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Archeologický ústav AV ČR, Brno

Workflow pro automatické rozpoznávání archeologických nálezů pomocí umělé inteligence (AI)

Workflow for Automated Archaeological Artifact Recognition using AI

Petr Pajdla & Ronald Harasim

Motivation and objectives

- **Manual processing** of archaeological archives is a tedious, time consuming, and **challenging task** prone to human errors and inconsistencies…
- This makes it a prime candidate for **automation**.
- Archives of **ARUP** & **ARUB** hold around:
    - **~140k** documents, ie. **~1.5m** pages
    - **500k** of various photographs
- **Improve/enhance** metadata in the Archaeological map of the Czech Republic and ARIADNE services.

(Imgaes: Archive of the Institute of Archaeology, Czech Acad. Sci, Brno)

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Advancing Frontier Research in the
Arts and Humanities

- Horizon EU project
- Focus on workflows and demonstrators

*“**Facilitating access** to digital **research infrastructures** and advancing frontier **knowledge in the arts and humanities** — across **disciplines, languages** and **media.**”*

Transnational Access – Travel Grants

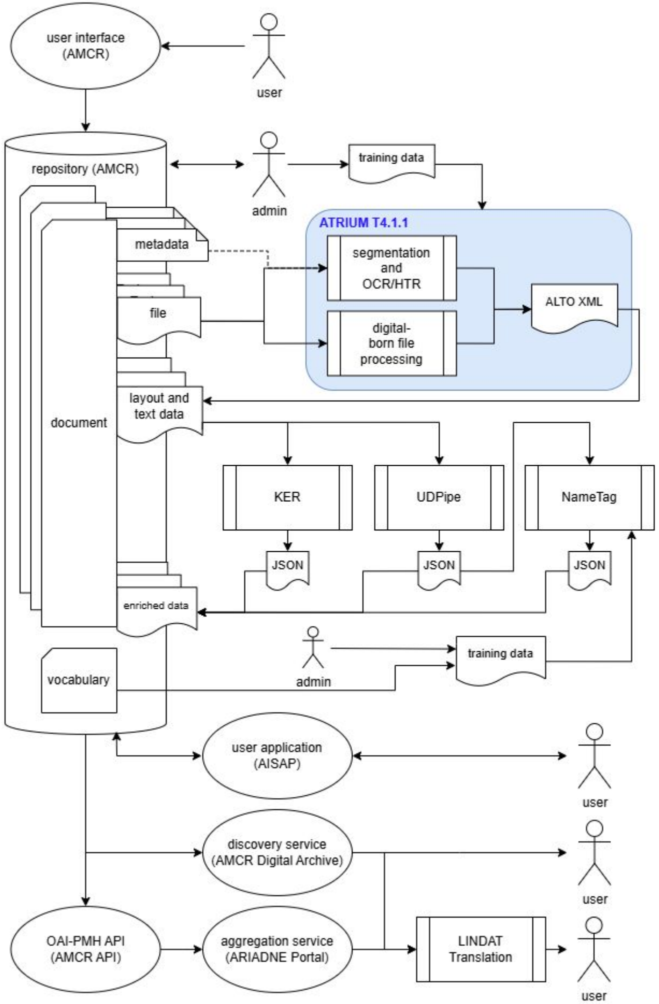
- Current call for applicants is open until 31 May, 2025!
  http://atrium-research.eu

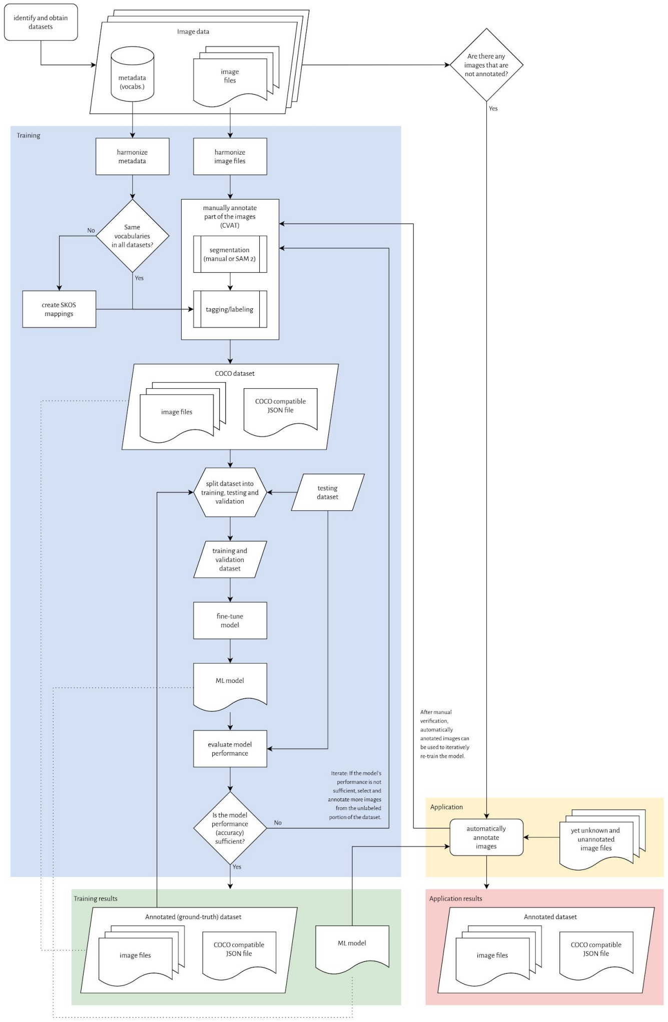
Workflows overview

- **Text-based** workflow

Model for page classification https://github.com/ufal/atrium-page-classification
(details in the poster by Dana Křivánková and Kate Lutsai)

- **Image-based** workflow

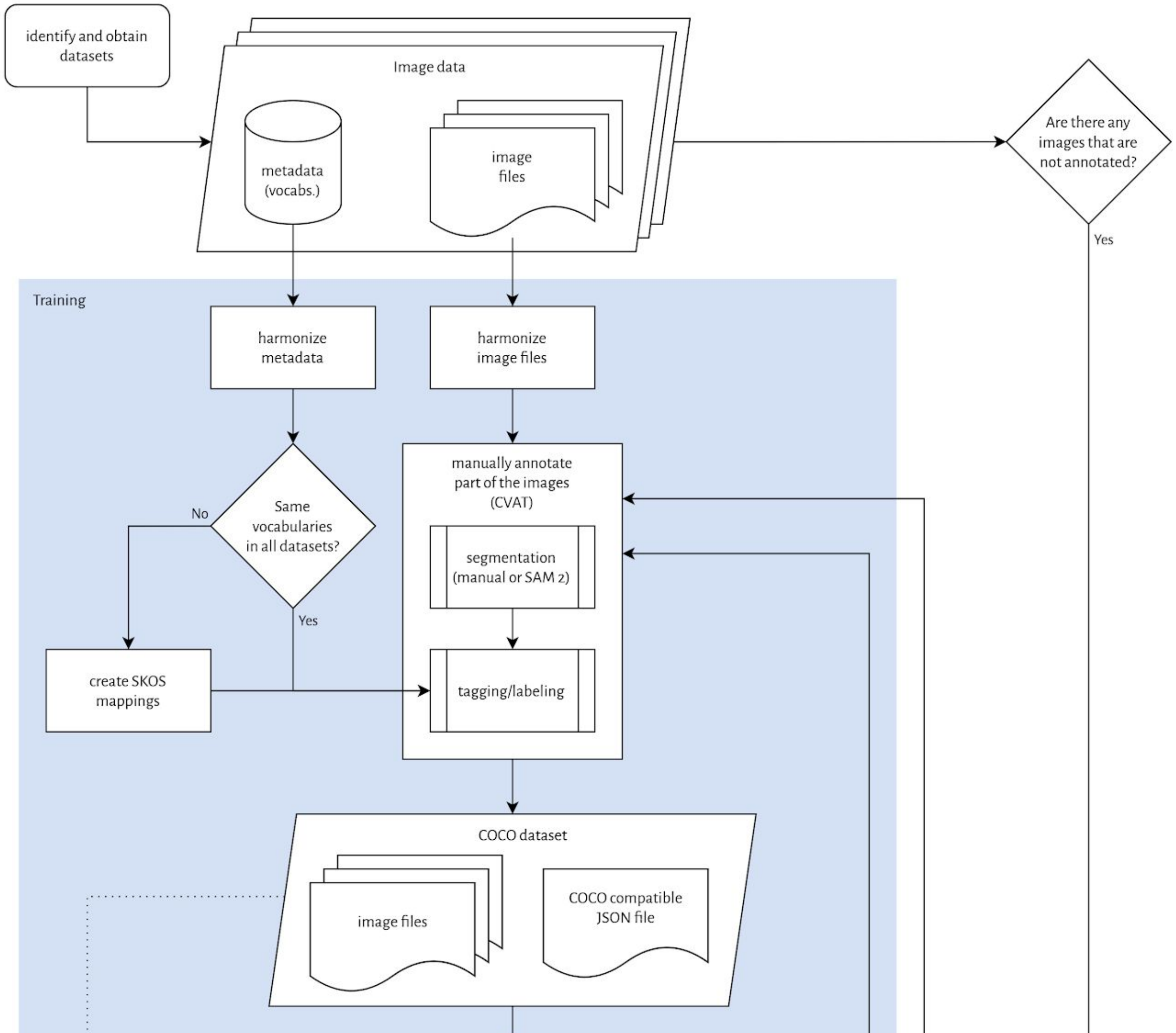




Automatic image annotation workflow

Goals:

- **Automatic annotation** of images (photographs) with terms from controlled vocabularies
- Enhanced **findability**, enriched **metadata**
- Object **extraction** etc.



(1) Consider the goal and use-case

(Image DOI: 10.60585/M-FT-110736000)

"This archaeological excavation reveals an ancient burial with human skeletal remains surrounded by stone artifacts and pottery fragments. Most notably, a prominent iron sword lies centrally alongside the body, suggesting a warrior or high-status burial. A stone headrest or marker is visible at the far end of the rectangular pit."

(Claude 3.7 Sonnet)

- ***Viewing* using LLMs**
  - Description in natural language followed by vocabulary matching
  - Optionally output in machine-readable format (eg. JSON)
  - *Expensive* in terms of computing resources and/or price
- ***Traditional* computer vision models**
  - Versatile and lightweight models
  - *"Garbage in, garbage out"*, does not hallucinate
  - *Expensive* in terms of time/workforce invested in the dataset creation

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(2) Gather and harmonize image data

Image data *come in all shapes and sizes…*

- Transform to a common bitmap format (JPEG)
  - TIFFs might be challenging (transparency, multi-page files etc.)
- 3-channel input expected (RGB)
- Further optimization depends on the model selection…

```python
def process_tiff_image(img: Image.Image) -> Image.Image:
    """Process TIFF images, handling multiple frames and bit depths."""
    # Count frames
    try:
        n_frames = 0
        while True:
            img.seek(n_frames)
            n_frames += 1
    except EOFError:
        pass

    # Return single-frame TIFF as is
    if n_frames <= 1:
        img.seek(0)
        return img

    # Find best frame (with most content)
    best_frame, max_std = 0, 0
    for i in range(n_frames):
        img.seek(i)
        std_dev = sum(abs(px - 128) for px in img.convert('RGB').convert('L').getdata()) / (img.width *
        if std_dev > max_std:
            max_std, best_frame = std_dev, i

    img.seek(best_frame)
    return img
```

(3) Align controlled vocabulary terms

- skos:mappingRelation
  - skos:closeMatch
  - skos:**exactMatch**
  - skos:broadMatch
  - skos:narrowMatch
  - skos:relatedMatch

https://marketplace.sshopencloud.eu/workflow/yLX6Bd

```python
def convert_image_mode(img: Image.Image) -> Image.Image:
    """Convert image to appropriate mode for JPEG saving."""
    original_mode = img.mode

    # Convert based on mode
    if original_mode in ('I;16', 'I'):
        img = img.point(lambda i: i * (255.0 / 65535.0)).convert('L')
    elif original_mode == 'F':
        img = img.convert('RGB')
    nal_mode == 'P' and 'transparency' in img.info):
    55, 255, 255))
    nel('A'))
```

W3C Recommendation

W3C®

SKOS Simple Knowledge Organization System Reference

W3C Recommendation 18 August 2009

This version:

http://www.w3.org/TR/2009/REC-skos-reference-20090818/

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Datasets /1

*Photographs of **finds***

- *AMCR-PAS*
  - **>7.5k** finds, **~10k** photographs
- *“Lovec pokladů”* (*“Treasure hunter”*)
  - **>300k** finds
  - photographs by metal detectorists
  - quality varies greatly
- *Portable Antiquities Scheme*
  - **>750k** finds (with images)
  - high quality of images
- *Montelius dataset*
  - includes drawings and images scanned from published resources





(Images: AMCR-PAS, Lovec pokladů, Portable Antiquities Scheme)

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Datasets /2

*Photographs of **fieldwork***

- *ARUP digital photographs of fieldwork collection*
  - **>60k** photographs
- *ARUP & ARUB archival photographs*
  - **~300k** photographs
  - various scenes, fieldwork, people, finds, sites etc.
  - mostly b/w photographs

(Images: Digital Archive of the Archaeological Map of the Czech Republic)















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(4) *Annotate images*

- Various **annotation platforms**...
  - CVAT (Computer Vision Annotation Tool)
    https://www.cvat.ai/
  - VIA (VGG Image Annotator)
    https://www.robots.ox.ac.uk/~vgg/software/via/
- BBoxes vs **segmentation**
- Segment Anything Model (**SAM2**)
  - Semantic segmentation
  - https://ai.meta.com/sam2/
- **COCO** compatible **JSON**

- Annotation of **AMCR-PAS dataset**
  - **9764** images, **7303** annotated (**~65 %**)
  - **7426** objects (annotations)
  - speed: **~50** objects per hour


```
"annotations": [
    {
        "id": 1,
        "image_id": 1,
        "category_id": 1,
        "segmentation": [
            [
                555.0,
                682.0,
                548.0,
                683.0,
                529.0,
                697.0,
                518.0,
                701.0,
                492.0,
                717.0,
                429.0,
                766.0,
                382.0,
                857.0,
                361.0,
                910.0,
                361.0,
                931.0,
                354.0,
                949.0,
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                1026.0,
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                586.0,
                1041.0,
```


(Image DOIs
10.60585/M-FT-110736000 and
10.71928/M-202300087-N00394)

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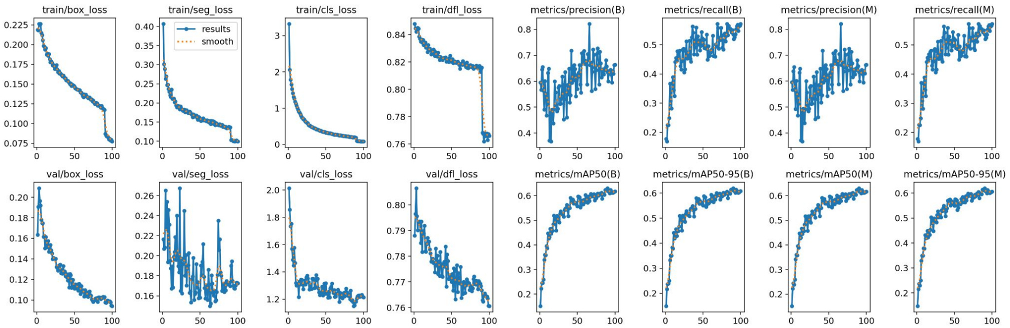
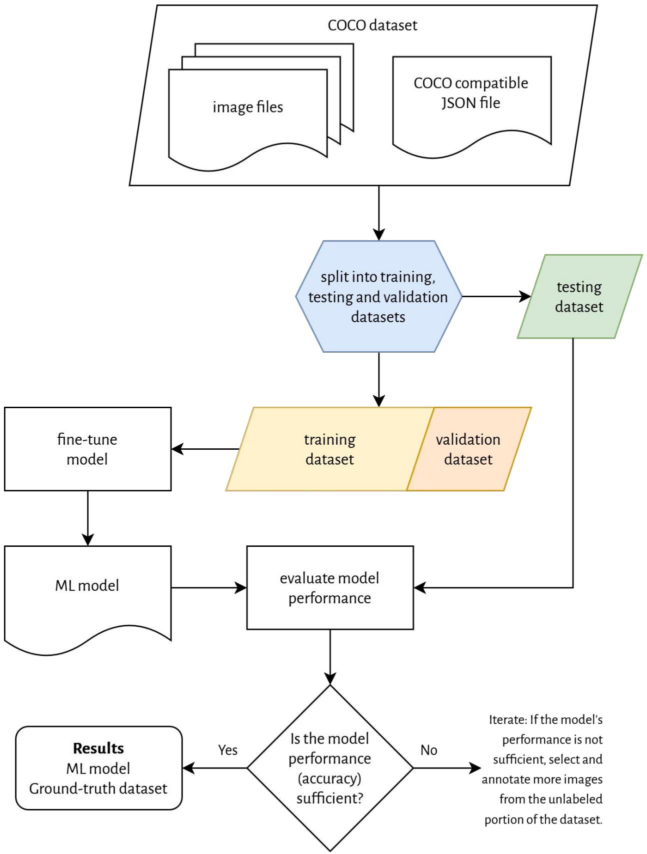
(5) Re-train/fine-tune the model

- Split into **training**, **validation** and **testing** datasets
  - **Imbalanced** dataset – proportional representation of classes...

- **YOLO v11 seg.**, 100 epochs, PyTorch
  - Best results with **340x340px** resolution
  - Detection (BBox) mAP50–95 ≈ 0.61
  - Segmentation (mask) mAP50–95 ≈ 0.61





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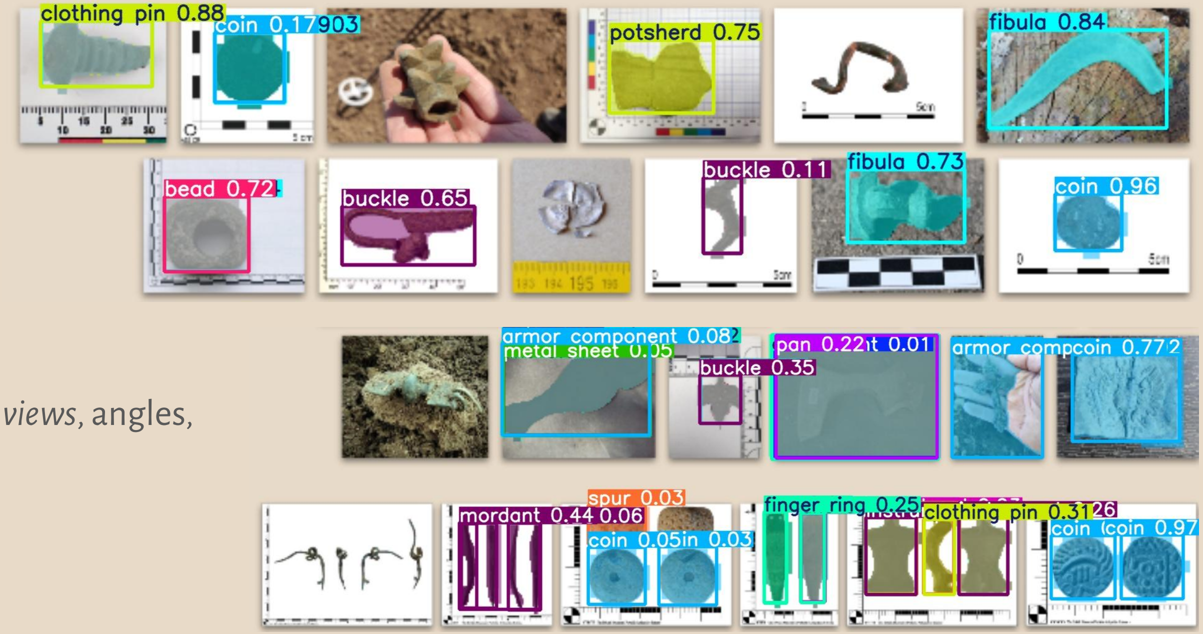
(6a) Apply the ML model

Apply the model, verify the results, iterate...

- First *good* version of the model helps with further annotations...
- *Ground-truth* dataset grows

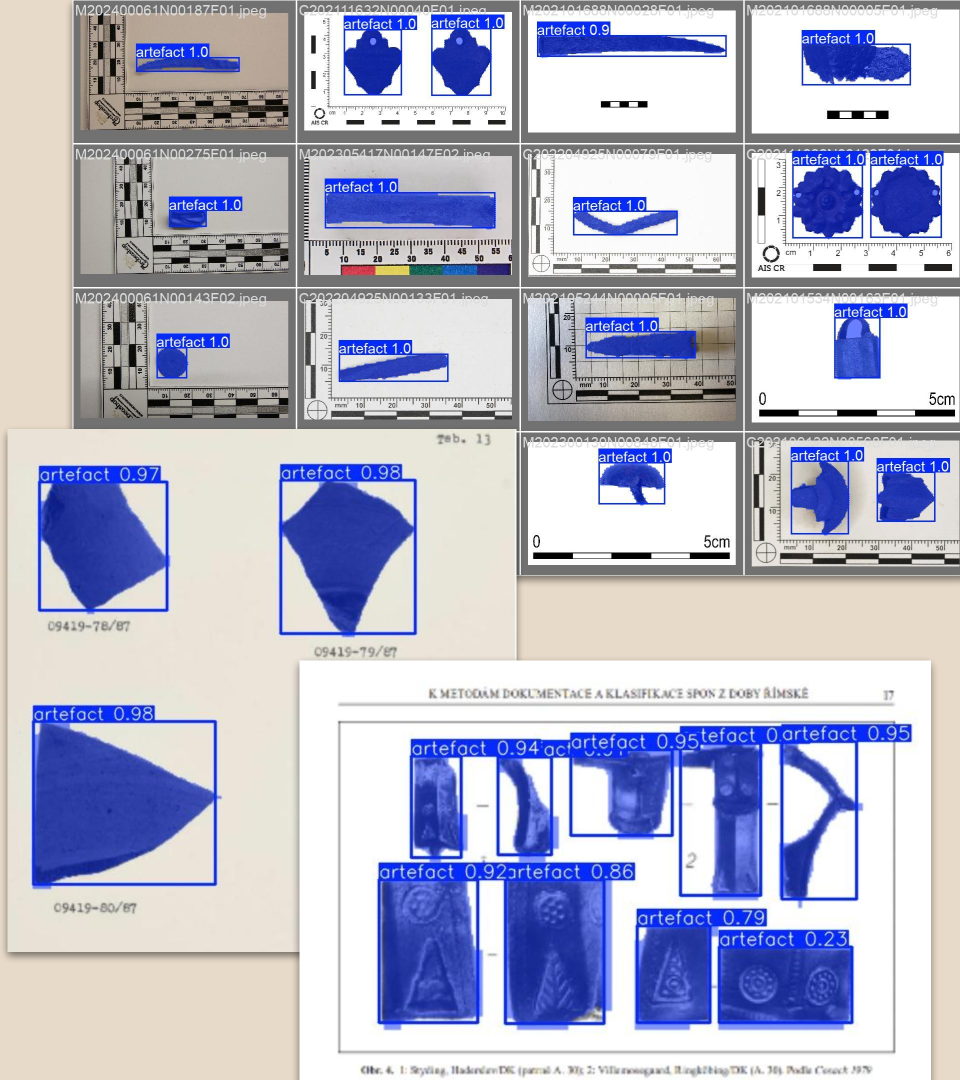


TODOs:

- Cope with **imbalanced dataset**
- Cope with **variability** of different *views*, angles, sizes etc.
- Enlarge *ground-truth* dataset...

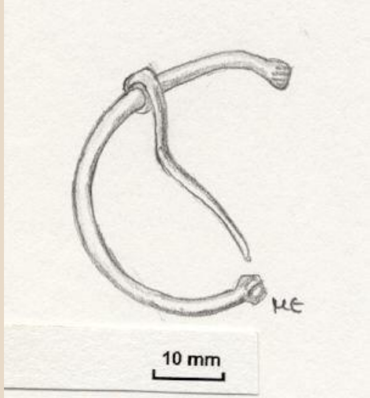
(6b) Artifact Database

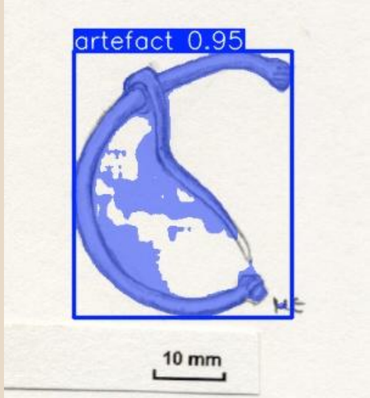
1. **Input:** Photographs containing artifacts.
2. **Detection & Segmentation:** A pre-trained model automatically finds and precisely outlines (segments) artifacts in the photographs.
3. **Artifact Extraction:** Identified artifacts are "cut out" from the photographs as separate images.
4. **Vectorization (Visual Transformer):** Each extracted artifact is processed by a Visual Transformer, which creates a unique semantic vector (a numerical "fingerprint" of the artifact).
5. **Database Storage:** All vectors representing the artifacts are stored in a specialized vector database.



(6b) Searching for similar Artifacts

1. **Input (Query):** A new image of an artifact for which we want to find similar ones.
2. **Query Processing:**
   a. The input image undergoes the same **detection, segmentation, and extraction** process as during database creation.
   b. The extracted artifact from the query is then converted into a **vector** using the same Visual Transformer.
3. **Database Comparison:** The query artifact's vector is compared against all vectors in the artifact database.
4. **Output:** Display of artifacts from the database whose vectors are mathematically most similar to the query vector.





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Sidenote: LLM Fine-Tuning & Deployment

Models used:

- Qwen 2.5 VL
- Gemma 3 27B

Our Local Setup:

- **Hardware:** In-house NVIDIA RTX 4090 GPUs (24GB VRAM)
- **Fine-tuning Engine: Unsloth** library (for efficient training)
- **Serving Framework: Ollama** (for local model utilization)

Focus: Tailoring advanced LLMs for our specific applications using our own infrastructure.

unsloth

MAiA

Managing Artificial Intelligence in Archaeology

*'MAIA is here to **investigate** Artificial Intelligence (**AI**) **applications** within **archaeology**.'*

- https://www.maiacost.eu/
- COST Action CA23141
- > 200 members...
- At least 3-4(?) **surveys** planned...
- Training **school** on **data management for AI applications** at **ADS** (York, 2nd week of September?)

Working groups:

1. State of the Art: AI and Archaeology
2. Digital Comparative Collections and AI Training Data for Archaeology
3. AI and Archaeological Research
4. Dissemination and Communication

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Thank you for listening!

For more information, please visit https://www.atrium-research.eu/

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