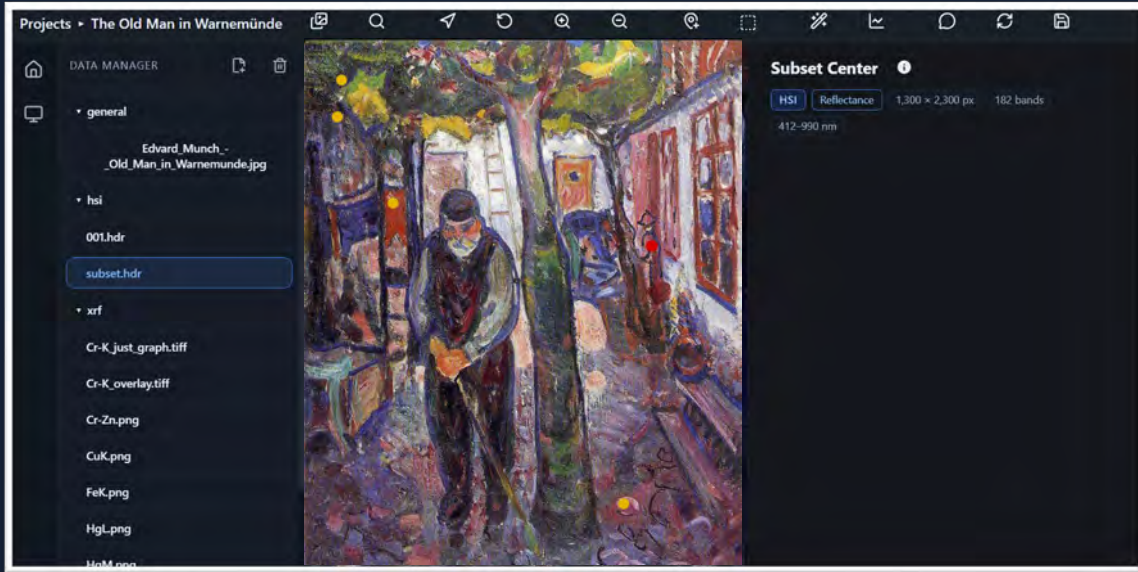




Developing a Multimodal Image Analysis and Visualisation Tool for Paintings

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Motivation

1 Imaging in Cultural Heritage

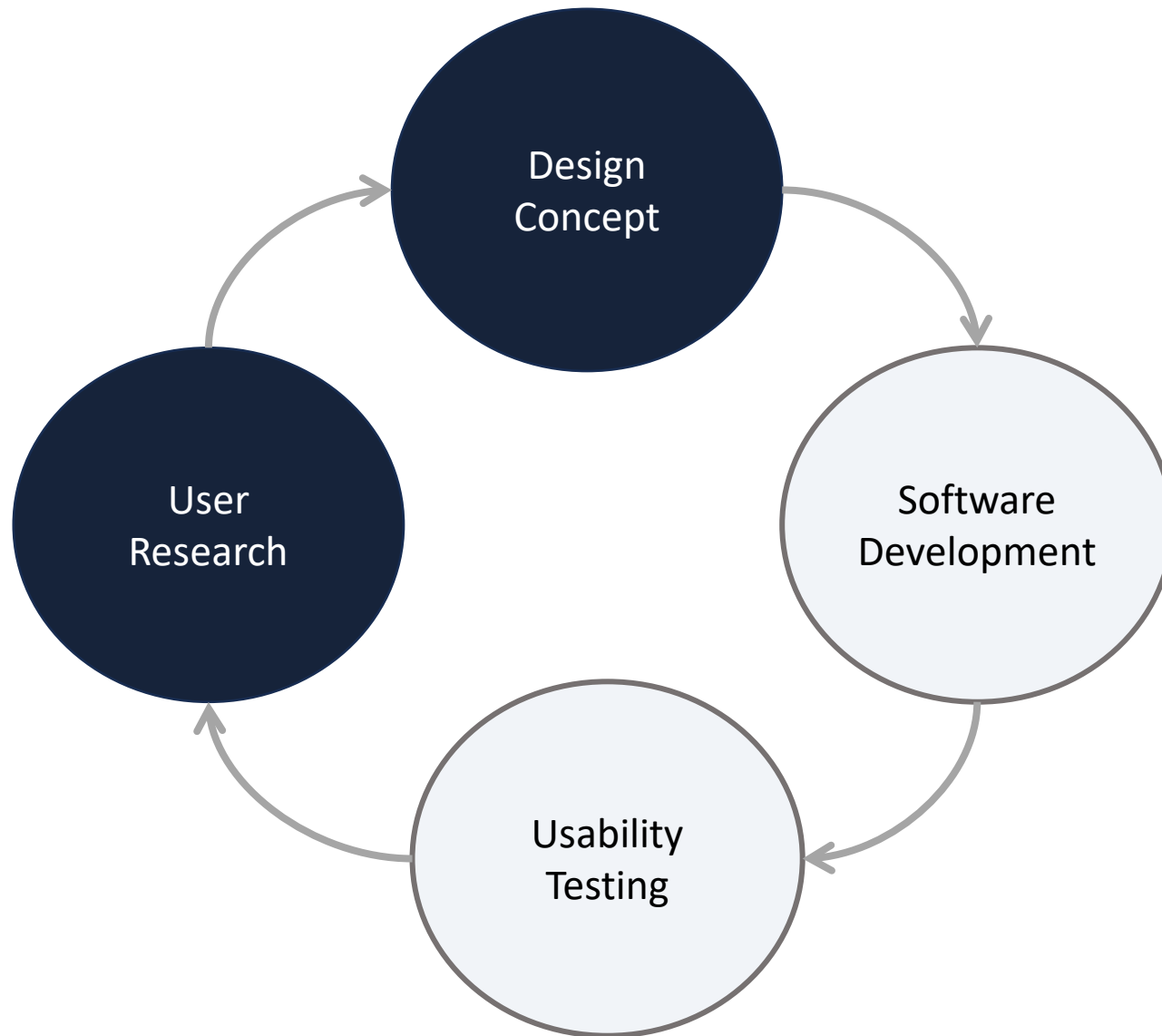
- Non-invasive imaging has substantially advanced the analysis of CH artefacts, for instance, hyperspectral imaging (HSI) and macro X-ray fluorescence (MA-XRF)
- **Applications:** pigment identification and mapping
- **Use cases:** assessment of conservation activities

2 Workflow and Software

- High-dimensional data needs specialised software
- **A survey** of workflows and software preferences found that CH professionals combine tools rather than use one platform
- Tools range from general-purpose editors to specialised imaging software

3 No software yet supports analysis across several imaging types

Software Development and Contributions



Contributions

- **User research:** requirements of conservators, conservation scientists and imaging scientists working with paintings
- **Design concept of a multimodal imaging tool:** integration of analysis, visualisation and comparison of imaging data for pigment identification and mapping

User Research

Survey Methodology

- Surveys to capture opinion and trend data related to a specific topic
- Source: subset of 2025 survey data (n=82)
- Questionnaire about imaging and software preferences
- **Base for design concept** refined by team (one conservation scientist, two imaging scientists)

32 respondents

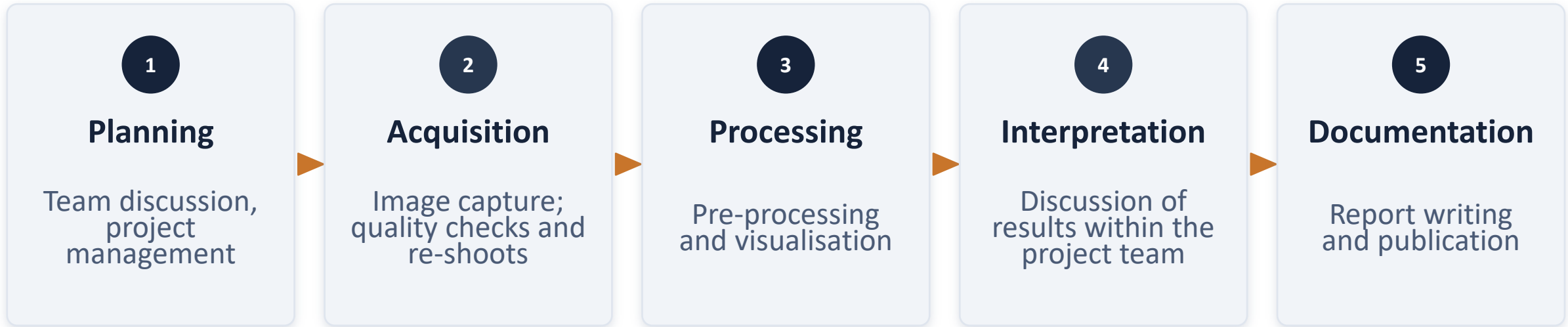
Conservators, imaging scientists and conservation scientists working on paintings

71.2 % based in Europe

43.8 % cultural institutions

78.1% Single occupation (e.g.,
40.6% as imaging scientist)

Imaging Project Workflow

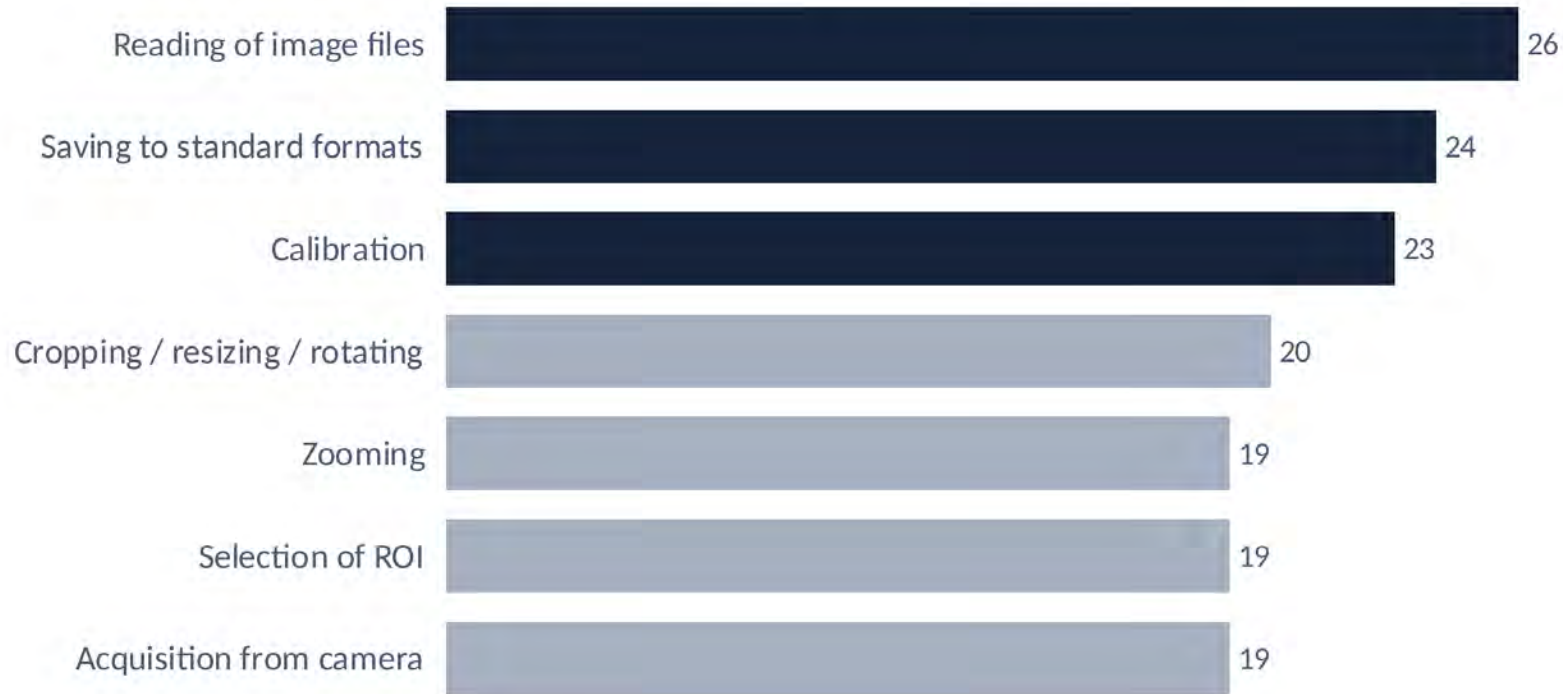


Modality use is broad, not dominated by one technique

- **Available at the institution:** UV induced fluorescence (21), multispectral imaging (20), mobile phone photography (18)
- **Currently used:** Infrared reflectography and UV induced fluorescence (5 each)
- **Used in the past:** HSI (10), multispectral imaging and SEM (8 each)

Feature Requirements

Top features ranked “Essential” (responses)



Computation is “nice to have”

ICA, pigment mapping, classification, image statistics and customisability rank low as essential, high as desirable

Workflow Translation

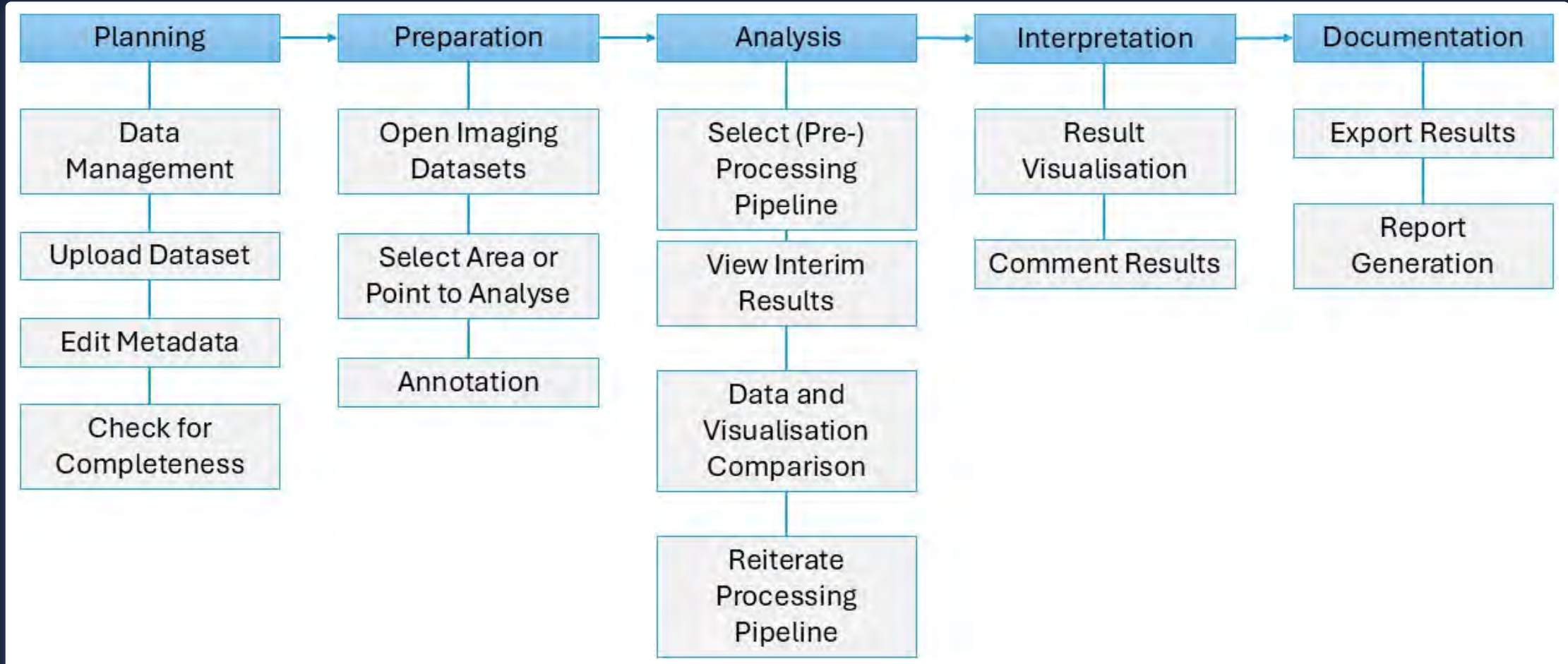
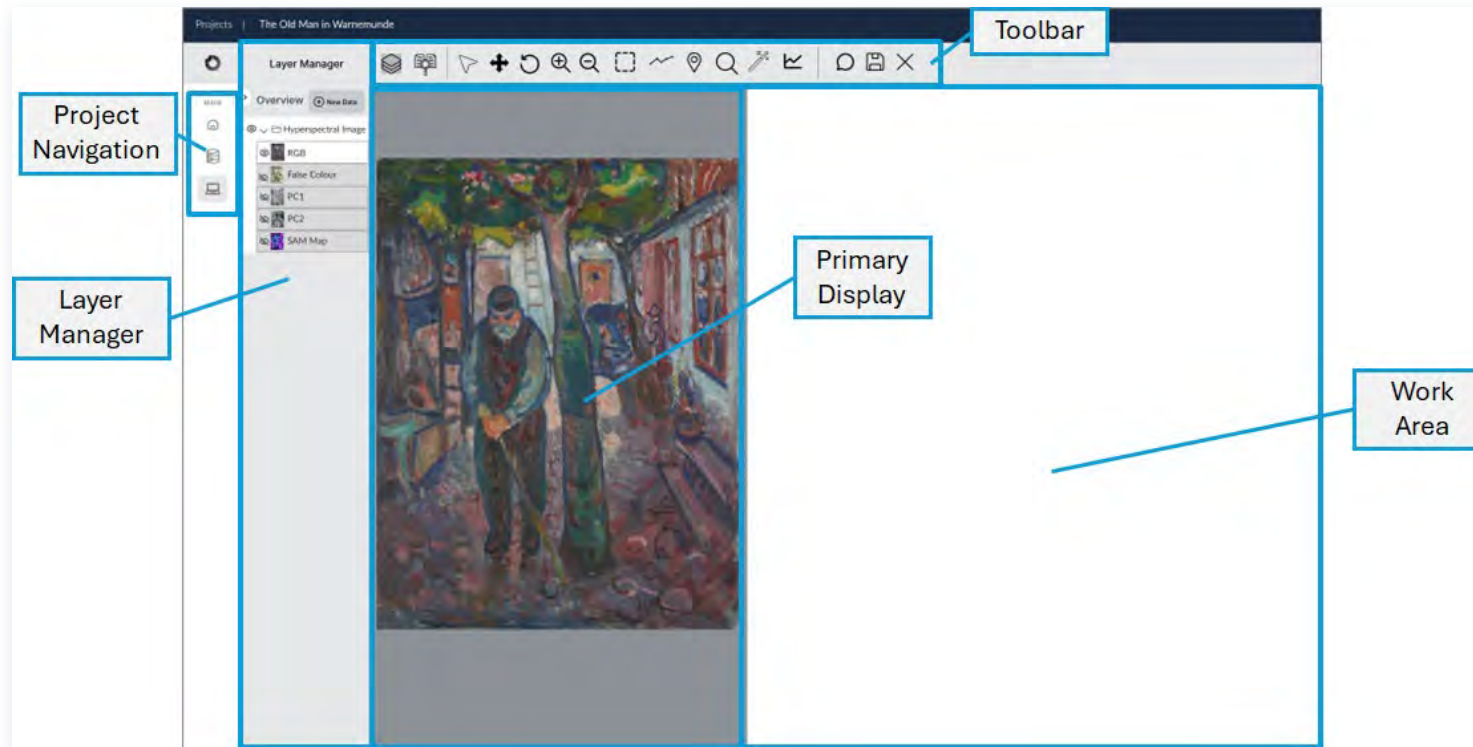


Fig. Tool workflow overview based on the five recurring steps in a typical imaging workflow.

Tool Layout



- **Project Navigation**
Project metadata, dataset upload and database management
- **Layer Manager**
Drag-and-drop loading, ordering, overlays and mirrored comparison
- **Toolbar**
Viewing, ROI selection, annotation, processing, spectra, export
- **Primary Display**
Currently selected image; ROI selection surface
- **Work Area**
Second display, detail view or processing pipelines

Concept uses **imaging data of Old Man in Warnemünde** (Munch, 1907): 1. HSI: HySpex VNIR-1800, 0.4–1.0 μm (Deborah et al. 2017); 2. MA-XRF from a MOLAB campaign (Rosi et al. 2022).

Tool Layout

Project Management, TBA

Home

Monitor

Data Addition/Deletion

Display Management; TBA

Image Selection

Image Display Operations

ROI Selection

HSI Operations

Export; TBA

Projects > The Old Man in Warnemünde

DATA MANAGER

general

Edvard_Munch_-_Old_Man_in_Warnemunde.jpg

hsi

001.hdr

subset.hdr

xrf

Cr-K_just_graph.tiff

Cr-K_overlay.tiff

Cr-Zn.png

CuK.png

FeK.png

HgL.png

Image Display Operations

ROI Selection

HSI Operations

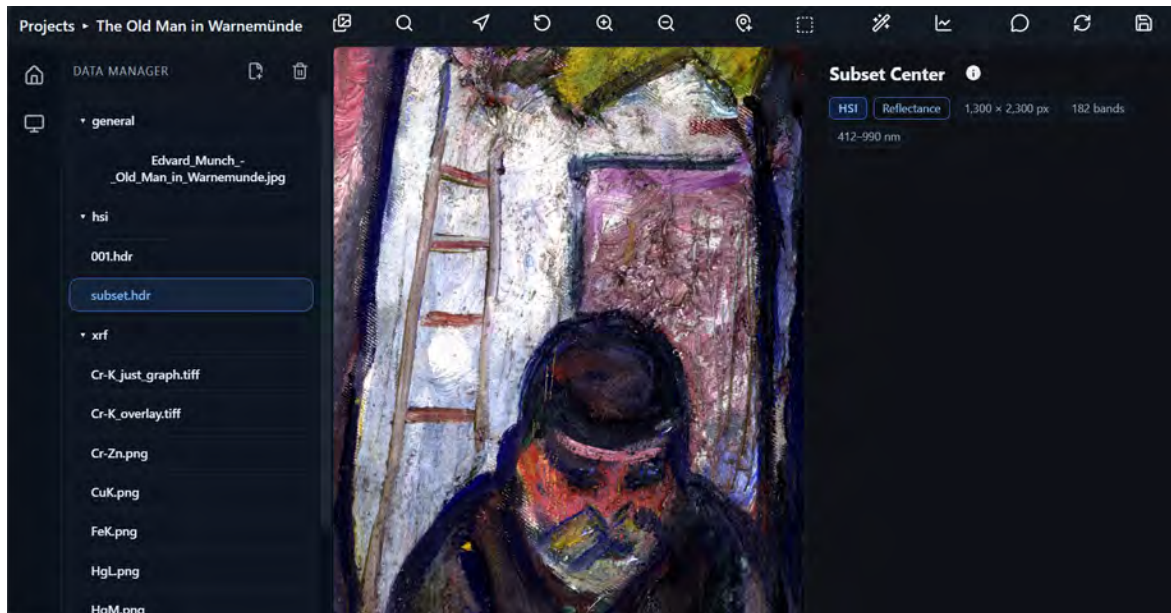
Export; TBA

Subset Center

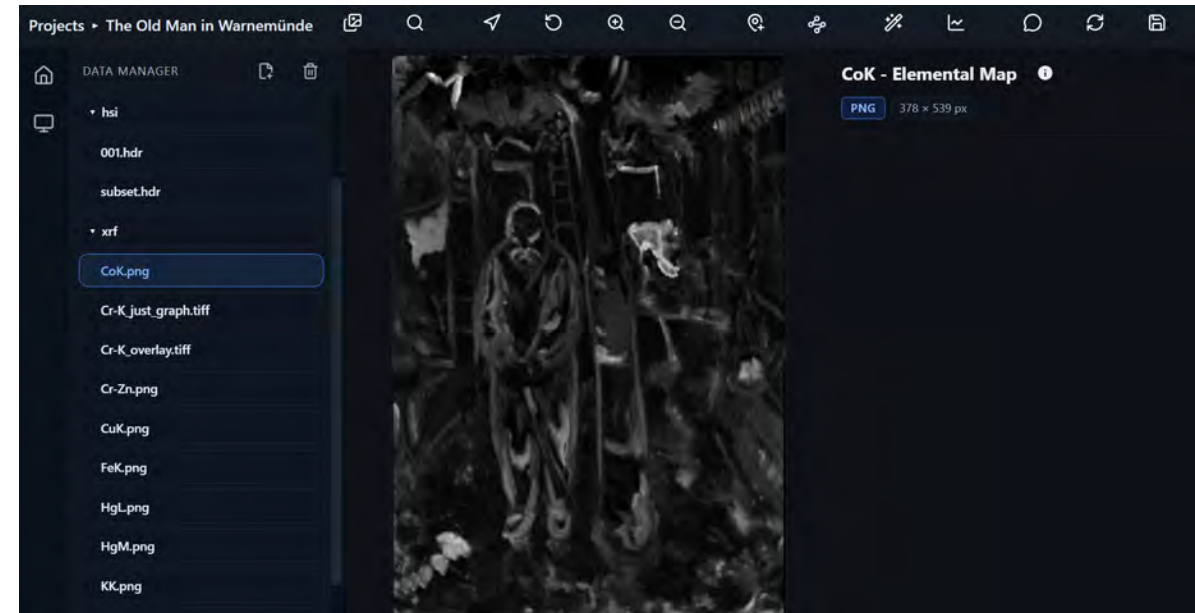
HSI Reflectance 1,300 × 2,300 px 182 bands

412–990 nm

Data Import

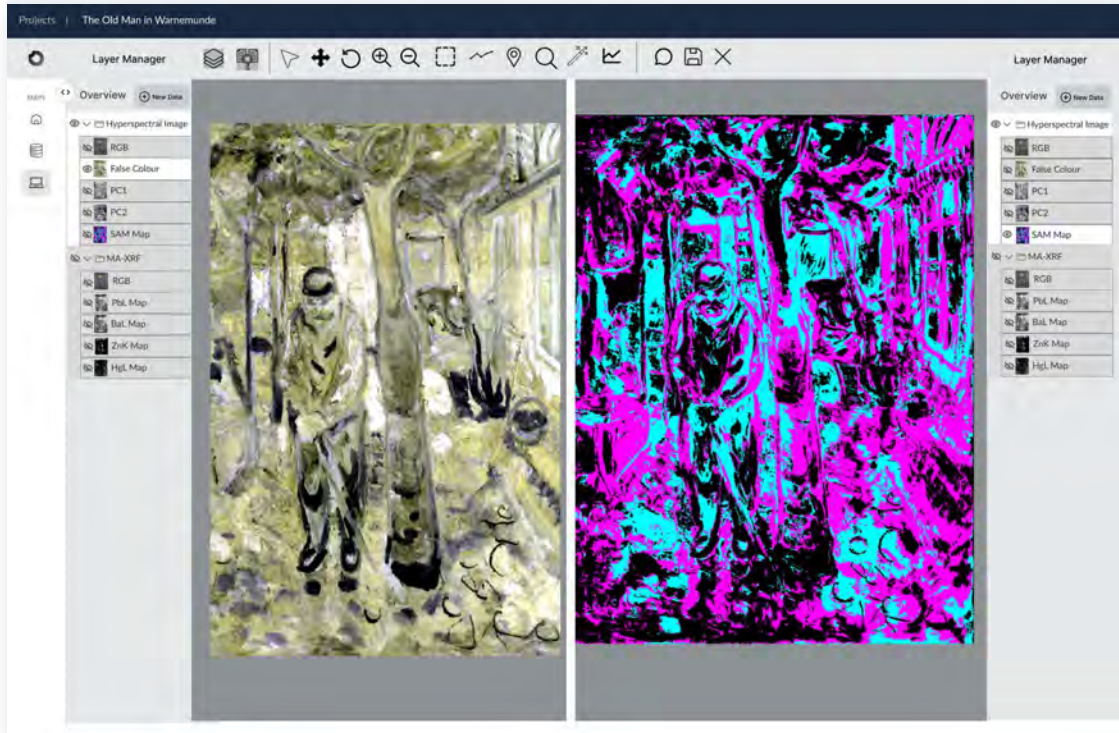


RGB preview from spectral data

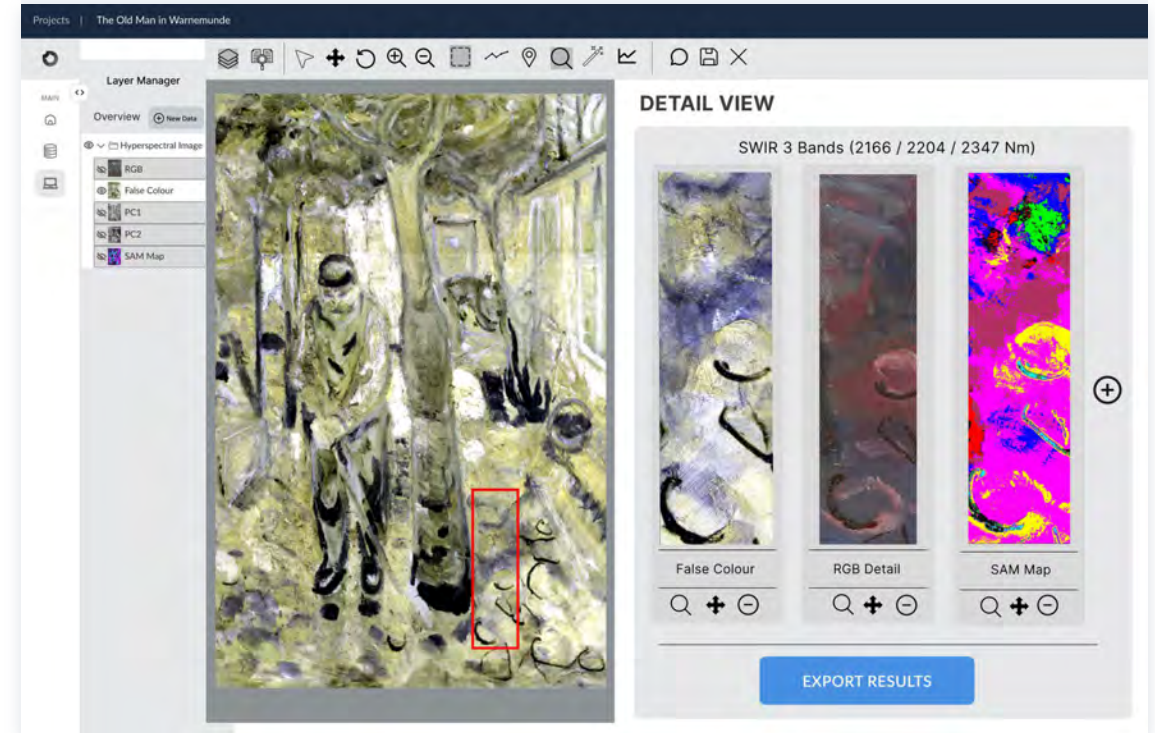


MA-XRF elemental map showing cobalt distribution

Viewing modes for cross-modal comparison

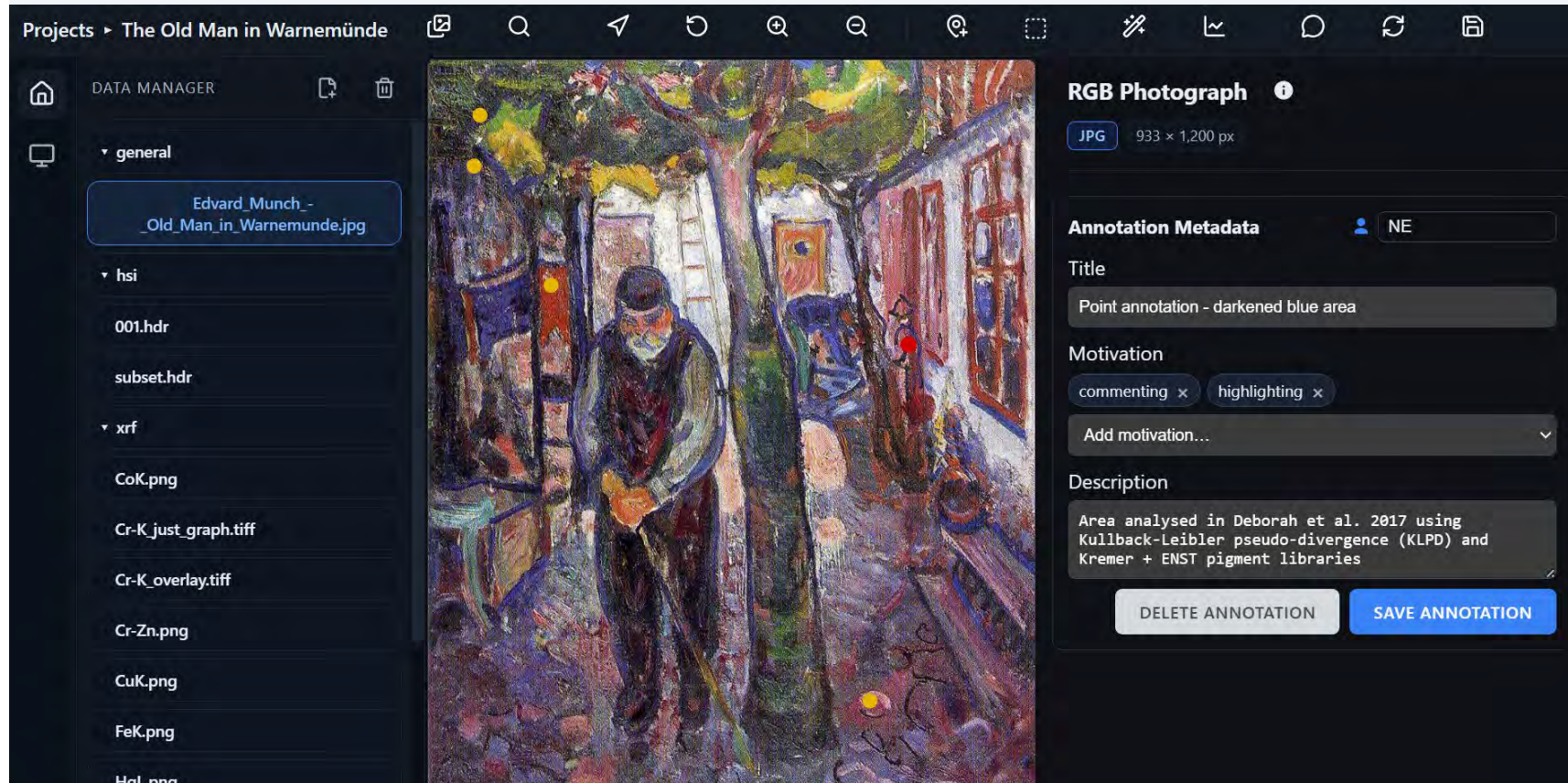


Comparison View showing selected false-colour and SAM map visualisations.



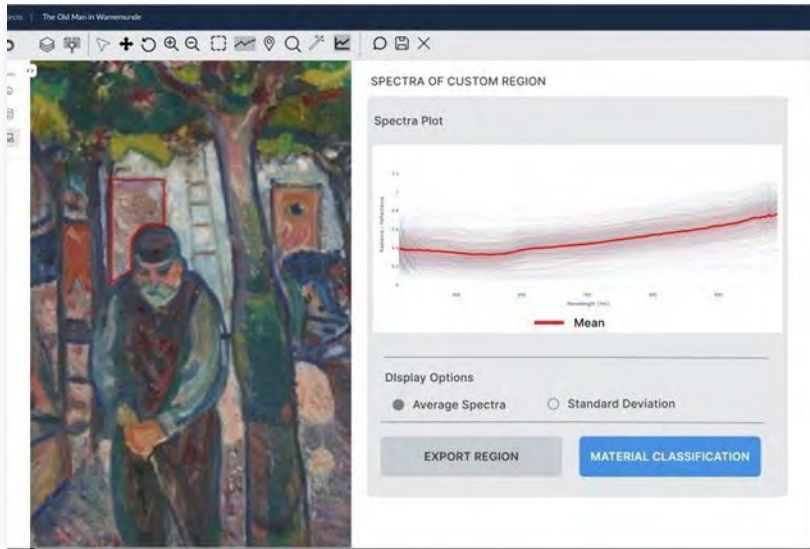
Detail View illustrating ROI inspection across multiple representations (e.g., False Colour and RGB).

Annotations



Example annotation following W3C Web Annotation Data Model (WADM) to mark areas that have been previously investigated.

ROI definition and HSI pigment classification

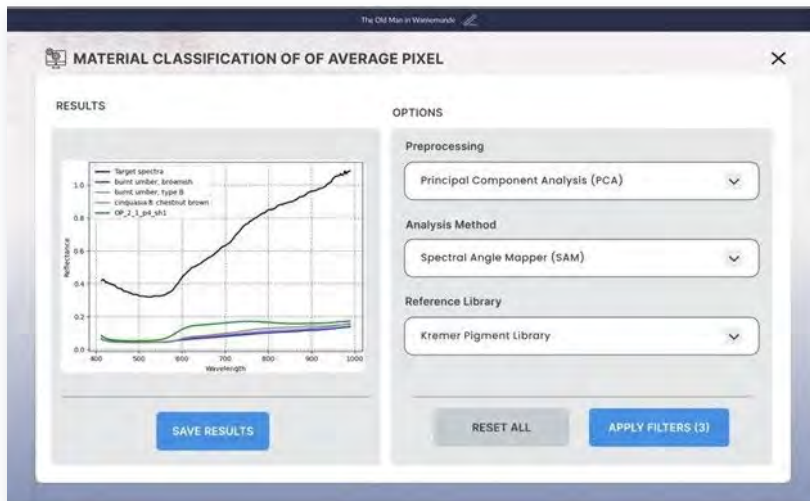


Flexible ROI definition

- Geometric shapes for macro-level fragments;
- Point selection for pixel-wise investigations

Spectral preview

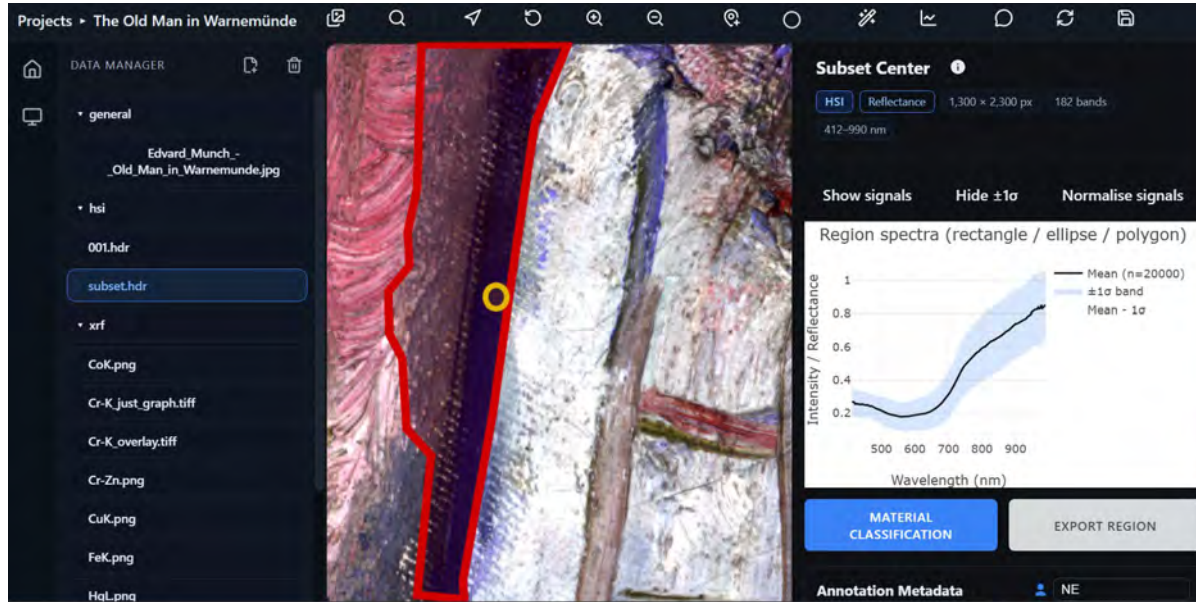
- Mean spectra and standard deviation over the selected region



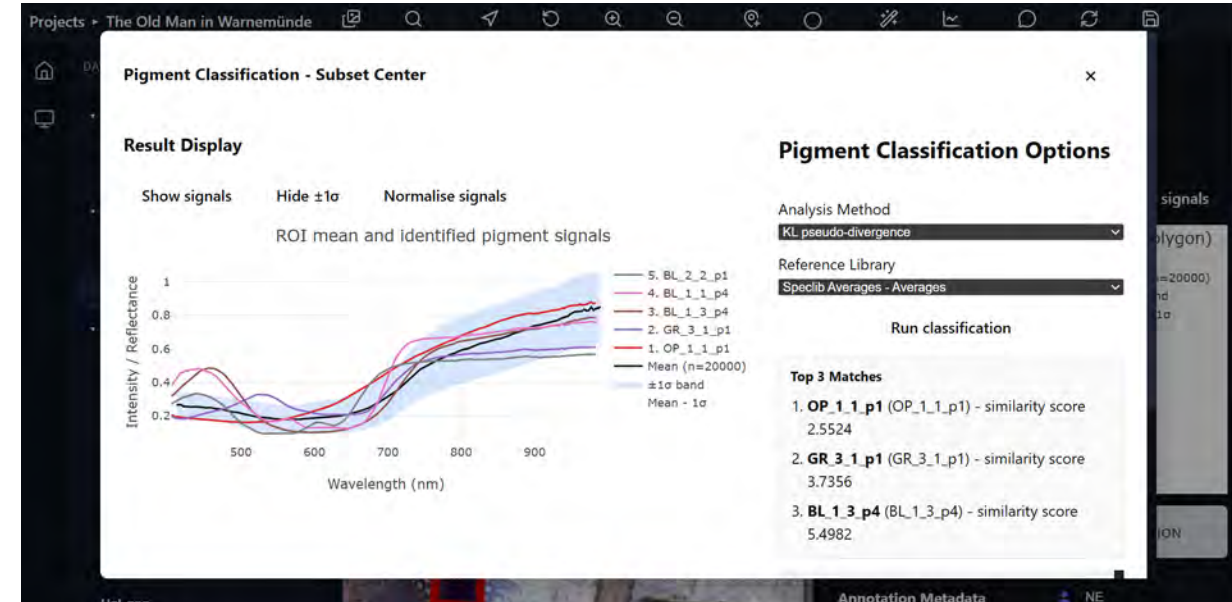
Configurable classification

- PCA for noise removal; distance functions including SAM, SCM, SID, cosine and Euclidean distance; pre-trained deep learning models
- Reference libraries such as the Kremer pigment library

Use Case: Re-examining Segmentation Results



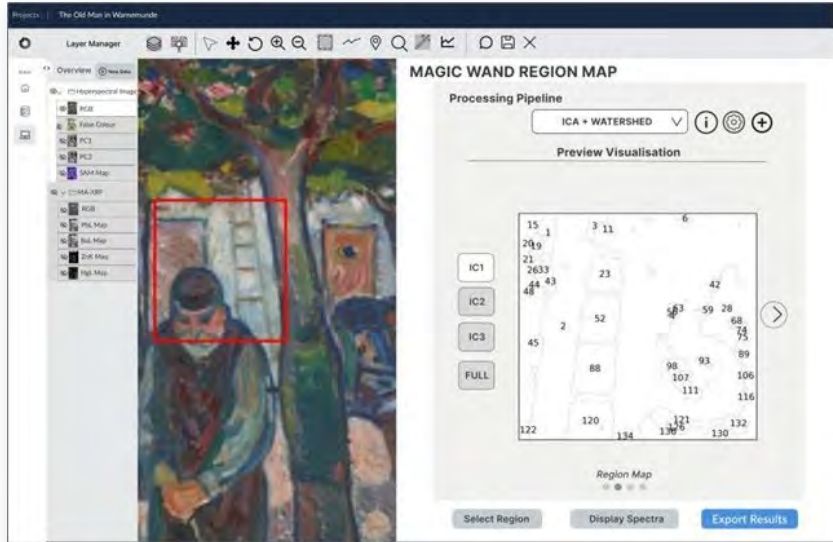
Selected ROI (44,216 pixels) with imaging data preview



Pigment classification menu with result display

Automatic ROI generation for larger fragments

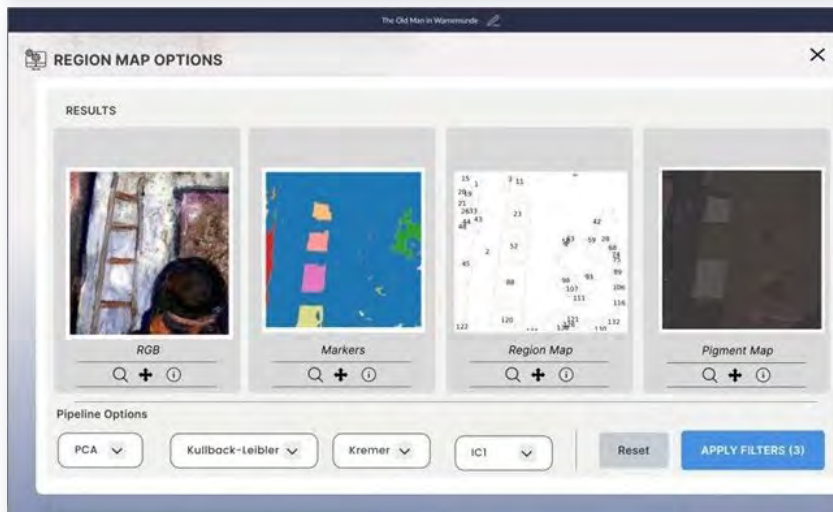
(A)



Pattern recognition across a fragment

- Sub-regions of similar pigment composition are identified and can be fed directly into a classification pipeline and pigment map

(B)

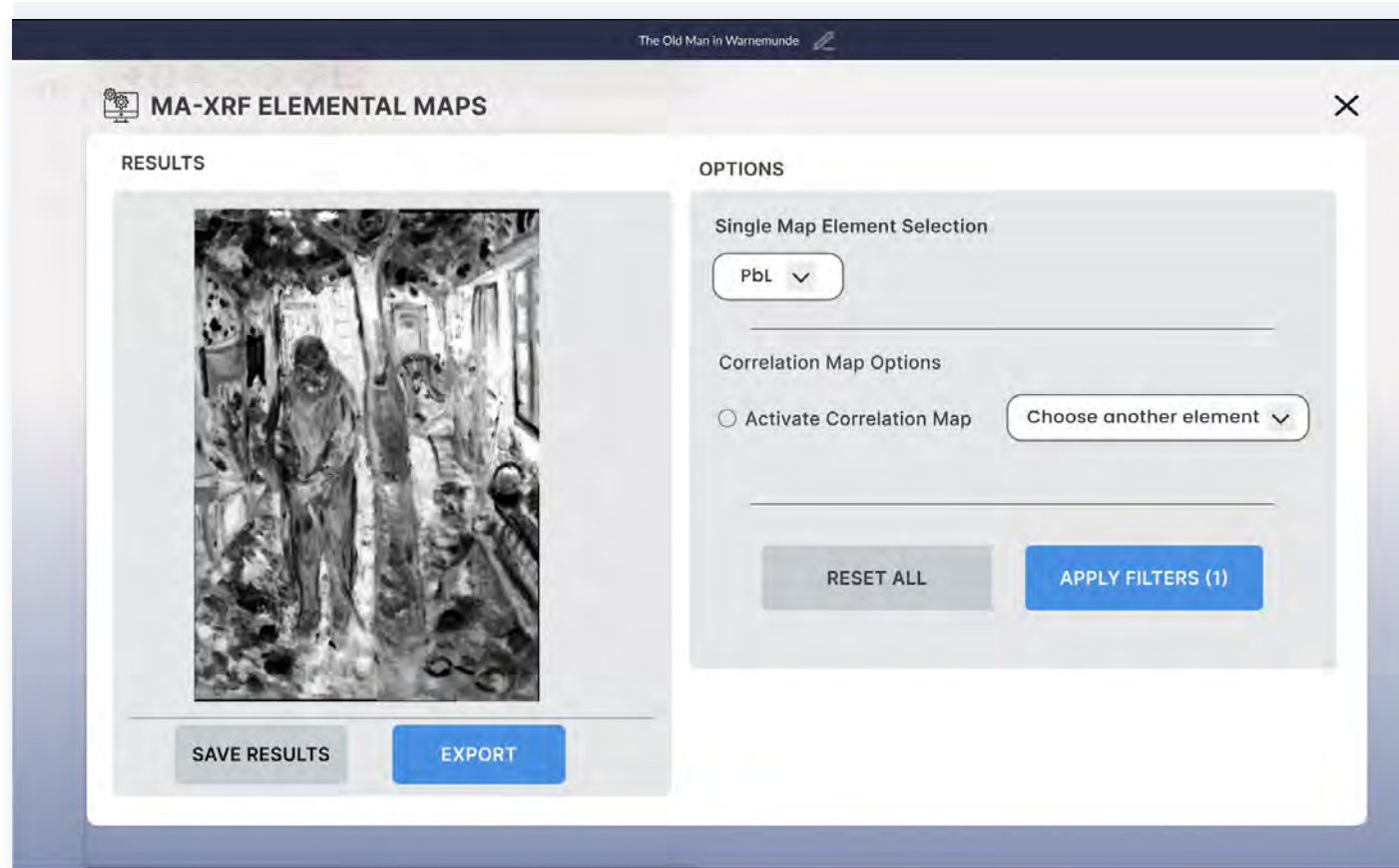


Alternatives and extensibility

- Superpixel segmentation, K-means clustering and deep learning variants such as a modified U-Net.
- Custom models and scripts

(A) preview display · (B) pipeline options

MA-XRF elemental maps in the same environment



Example of MA-XRF elemental map visualisation. Menu draft to load one or multiple elemental maps and create correlation maps.

Concept for multimodal imaging tool for painting analysis

User Research

1

Survey results: Conservators, conservation scientists and imaging scientists share a five-stage workflow, but no shared tool fulfils all the needs

Design Concept

2

Five components for manual and automated analysis. Features for manual and automatic image analysis, annotation and documentation.

Next steps

- **Prototype:** Implementation and integration of advanced processing, e.g. spectral unmixing
- **Open-source release** for long-term accessibility

Thank you! Questions?



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SpectraPaint
GitHub