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FACULTY OF ENGINEERING AND ARCHITECTURE

Artificial intelligence in art conservation and preservation: Experience from the Ghent Altarpiece

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Ghent University

Technical Art History Series – Digital Imaging Methods for Cultural Heritage
organized by the Rijksmuseum, the Computational Imaging group at CWI Amsterdam, and the Venice Centre for Digital and Public Humanities
25 May 2021

TELIN Welcome to the Department of Telecommunications and Information Processing

TELIN | DDCM | DIGCOM | GAIM | IPI | SMACS

- DDCM Database Document and Content Management
- DIGCOM Digital Communications
- GAIM Group for Artificial Intelligence and Sparse Modelling
- IPI Image Processing and Interpretation
- SMACS Stochastic Modeling and Analysis of Communication Systems

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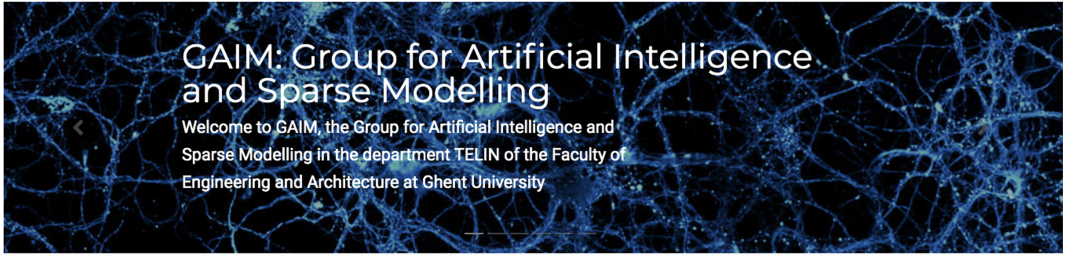
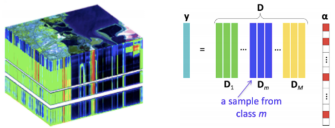
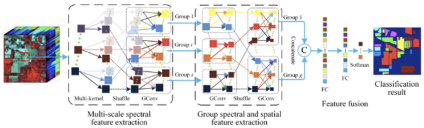


Sparse modelling in high-dimensional data analysis



Deep learning in sensor fusion and HSI analysis



Signal & image processing – machine learning – information theory

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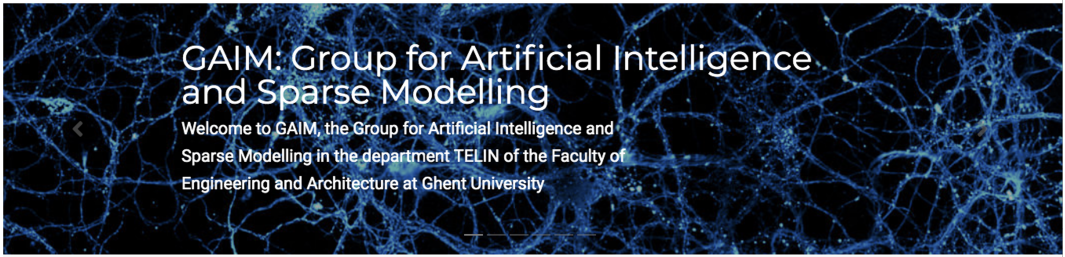
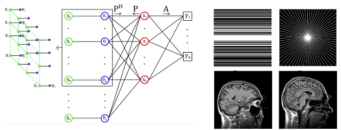
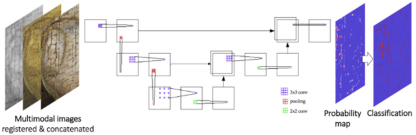


Graphical models in sparse image recovery

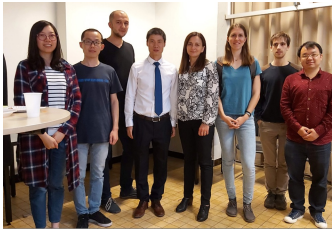


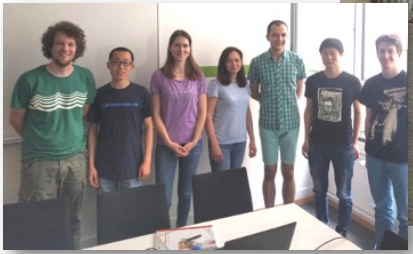
Deep learning in digital painting analysis



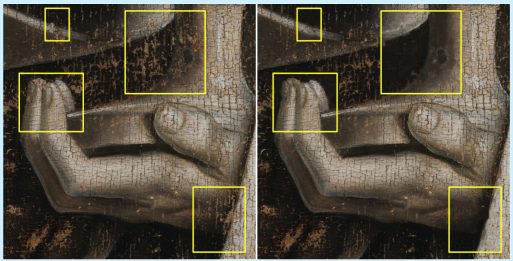
Signal & image processing – machine learning – information theory

Research group GAIM

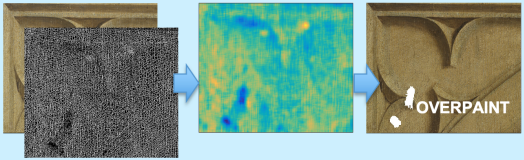


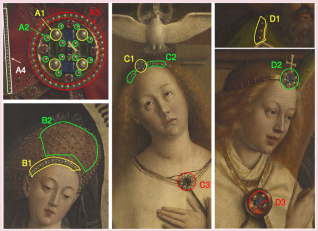


AI Supporting Conservation & Restoration and Analysis of Paintings

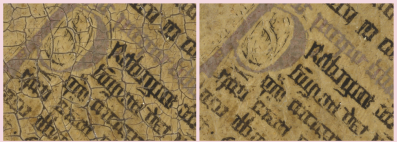


Paint loss and crack detection, virtual restoration





painter style characterization



improve readability of the inscriptions

The *Ghent Altarpiece*

Hubert and Jan Van Eyck, completed in 1432.

The *Ghent Altarpiece*

Hubert and Jan Van Eyck, completed in 1432.

Restoration of the *Ghent Altarpiece* 2012-2019

Restoration of the *Ghent Altarpiece* 2012-2019

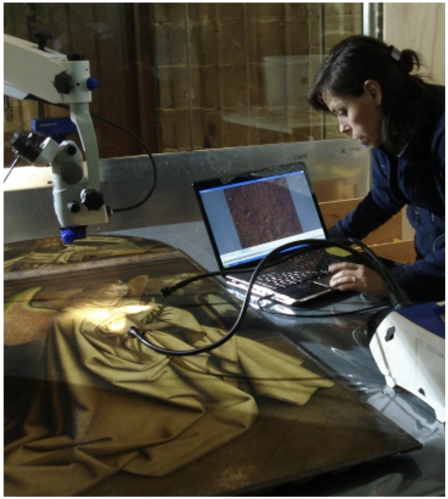
SCIENCE

The New York Times

A Master Work, the Ghent Altarpiece, Reawakens Stroke by Stroke

By MILAN SCHREUER DEC. 19, 2016

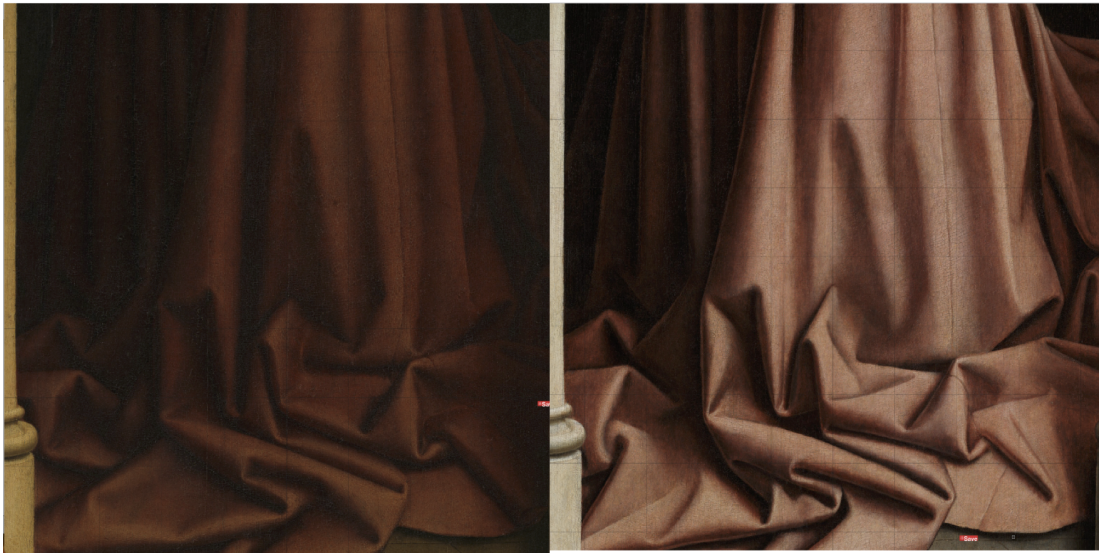
Restoration of the *Ghent Altarpiece* 2012-2019



Art restorers Bart Devolder and Hélène Dubois

Ghent Altarpiece restoration – Phase 1

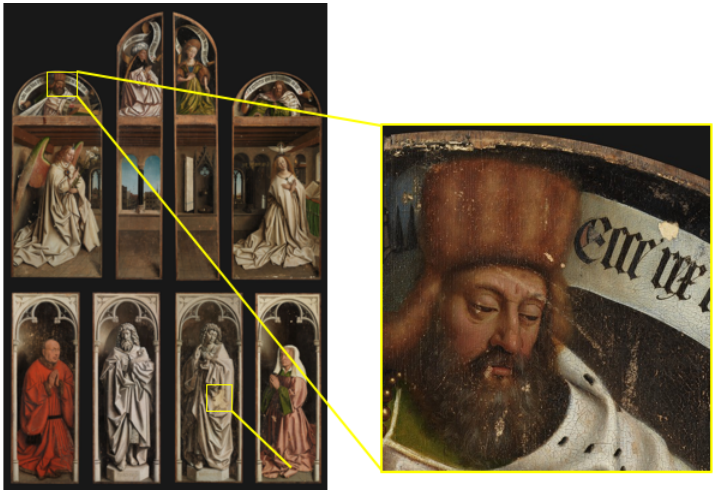
Ghent Altarpiece restoration – Phase 1



Ghent Altarpiece restoration – Phase 2 (inner panels)

The *Mystic Lamb* – before and after the restoration.

Paint losses revealed after cleaning



Why do we need automatic paint loss detection?

Paint loss detection is crucial for

- documenting purpose
- virtual restoration
- decision making in the actual restoration process

Currently done manually:

- labor intensive
- only rough indication
- prone to errors

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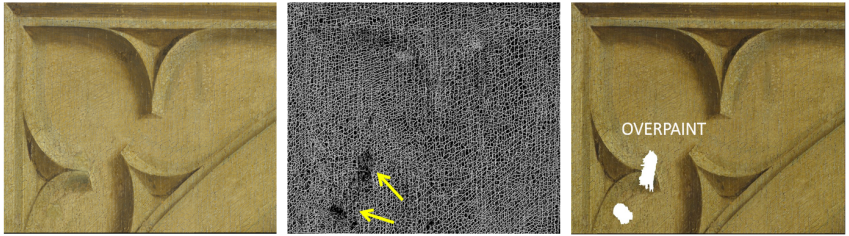
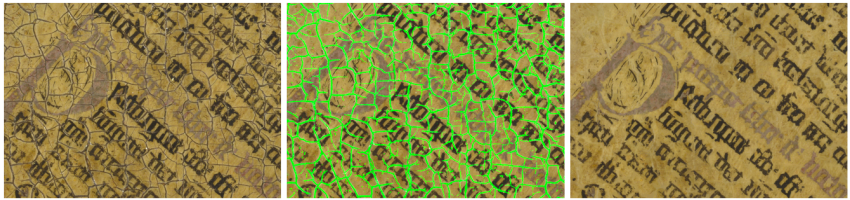
Crack detection



Diagnostics, overpaint detection.

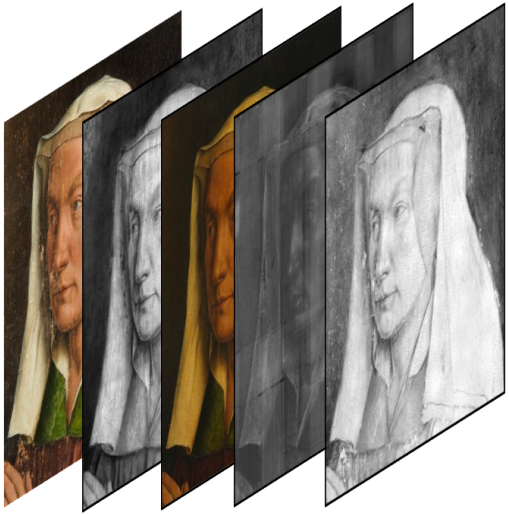


Input for virtual crack filling. Improving readability of inscriptions.

Challenges: Information extraction from multimodal data

Extracting useful information from multiple modalities, with

- huge data
- imperfect alignment
- scarce annotations
- erroneous annotations



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Paint loss detection problem - difficulties

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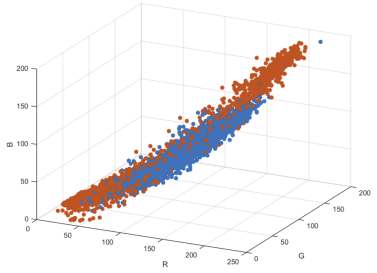

A scatter plot of RGB values for randomly selected paint loss and background pixels in the macrophotography after cleaning (red: paint loss; blue: background).

A multimodal approach

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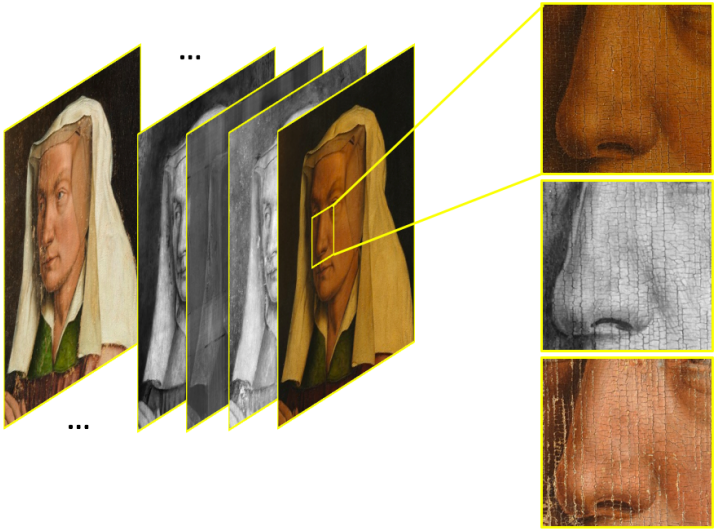
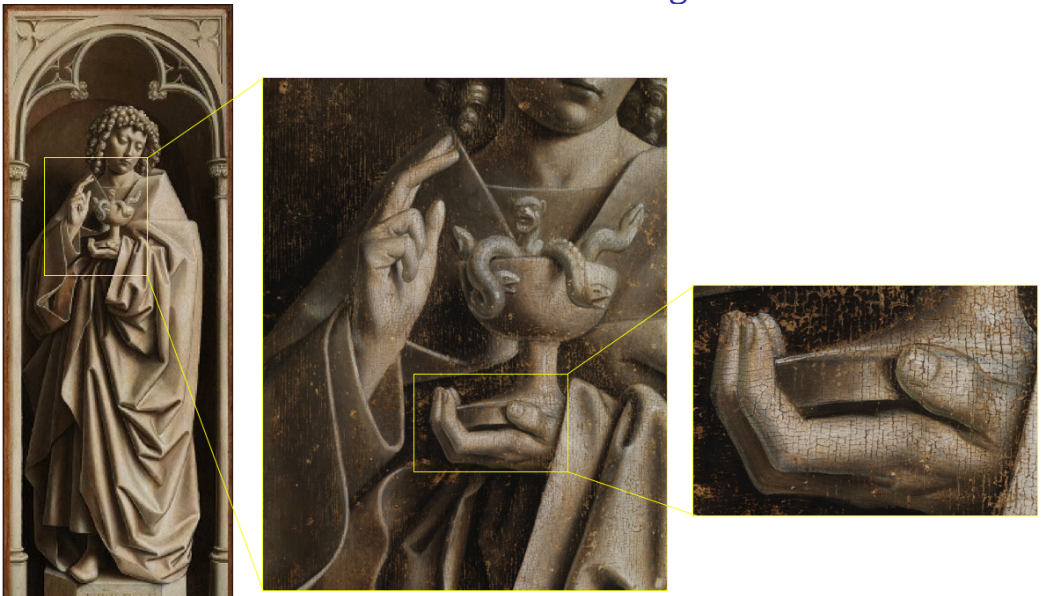
Registration of multimodal images

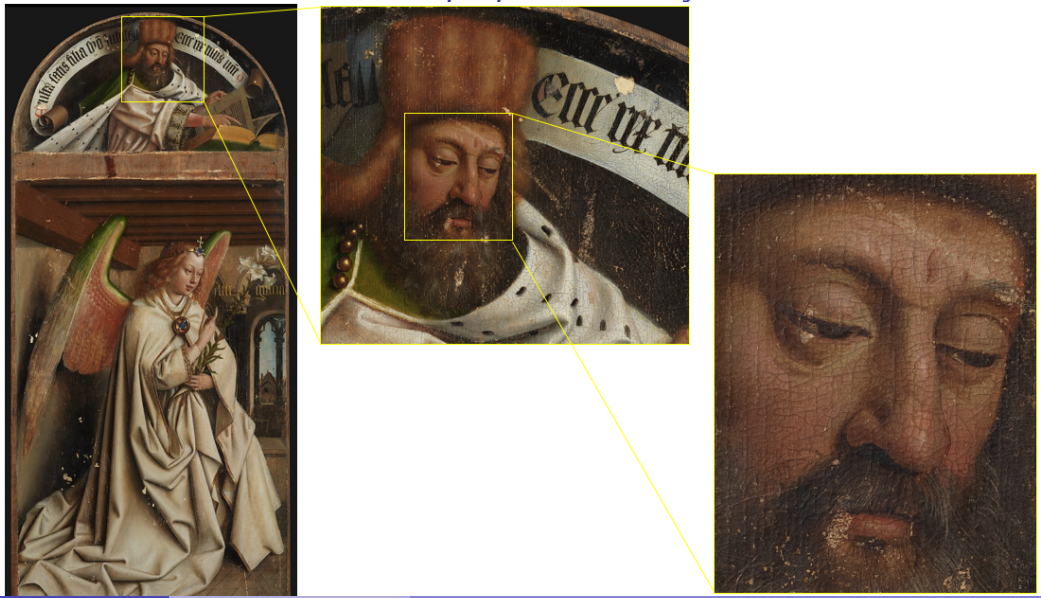


Crack patterns can be employed as landmarks.

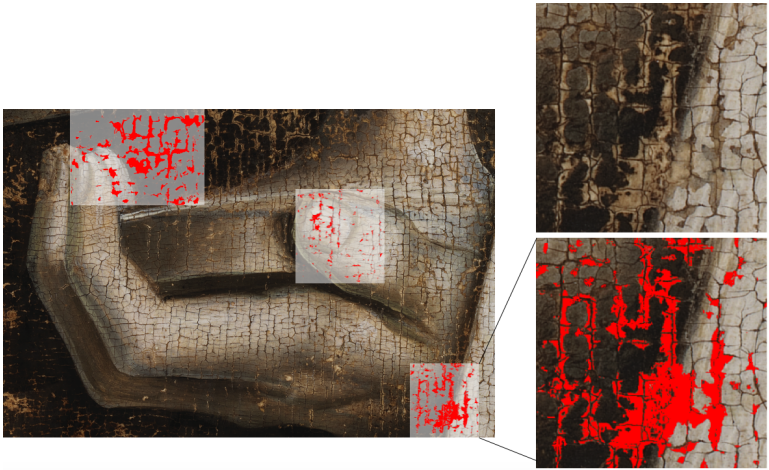
Paint loss detection data sets - *John the Evangelist*



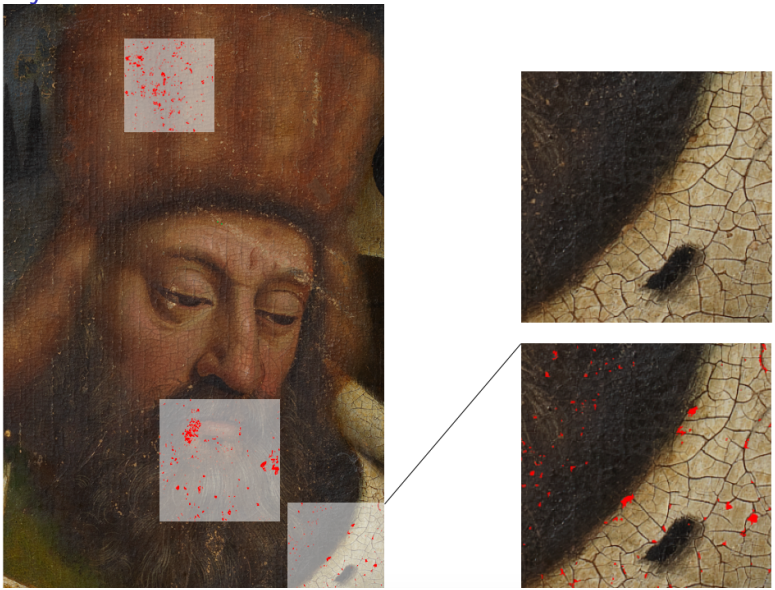
Paint loss detection data sets - *prophet Zachary*



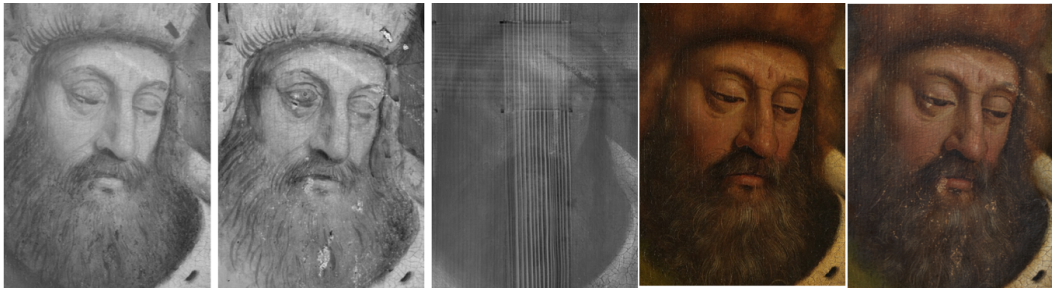
Annotations by art restorers



Annotations by art restorers



Multimodal Data



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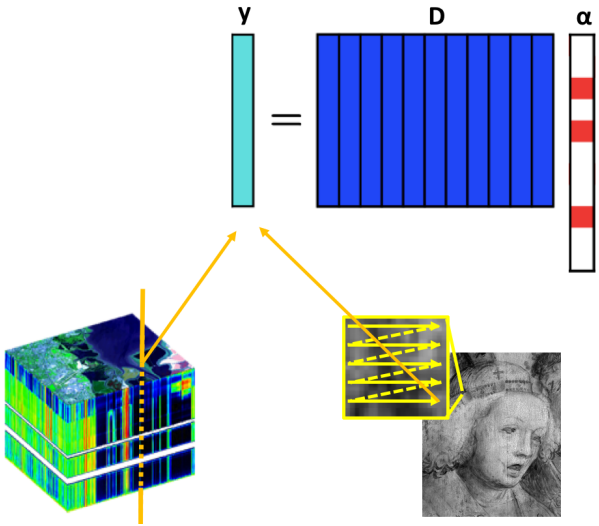
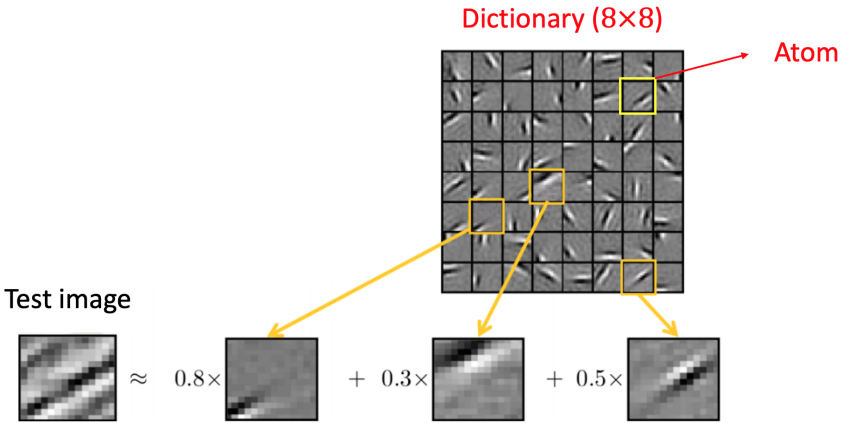
- Annotations done on macrophotographs during the treatment;
- Dictionaries for sparse representation classification constructed from the available multimodal data. The available modalities may differ from one panel to another.

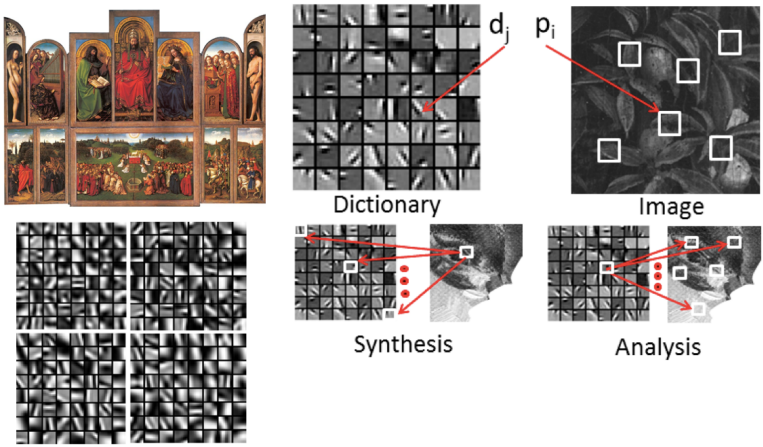
Sparse representation



Sparse coding and dictionary learning



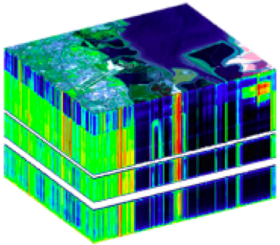
Application in Painter Style Characterization

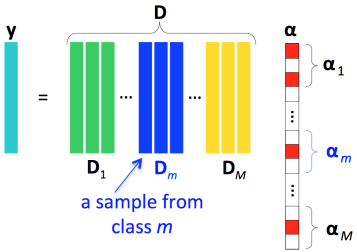


[Hughes et al, 2009], [Latić and Pižurica, 2014]

Sparse Representation Classification

[Wright et al, 2009]

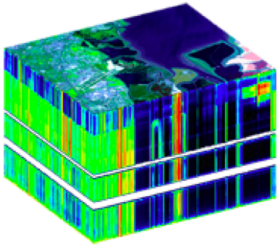


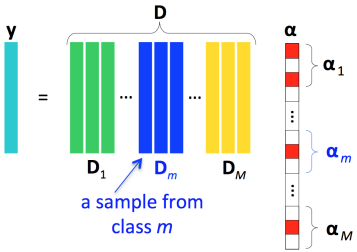


1. Construct structured dictionary $D = [D_1 ... D_n]$ from the annotated samples

Sparse Representation Classification

[Wright et al, 2009]

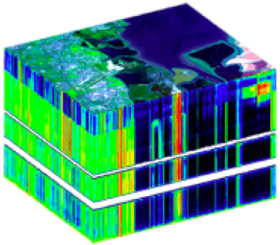


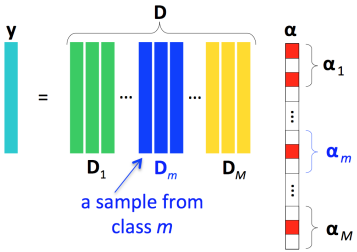


1. Construct structured dictionary $D = [D_1 ... D_n]$ from the annotated samples
2. Find the coefficients α by solving the sparse coding problem

Sparse Representation Classification

[Wright et al, 2009]

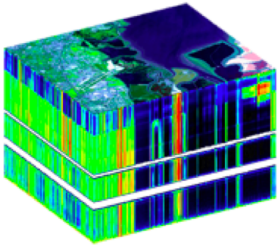


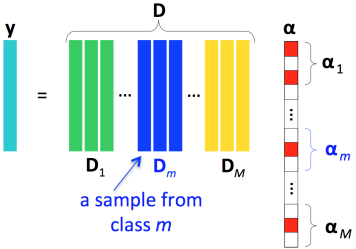


1. Construct structured dictionary $D = [D_1 ... D_n]$ from the annotated samples
2. Find the coefficients α by solving the sparse coding problem
3. Calculate the errors when representing the input y with each sub-dictionary D_i

Sparse Representation Classification

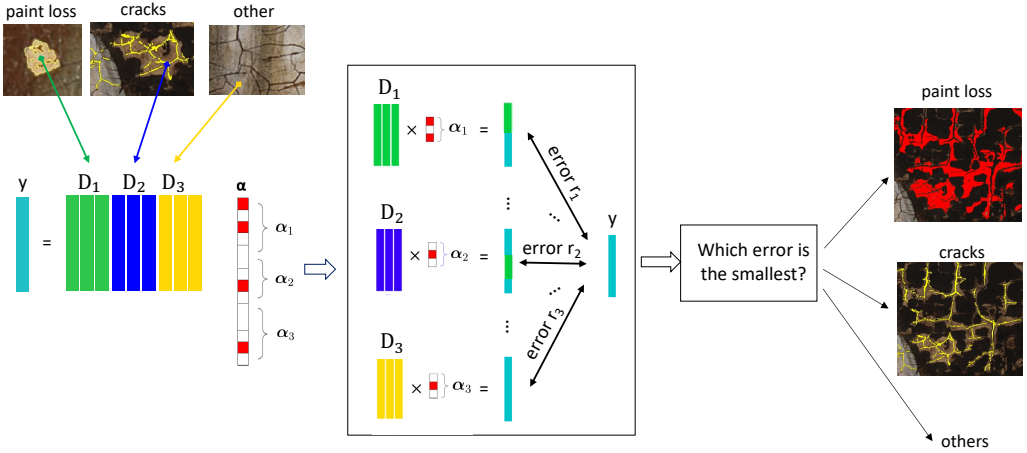
[Wright et al, 2009]





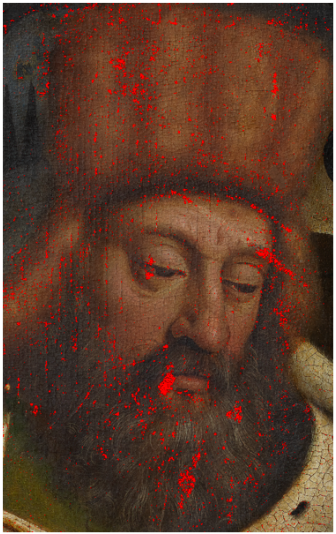
1. Construct structured dictionary $D = [D_1 ... D_n]$ from the annotated samples
2. Find the coefficients α by solving the sparse coding problem
3. Calculate the errors when representing the input y with each sub-dictionary D_i
4. Assign y to the class that gives the smallest error

Sparse Representation Classification

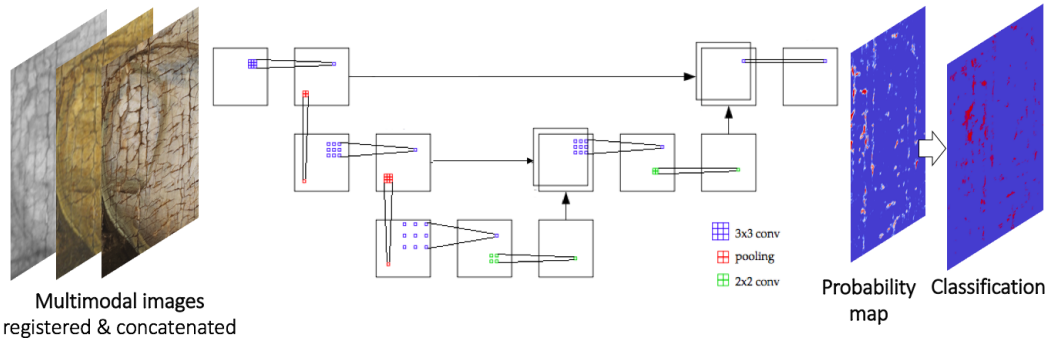


S. Huang, B. Cornelis, B. Devolder, M. Martens and A. Pižurica. Multimodal Target Detection by Sparse Coding: Application to Paint Loss Detection in Paintings. IEEE Transactions on Image Processing, 2020.

Paint Loss Detection Results



A multiscale deep learning method for paint loss detection



L. Meeus, S. Huang, B. Devolder, M.Martens, and A. Pižurica (2018).
Deep Learning for Paint Loss Detection: A Case Study on the Ghent Altarpiece. IP4AI.

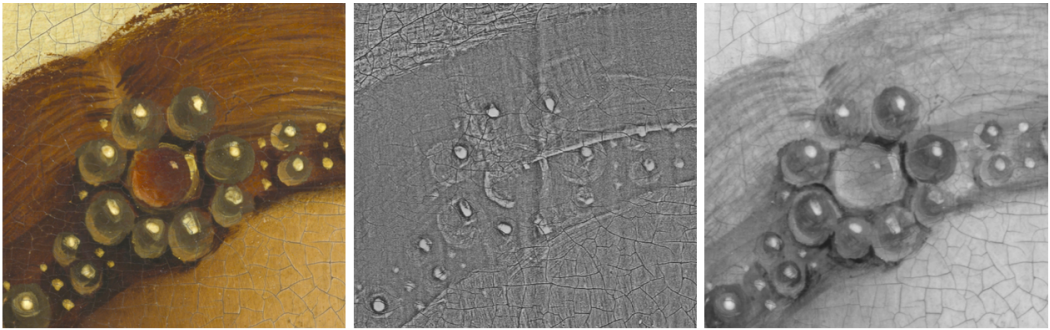
A multiscale deep learning method for paint loss detection

Size: 5954×7546; processed in < 1 minute

Deep learning in crack detection

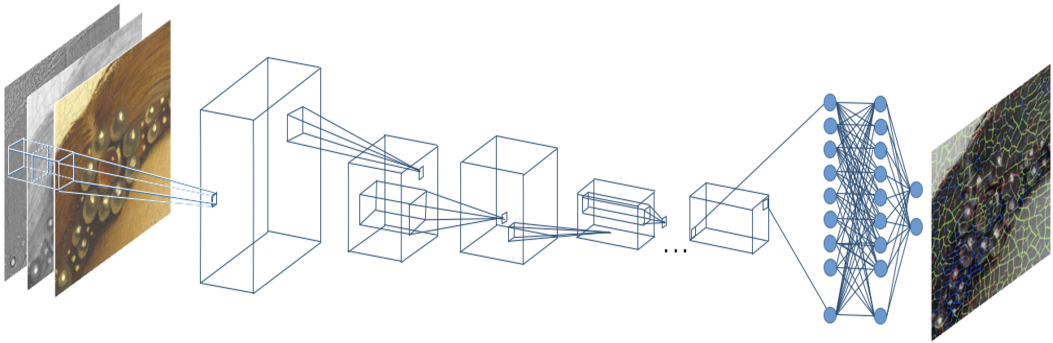
Crack detection in roads reported in [Lei et al,2016], [Cha et al, 2017].
However, crack detection in paintings is much more challenging!

Crack detection from multimodal data



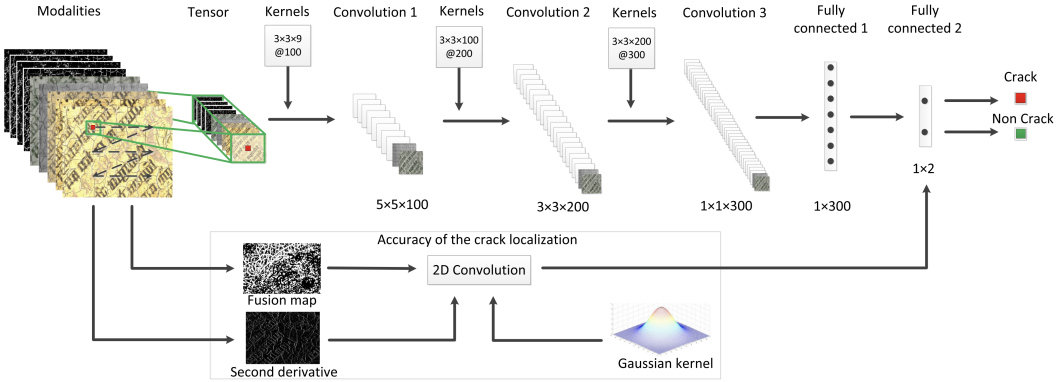
detail of the panel *Singing Angels*

A deep learning method for crack detection in paintings



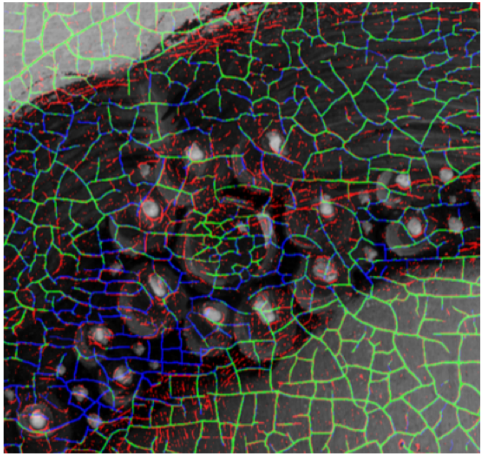
R. Sizyakin, B. Cornelis, L. Meeus, M. Martens, V. Voronin, and A. Pižurica (2018). A deep learning approach to crack detection in panel paintings. IP4AI.

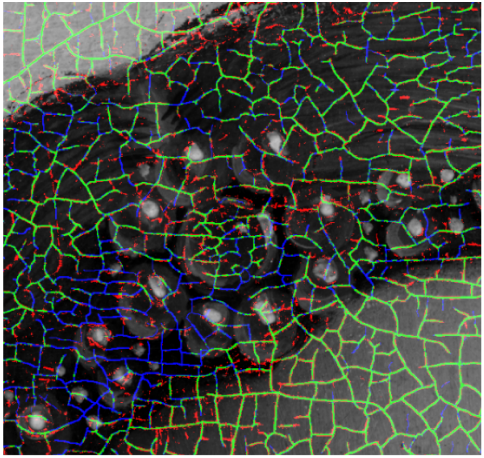
Crack detection in paintings



R. Sizyakin, B. Cornelis, L.Meeus, H. Dubois, M. Martens, V. Voronin, and A. Pižurica . Crack Detection in Paintings Using Convolutional Neural Networks. IEEE Access, 2020.

Crack detection: panel *Singing Angels*

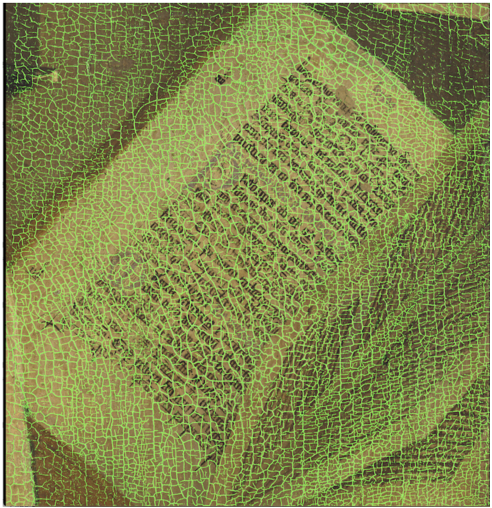




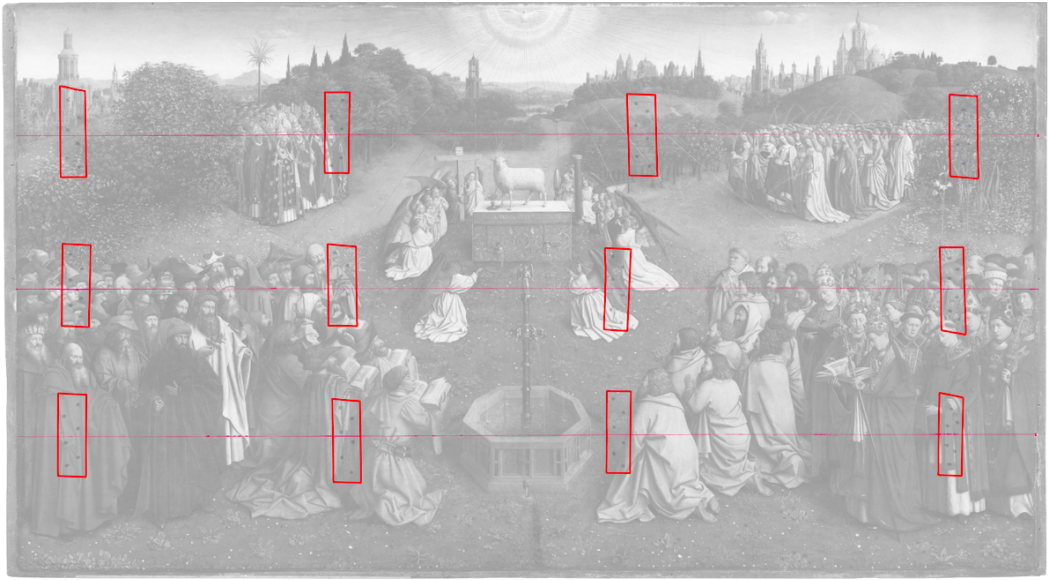
Left: A Bayesian multimodal method (BCTF). Right: CNN-based.
red – false detections; blue – missing cracks; green - -correct.

Challenging cases for crack detection

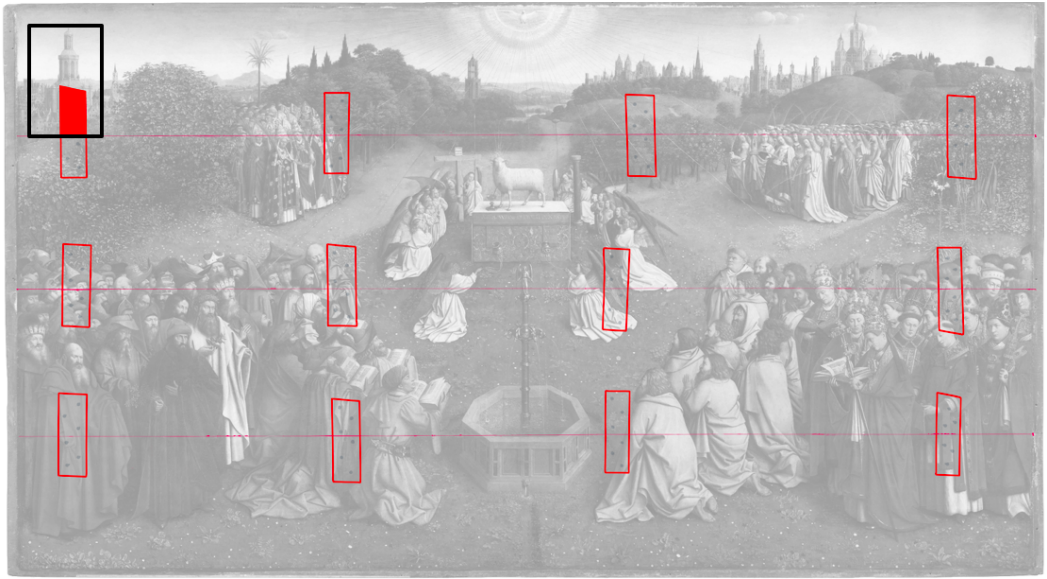
Challenging cases for crack detection



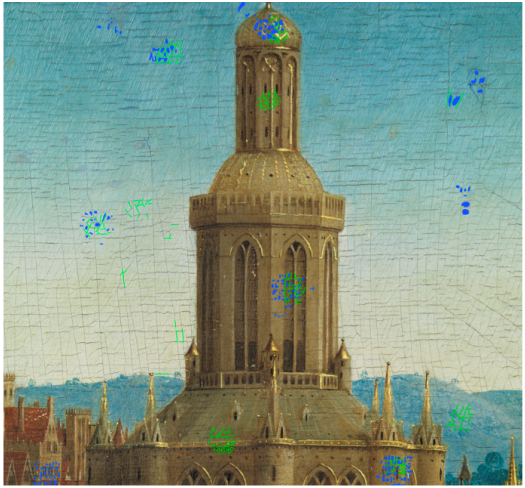
Case study on the central panel

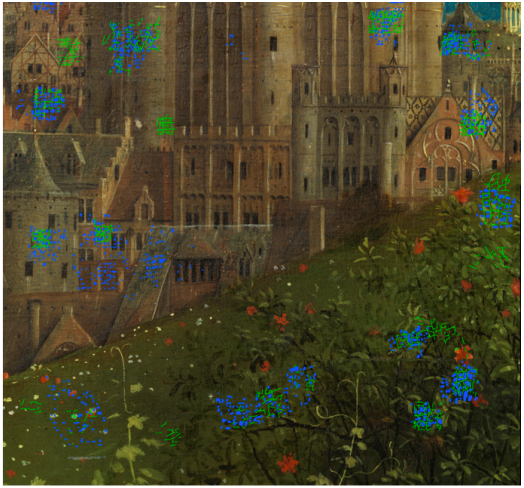


Case study on the central panel

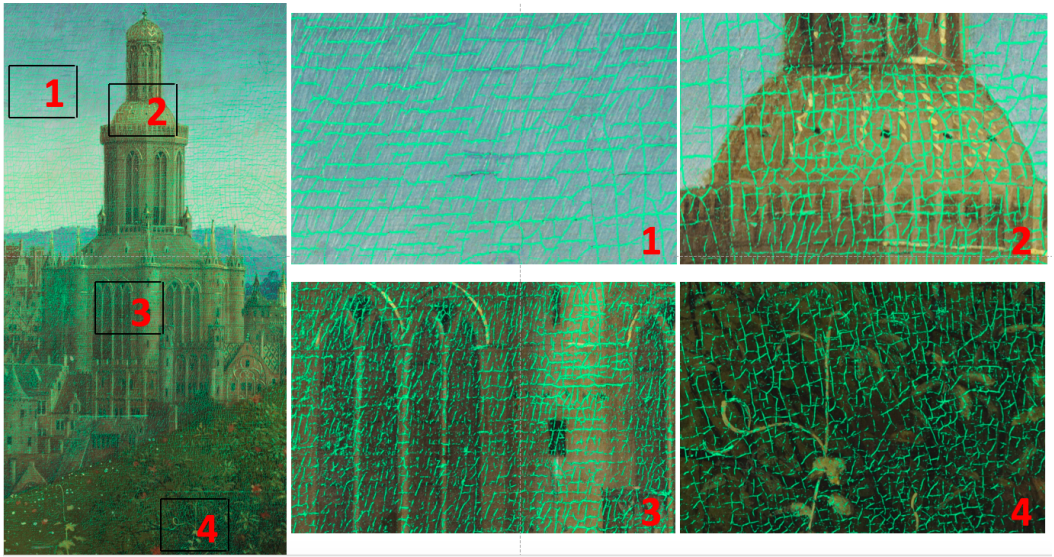


Case study on the central panel

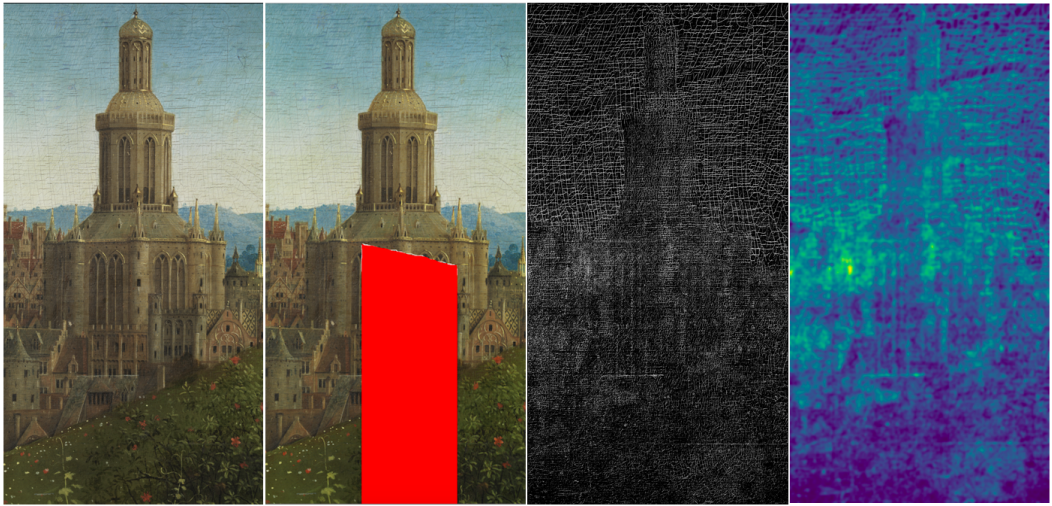




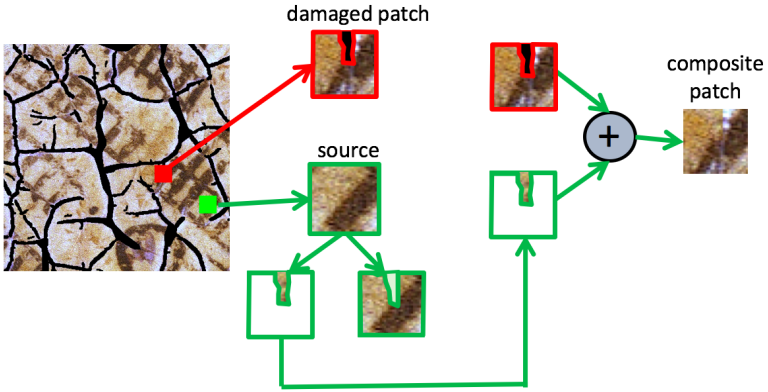
Case study on the central panel



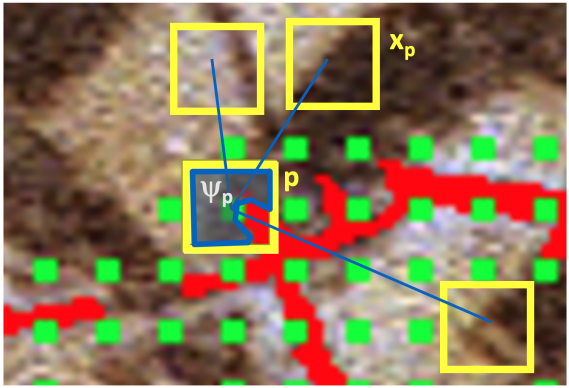
Case study on the central panel



Patch-based inpainting

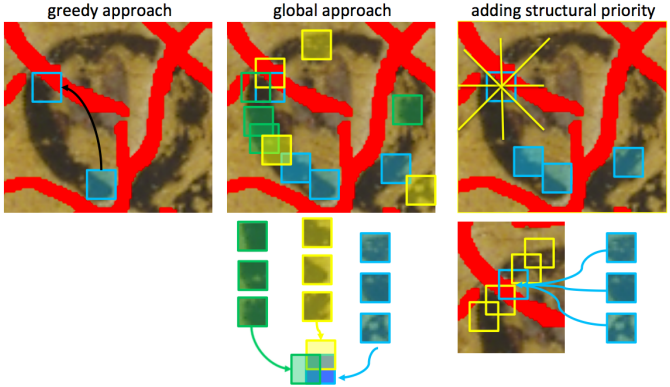


Inpainting concept



T. Ružić and A. Pižurica et al. Context-aware patch-based image inpainting using Markov random field modeling. *IEEE Transactions on Image Processing* 2015

A summary of patch based inpainting

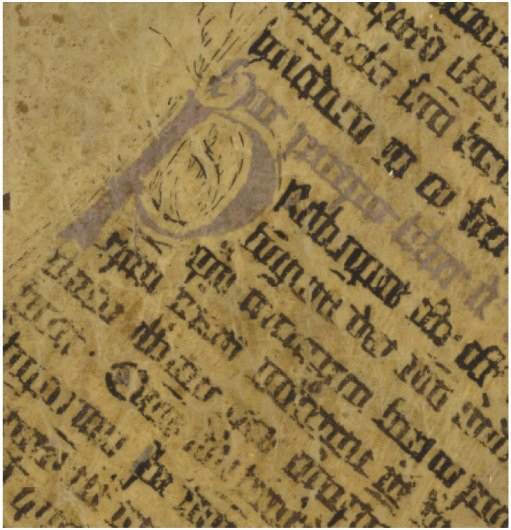


$$P_{i,j} = \mathcal{S}(\phi_i, \phi_j) + \max_k \sum_{l \in N_{j,k}} \mathcal{S}(\phi_i, \phi_l)$$

A. Pižurica et al. Digital Image Processing of the Ghent Altarpiece. *Signal Process. Mag.* 2015

Crack inpaiting

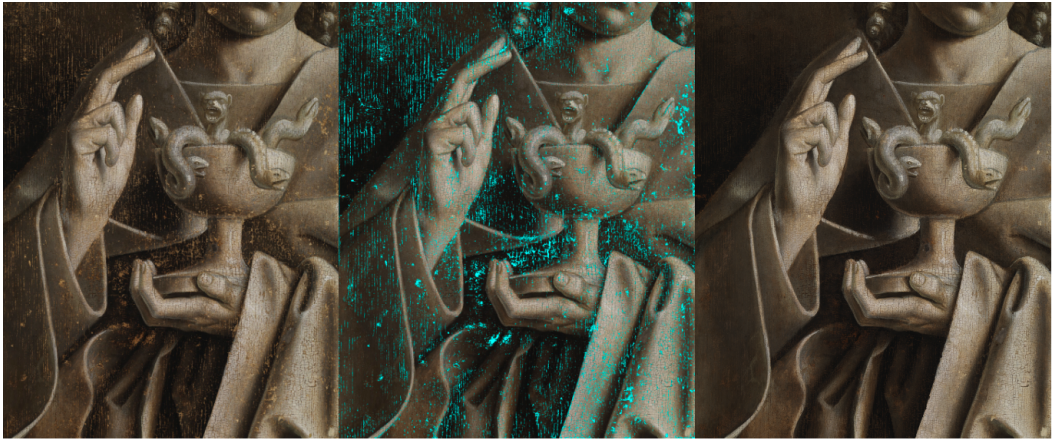
Crack inpaiting



Virtual Restoration

Automatic paint loss detection;
inpainting method of [Ružić and Pižurica, TIP, 2015].

Virtual Restoration



Automatic paint loss detection;
inpainting method of [Ružić and Pižurica, TIP, 2015].

Virtual Restoration

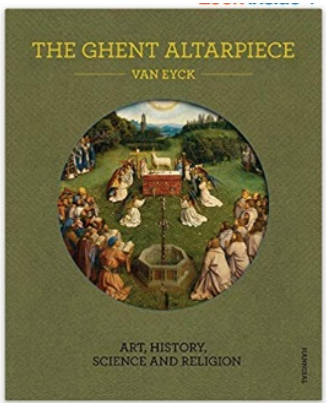
Automatic paint loss detection;
inpainting method of [Ružić and Pižurica, TIP, 2015].

Virtual Restoration

Left: Input; Middle: virtual restoration; Right: actual restoration.

Recent book on the Ghent Altarpiece

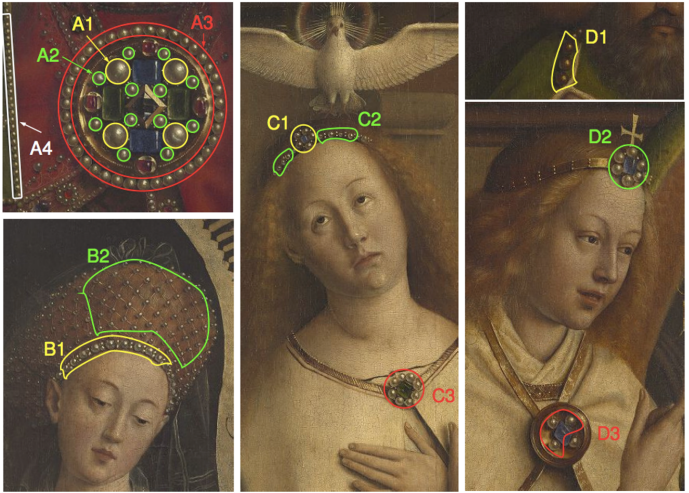
THE GHENT ALTARPIECE – ART, HISTORY, SCIENCE AND RELIGION (NEW)
Danny Praet, Maximiliaan P.J. Martens e.a.

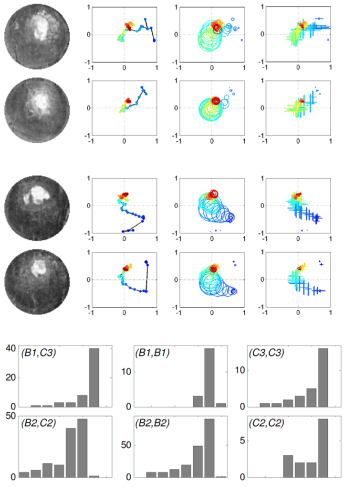


Paperback: 304 pages
Publisher: Cannibal Publishing (October 14, 2019)

Restored panels of the *Ghent Altarpiece* (2021)

Restored panels of the *Ghent Altarpiece* (2021)





A. Pižurica, L. Platisa, T. Ružic, B. Cornelis, A. Dooms, M. Martens, H. Dubois, B. Devolder, M. De Mey, I. Daubechies, **Digital Image Processing of the Ghent Altarpiece: Supporting the painting's study and conservation treatment**, *IEEE Signal Processing Magazine*, July 2015.

Planned for the third restoration phase (from 2022)