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Mobile, ground-based VNIR-SWIR hyperspectral imaging for cultural heritage applications. Towards the study of complex architectural surfaces.

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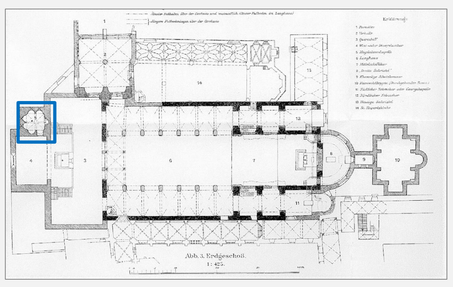
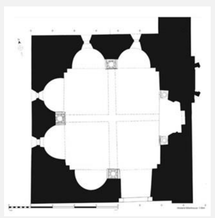
Introduction

In the field of scientific analysis of cultural heritage, **hyperspectral imaging** (HSI) is increasingly applied as an extremely versatile method for different typologies of artworks, for **monitoring**, **documentation**, and **non-destructive characterization** of **artistic materials**. Despite being well-established for investigating polychrome surfaces in a laboratory-like situation, a significant research gap lies in the **systematic application** of HSI for the study of **architectural surfaces with complex geometries on site**. We apply a mobile HSI system with an extended spectral range (VNIR-SWIR) to the classification of wall painting materials in a medieval chapel as a case study*

*PhD-project of Simon Mindermann

The Magdalen Chapel

The Magdalen Chapel is a part of the monumental church of **St. Emmeram in Regensburg** (Germany), built in the **11th century**. The Chapel was used for liturgical purposes until the monastery was dissolved in 1810. After that, it was used as a storage room.


The Palimpsest of the Wall Paintings

The Magdalen Chapel shows a unique palimpsest made of overlapping and unrelated **wall paintings from four different painting phases simultaneously visible**, dated between the 12th and the 17th centuries. At some point, the walls were whitewashed and only partially uncovered in the 1980s. Nowadays, the chapel is closed to the public, and the fragmentary status of the wall paintings hinders their readability, posing queries about their conservation.

The Imaging System

Portable HySpex dual-sensor, push-broom hyperspectral scanning system:

HySpex VNIR-3000N:

spectral range:	400 – 1000 nm
Spectral resolution:	2 nm
Active pixels:	3000

HySpex SWIR-384:

Spectral range:	930 – 2500 nm
Spectral resolution:	5.45 nm
Active pixels:	384

- **Biaxial rotational stage** for large-area scans
- Lenses for variable **measuring distances:** 30 cm - 1 m - 3 m – 10+ m
- **System-mounted illumination:** 2x halogen spotlights
- System completely **portable**
- Software: Envi (NV5 Geospatial)

The Painting Phases

mid-12th century — I Phase

early-15th century — II Phase

end-15th century — III Phase

second half-17th century — IV Phase

Which materials were used in which painting phases? Can we map them using HSI?

Data Acquisition and Calibration

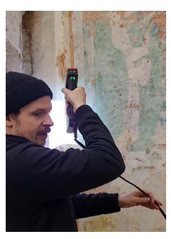
Data Acquisition
- Scanning distances between 1 and 3 m
- multiple scanning positions to measure complex geometries

Radiometric Calibration
- Dark current correction
- Dark subtraction and flat field correction using a Spectralon reflectance standard

Image Registration

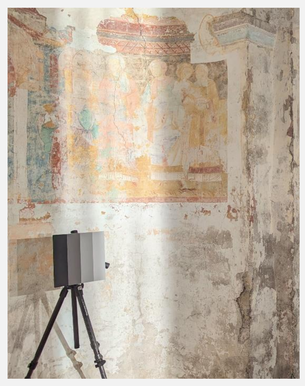
Co-registration and combination of SWIR and VNIR data (ENVI image registration workflow)

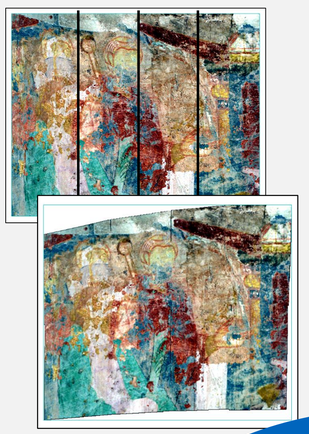
Geometric Correction



- Strong geometric distortion due to the rotational scanning movement and the complex geometry in the chapel
- Correction by slicing the data into Stripes and register/warp slices to rectified photogrammetric images

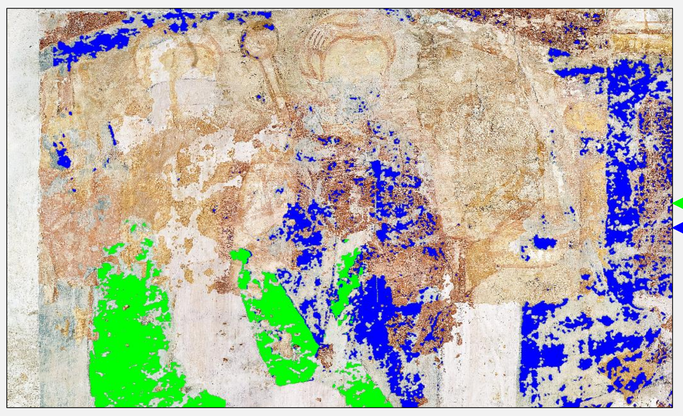
Outlook: Use of 3D scans of the walls for geometric correction

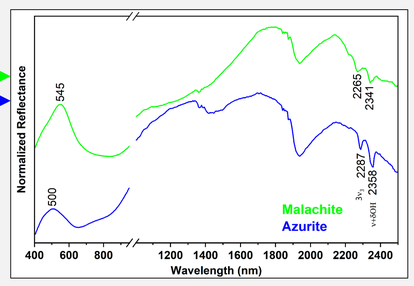




work in progress

Material Classification and Validation





Spectra and distribution of blue and green copper-carbonate pigments: **Azurite** and **malachite**
- Endmember selection: Manual and via ENVI spectral hourglass workflow
- Classifier: Spectral angle mapping (SAM)

Validation:
- Cross-validation with other non-destructive analytical methods (FTIR, RAMAN, macro XRF)
- Reflectance spectra from mock-ups which are replicas of wall paintings made following historical recipes.*
- Mappings will be compared against manual mappings done by a wall painting conservator*

*PhD-project of Nadia Thalguter

DFG Deutsche Forschungsgemeinschaft

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