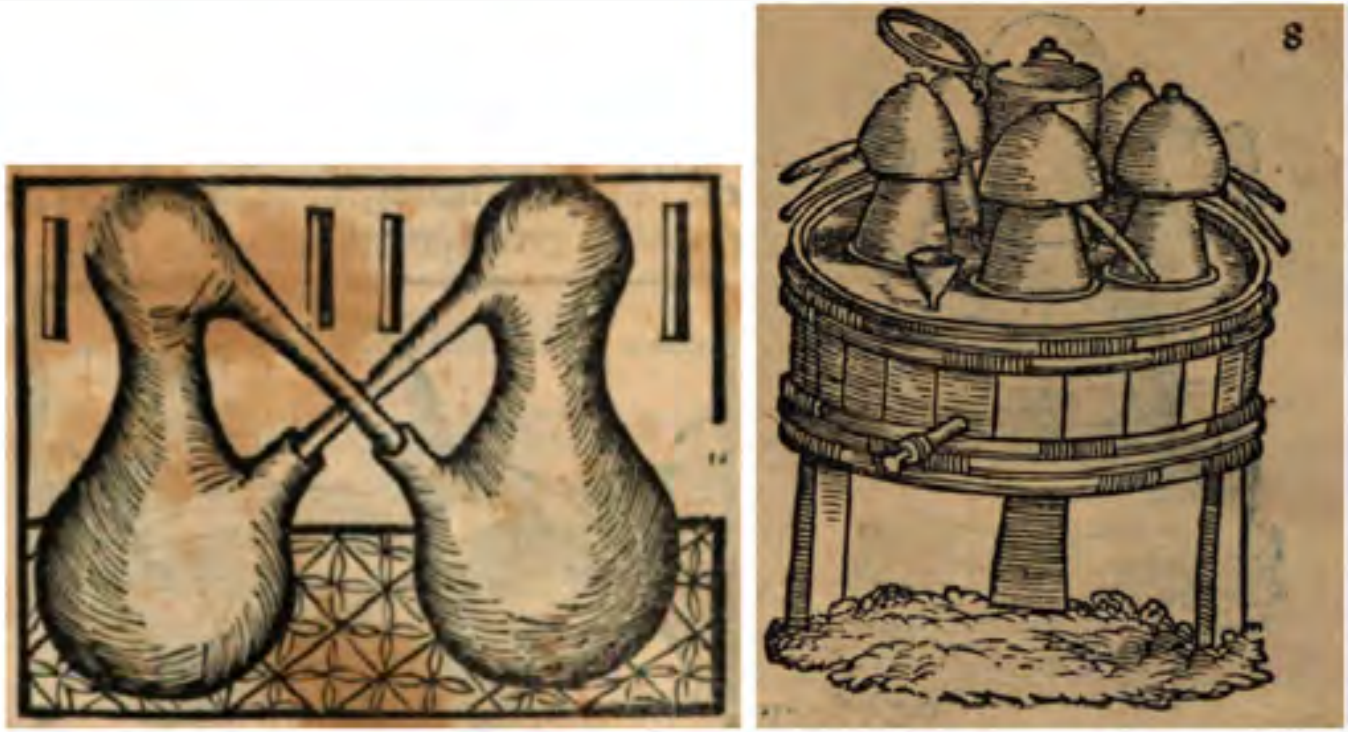
49E3933 alchemistic bath (*balneum*)
- *balneum arenae*
- *balneum Mariae*

49E3939 other alchemistic equipment

Figure 4: The category 'Alchemistic equipment' (49E393, https://iconclass.org/49E393) from Ute Frietsch's IconClass tags for alchemy [50].

Annotation Strategy

- Balancing number of classes with interpretability.
- Some distinctive alchemical tools excluded from annotation (e.g., alembics, moor's heads).
- Focus on explicitly alchemical tools to detect alchemical contexts.



Excluded classes: alembik and moor's head (Brunschwig 1512; Kerzenmacher 1589)

Preliminary Results

Introduction to Distant Viewing in DH

Challenges in Adapting Models for DH

- Rapid evolution in the DH sub-field of *Distant Viewing*.
- Enthusiasm for computer vision techniques.
- Challenges in object detection in early modern chemical apparatus depictions.
- Difficulty due to unique visual style and lack of familiarity with alchemical equipment.

Experimenting with Visual Feature Descriptors

- Use of ORB method for unsupervised clustering (Rublee et al. 2011).
- Approach initially designed for exact image reproduction.
- ORB's failure to identify patterns in early modern etchings.

Pixel Segmentation Approaches

Utilizing U-Net and SegFormer

- Deployment of U-Net with ResNet-34 backbone (Ronneberger, Fischer, and Brox 2015).
- Some correct plant detection, but overall erroneous classification.
- ResNet-based segmentation reaching only 33.0% accuracy after tuning.
- SegFormer B1 with occasional object area identification but incorrect categorization (Xie et al. 2021).

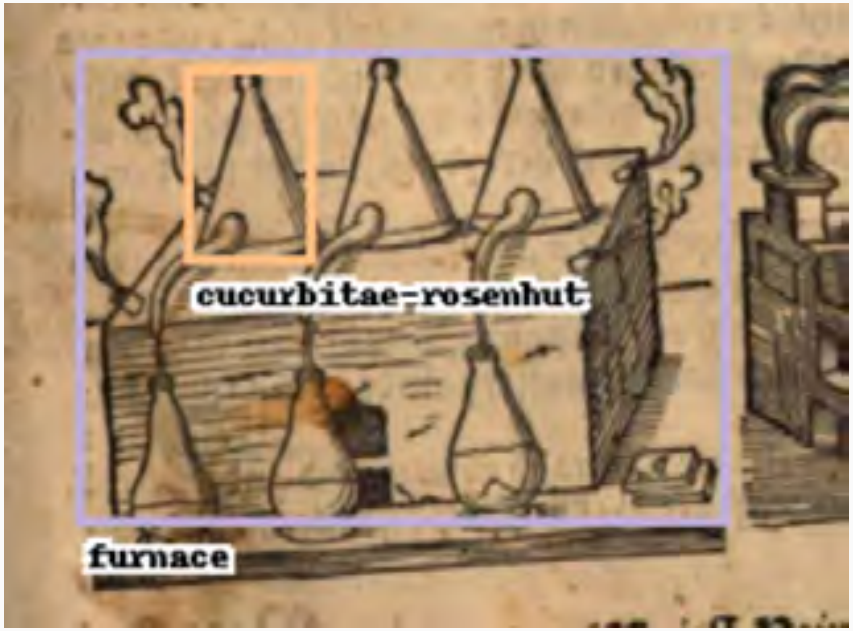
Exploring Representation Learning

Assessing Non-Supervised Models

- Use of SimSiam and SimCLR for unsupervised clustering.
- Siamese networks for unsupervised visual representation learning.
- SimCLR leveraging data augmentation for contrasting visual representations (Chen et al. 2020).
- Both methods underperforming on historical data.

Experimenting with YOLO Object Detection

- Application of YOLO version 8 for object detection.
- Challenges in detecting objects accurately.
- Difficulty due to distinct visual style of early modern etchings.



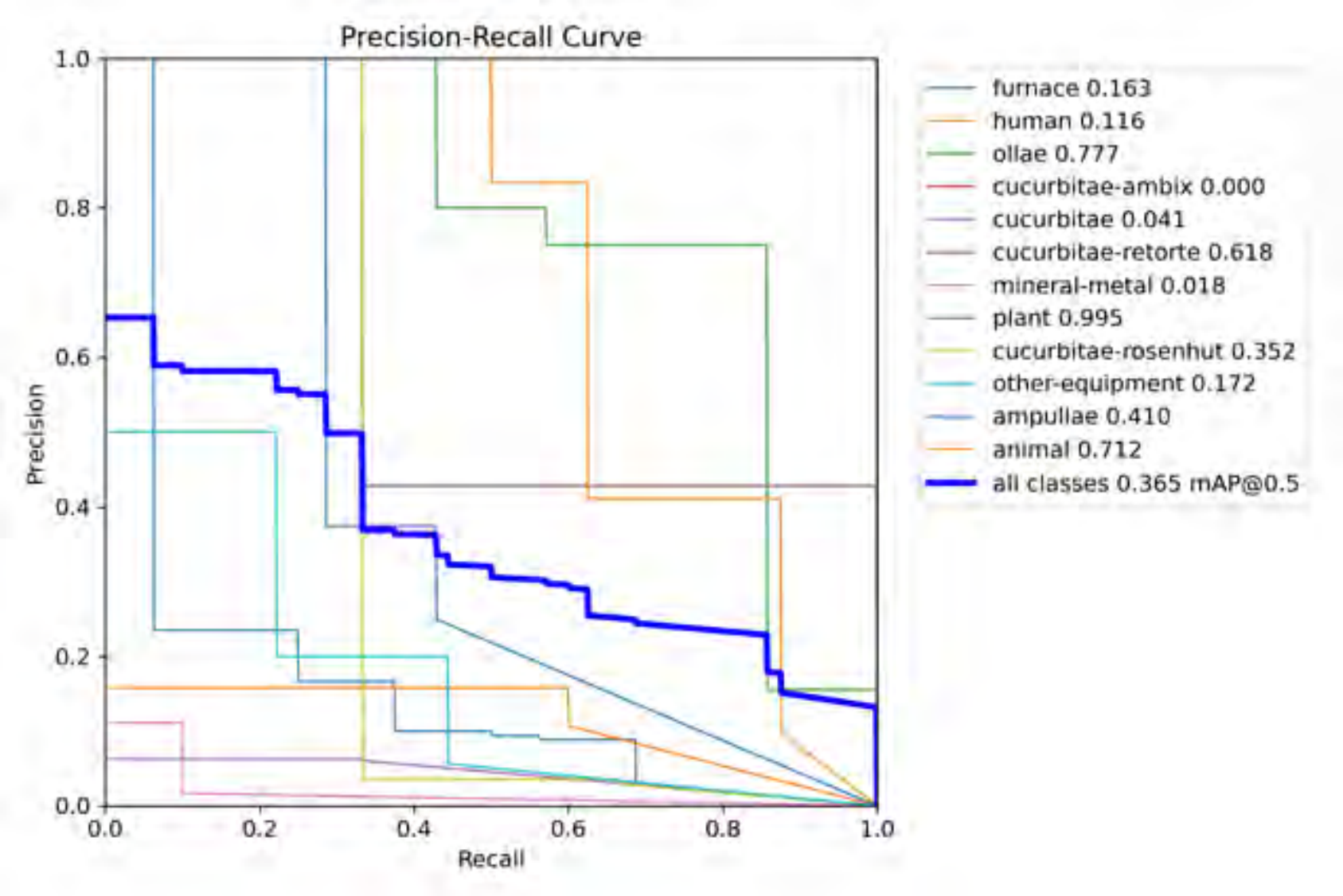
Annotation overlap issues affecting YOLO detection (Kerzenmacher 1589).

YOLO Training and Challenges

Training Approach and Results

- 50% of each class used for training, remaining for validation.
- Stratified sampling complicated due to overlapping labels.
- Custom algorithm used for image partitioning.
- Selected best training-validation split for minimal stratification error.

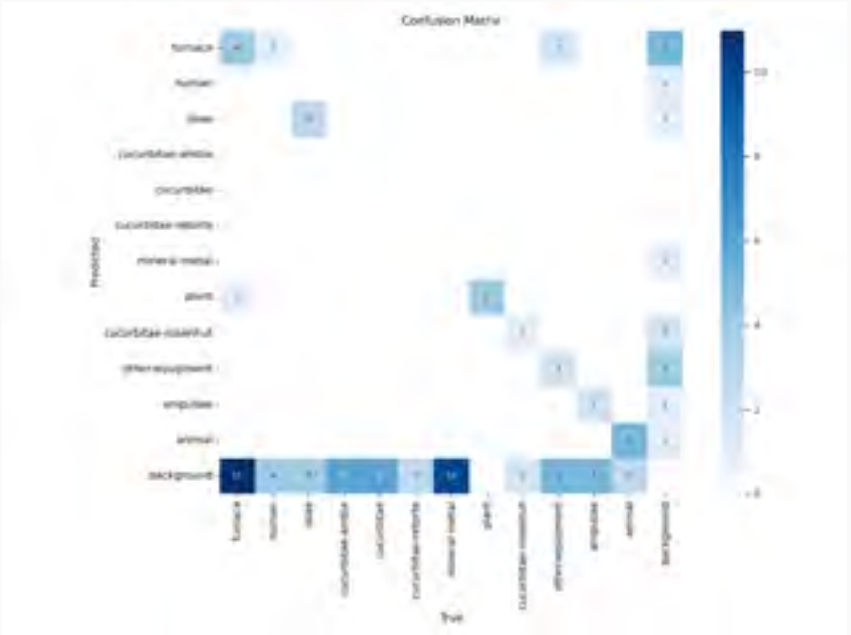
YOLO Training and Challenges



Precision-recall curves showing model learning progress.

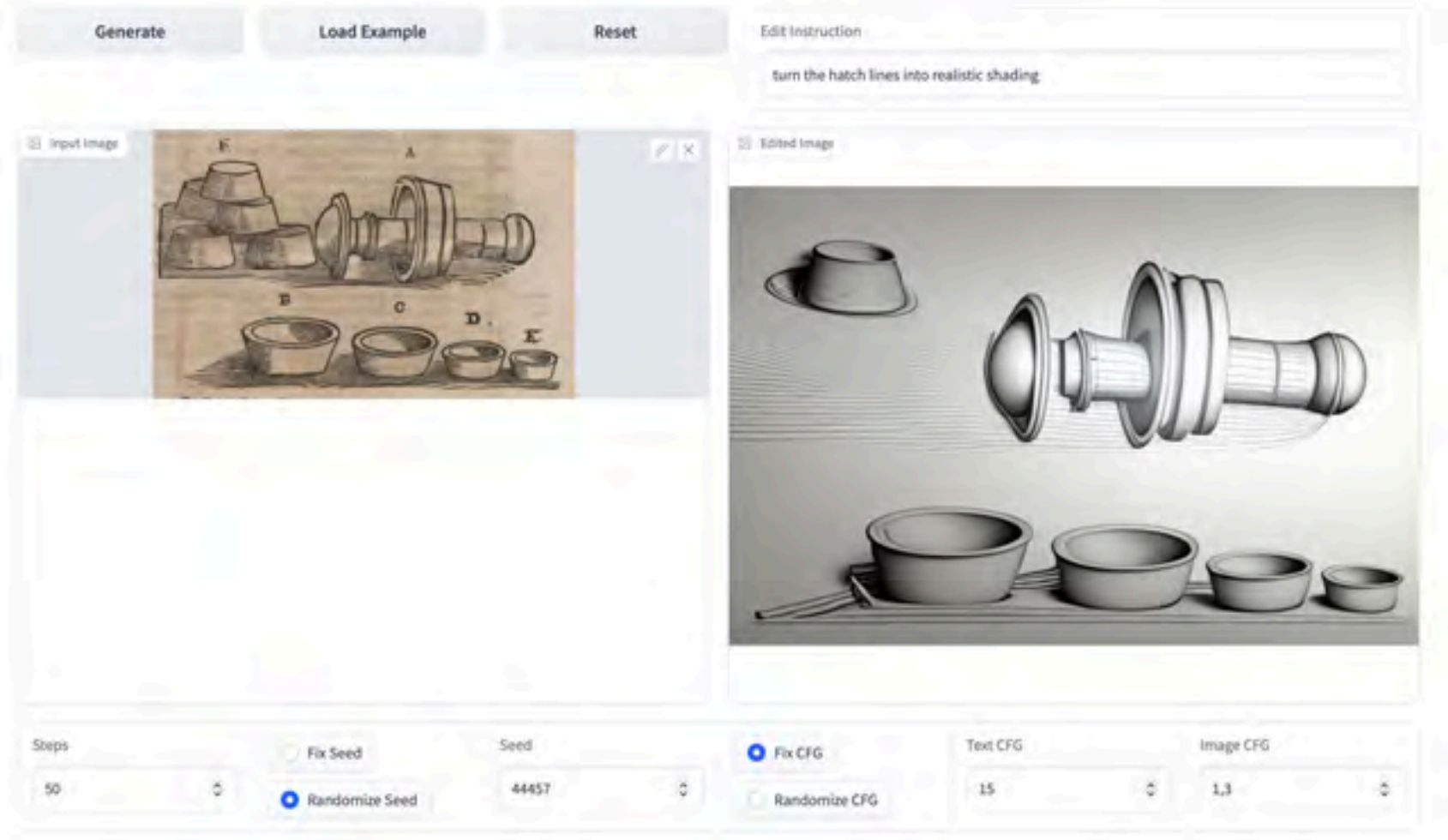
Analysis of YOLO Performance

- Challenges with object localization, not classification.
- Better detection of ‘plants’, ‘ollae’, and ‘animals’.
- Low precision in other classes.
- Issues with training data variance and annotation numbers.



Confusion matrix showing model learning but with poor results.

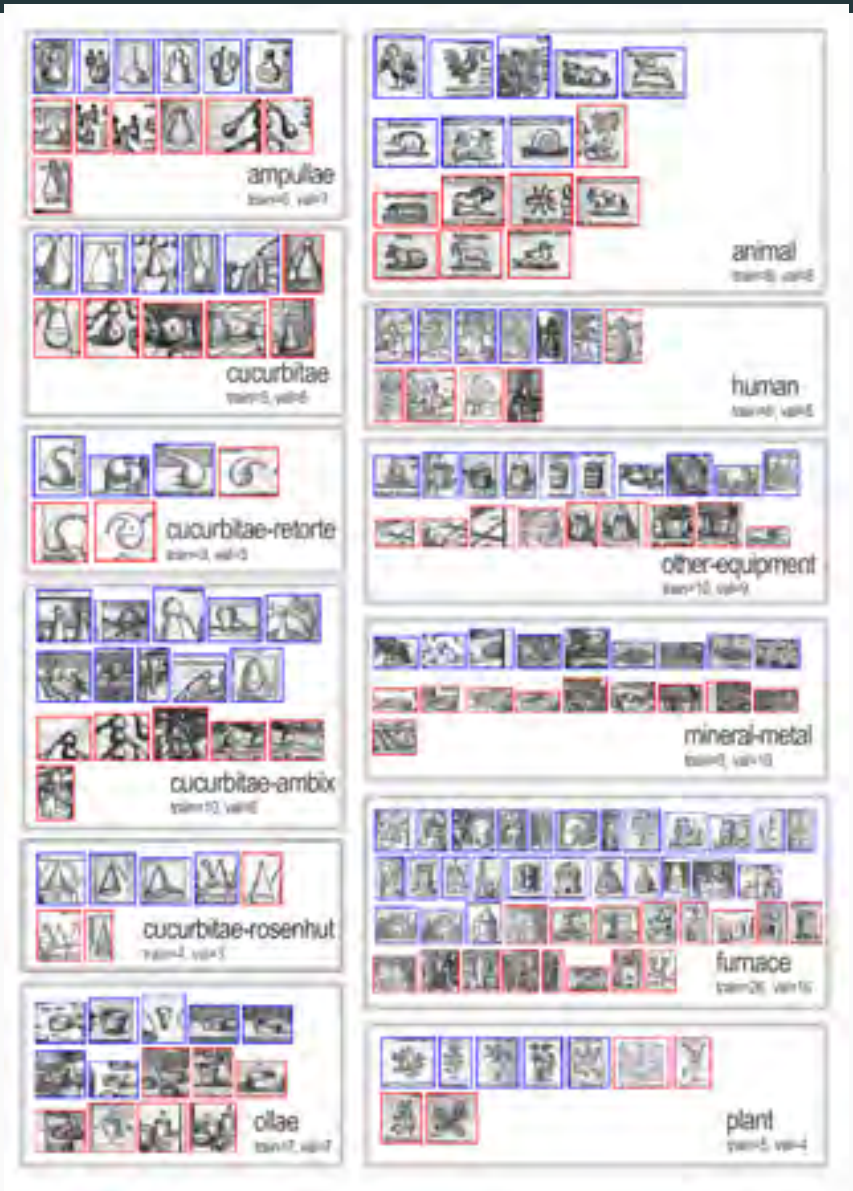
Future Work: Style Transfer



Style transfer using *instructpix2pix*, showing promising results but losing key features (Ercker 1598).

Annotation Variance and Training Set Distribution

- Complications with stratified sampling due to label overlap.
- Creation of non-overlapping sub-images for training and validation.
- Challenges in annotation due to image style and overlapping labels.



Training and validation sets by category, illustrating high visual

Conclusions and Future Work

Conclusions and Future Directions

- Early enthusiasm met with significant challenges in object detection.
- Unique challenges of early modern etchings for current models.
- Potential directions: one/few-shot approaches, style transfer, leveraging VLMs.
- The need for nuanced and data-specific approaches in DH.

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