



Digital Inpainting in the Context of Artwork Restoration.

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Outline

- A. Short presentation of myself, laboratories and field of work.
- B. Art restoration and digital inpainting.
- C. Evaluation of digital inpainting algorithms in context of art restoration.
- D. Inpainting in hyperspectral image documentation.



A. Short presentation

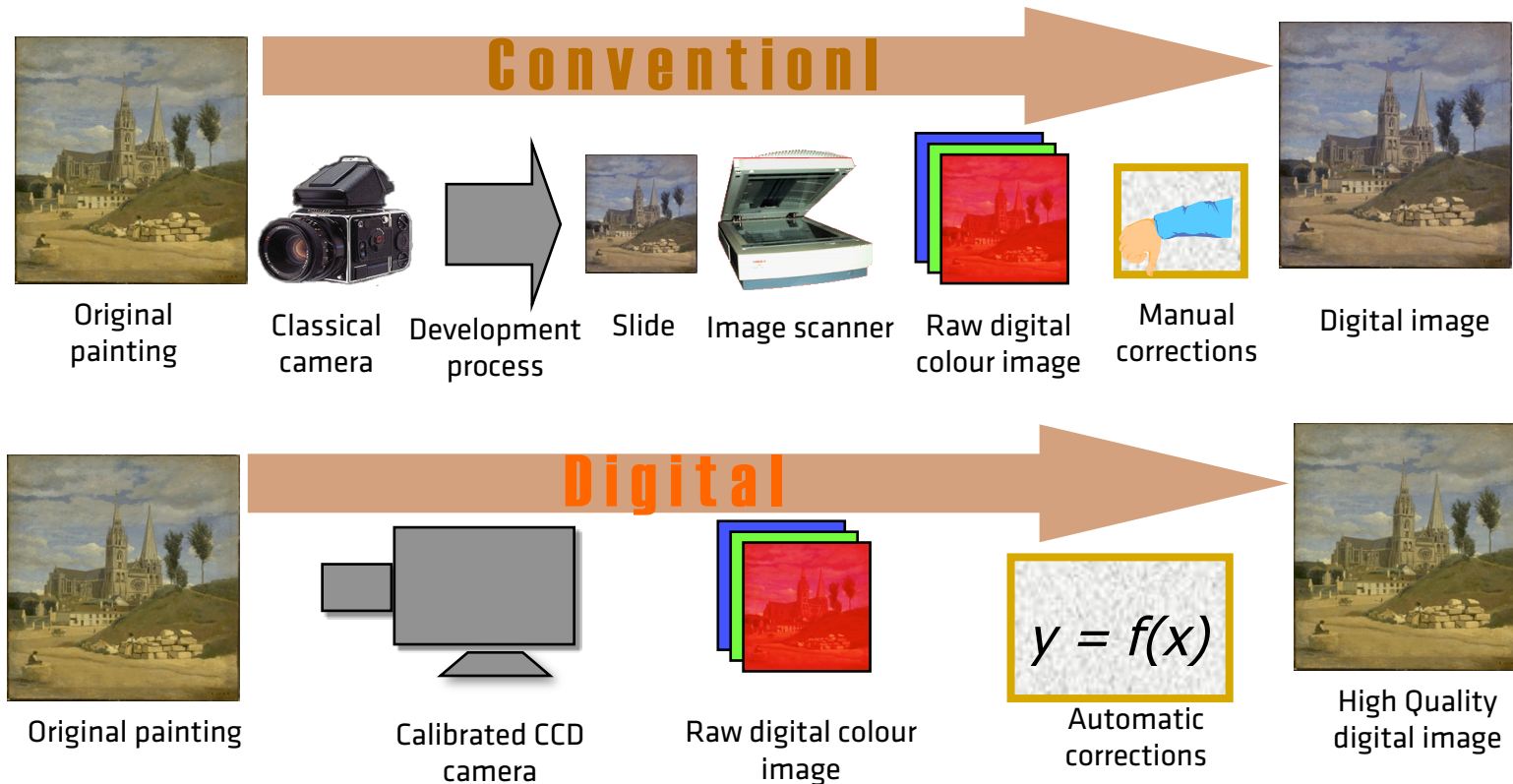


About myself

- Master Degree (Dipl. Inf.) in computers science at Ulm university with a focus in Computer Vision
- PhD student in a cooperation between the University of Burgundy and Gjøvik university college, supervised by:
 - Professor Jon Y. HARDEBERG (GUC)
 - Professor Yvon VOISIN (UB)
 - Associate Professor Alamin MANSOURI (UB)
 - Marius Pedersen, PhD (GUC)
- Acquisition and data analysis in the context of Cultural Heritage

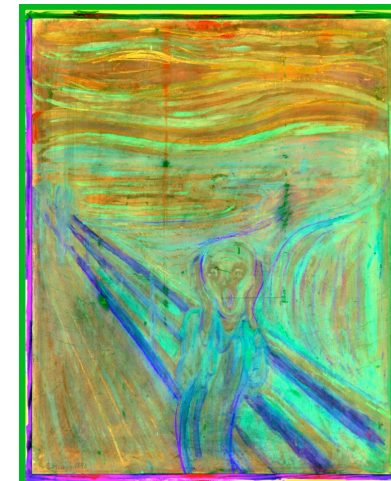
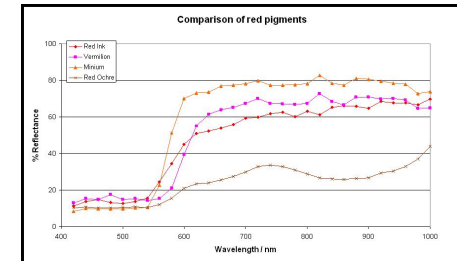
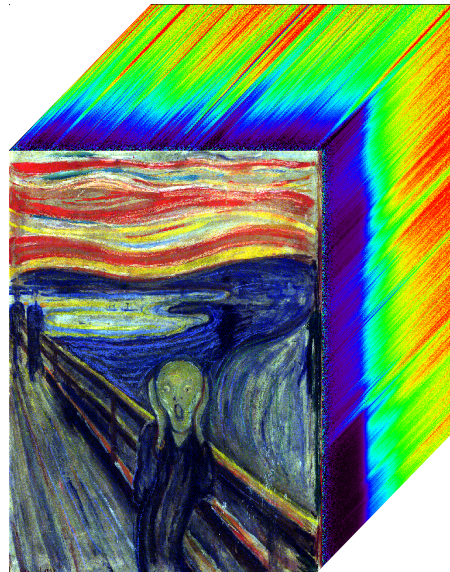
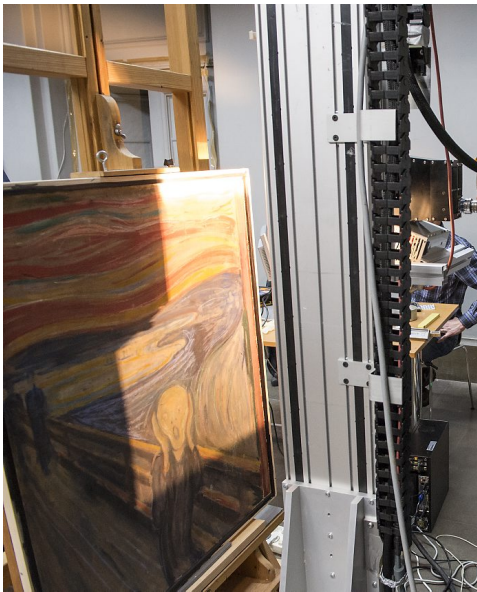


Background of the laboratory





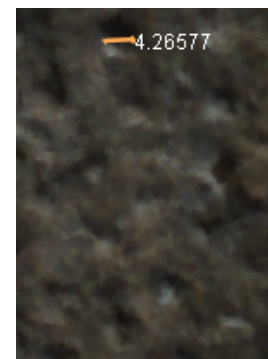
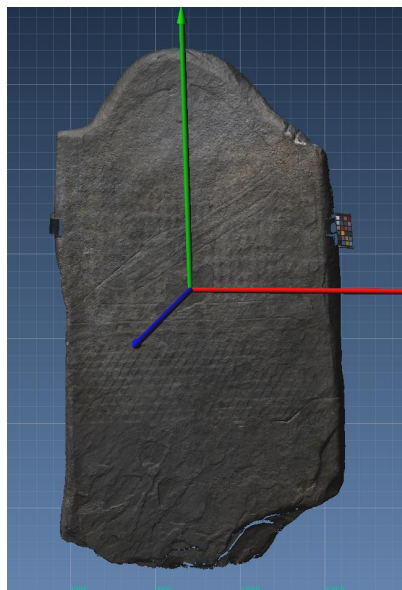
Spectral imaging





COLOR & SPACE IN
CULTURAL HERITAGE

3D colour acquisition



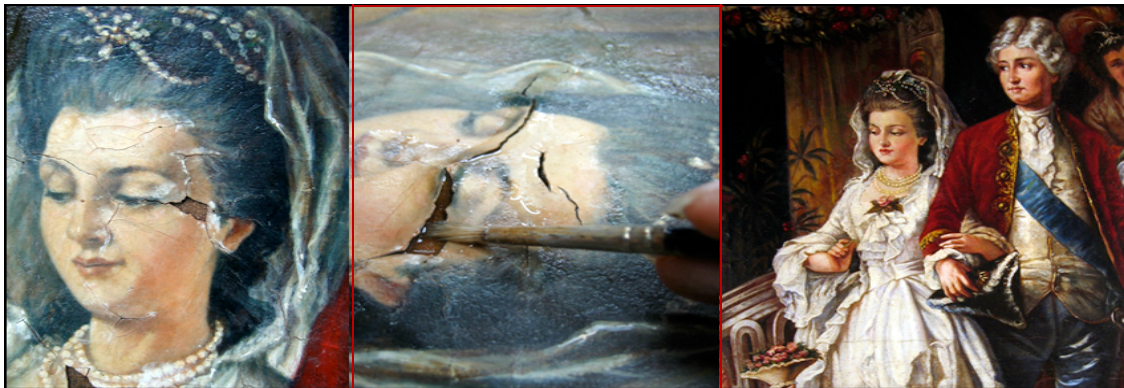


B. Art restoration and digital inpainting.



Manual Art Restoration

- Previous to any treatment: **Documentation** of the condition before any intervention. Research background of the painting, and used materials.
- Multiple interventions to **preserve** the state of an artwork.
 - surface cleaning, varnish removal, removal of previous fillings.
 - treatment of the canvas.
 - applying fillings, colours binders on losses of original paint.
- New Paint is **reversible** in water and should never cover old paint.





Different expressions

- **Inpainting:** To apply new paint in areas where original paint has been lost.
- Applying **fills** / **Retouching:** Often used synonym for inpainting in the context of art restoration.
- **Over-paint** (verb): Paint is applied [partly] on areas with original paint. Common practise of art restoration in the past.
- **Air-brush** (verb): Historical term for alteration of photos.
- **Error concealment:** Lost data (e.g. due to transmission) is replaced by synthetic data.



Art restoration as an inspiration for digital inpainting

- Detail of the fresco Cornelia, mother of the Gracchi by J. Suvee (Louvre). (a) Painting in an advanced state of deterioration. (b) Manually restored painting



(a)



(b)



Art restoration as a guideline

Conservators of the Minneapolis Institute of Arts were consulted, to present a guideline for early digital inpainting approaches:

- « 1. The global picture determines how to fill in the gap, the purpose of inpainting being to restore the unity of the work
- 2. The structure of the area surrounding Ω is continued into the gap, contour lines are drawn via the prolongation of those arriving at $\delta\Omega$
- 3. The different regions inside Ω , as defined by the contour lines, are filled with color, matching those of $\delta\Omega$
- 4. The small details are painted (e.g. little white spots on an otherwise uniformly blue sky). In other words, “texture” is added. »



How can digital inpainting support art restoration?

- Digital alteration of a painting useful for professional restorers?



'Soria Moria' painting by Theodor Kittelsen.



How can digital inpainting support art restoration?

- Digital inpainting could support manual intervention.
 - How to restore large areas ?
 - How to include expertise knowledge (of art history, early drafts, used materials) ?
- Low-priced digital inpainting as a visualisation.
 - For museum audience
 - In order to gain financial support.
- Conceal acquisition errors for documentation purposes.



C. Evaluation of digital inpainting algorithms



How to evaluate inpainting in context of art restoration

- Inpainting does not have the objective to recover the original, but a coherent visual experience.
- Multiple inpainting approaches/frameworks have been proposed.
- Can different inpainting algorithms be ranked in terms of the perceived quality?
- Few **quality metrics** to quantitatively evaluate the inpainting result have been proposed.
- Do quality metrics correlate with a perceived quality of inpainted images?

1. Evaluation of inpainting algorithms in context of art restoration
2. Evaluation of quality metrics



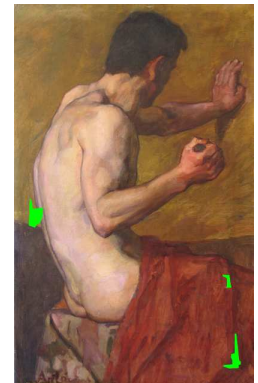
Evaluation in context of art restoration

- Inpainting is of the final steps in art restoration.
- Current approach is to do „simulate“ the cleaning of a painting.
- The evaluation of inpainting will remain artificial.





Images and masks



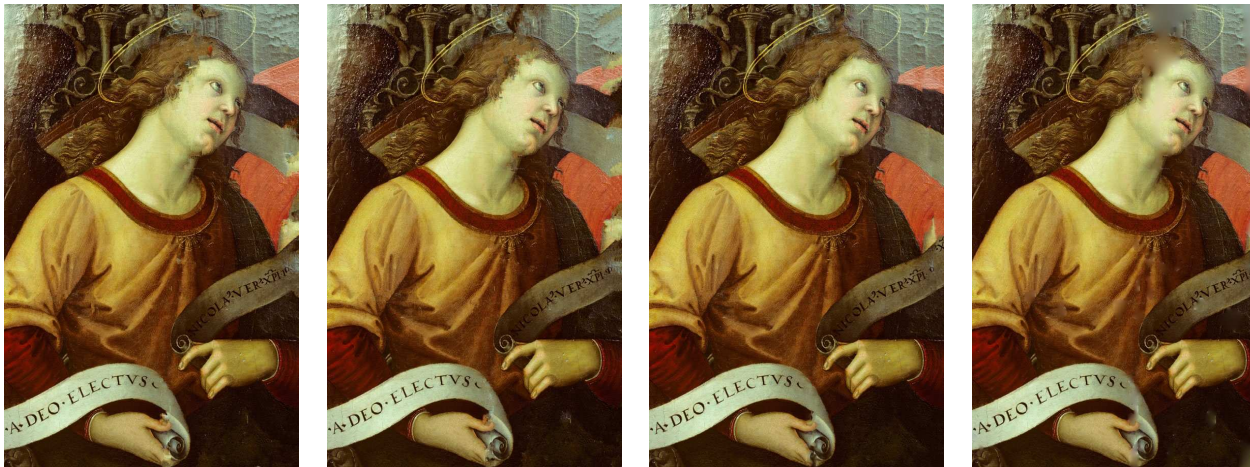
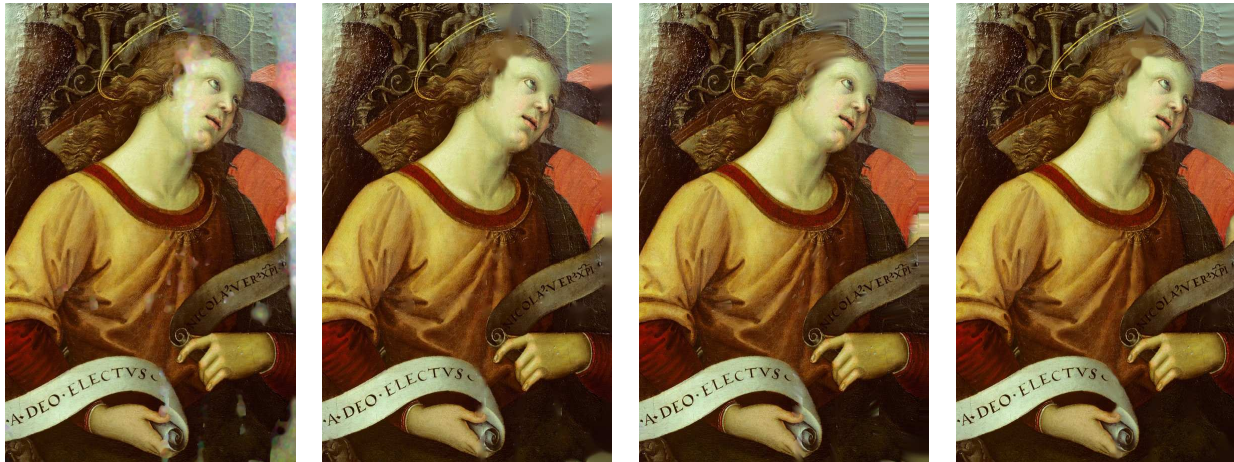


Evaluated algorithms

Year	Author(s)	Type	Gap size	Structure	Texture	Blur
2000	Bertalmio <i>et al.</i> [5]	PDE based	S	Yes	No	Yes
2004	Telea [7]	PDE based	S - M	Yes	No	Yes
2005	Tschumperle and Deriche [4]	PDE based	S - M	Yes	No	Yes
2004	Criminisi <i>et al.</i> [2]	Exemplar based	M - L	Yes	Yes	No
2010	Zhou and Kelly [3]	Exemplar based	M - L	Yes	Yes	No
2001	Oliveira <i>et al.</i> [9]	Fast (convolution)	S	No	No	Yes
2007	Bornemann and Marz [6]	Fast (PDE based)	M - L	Yes	No	Yes
2009	Barnes <i>et al.</i> [8]	Fast (Exemplar based)	M - L	Yes	Yes	No



Evaluated algorithms





Evaluation method

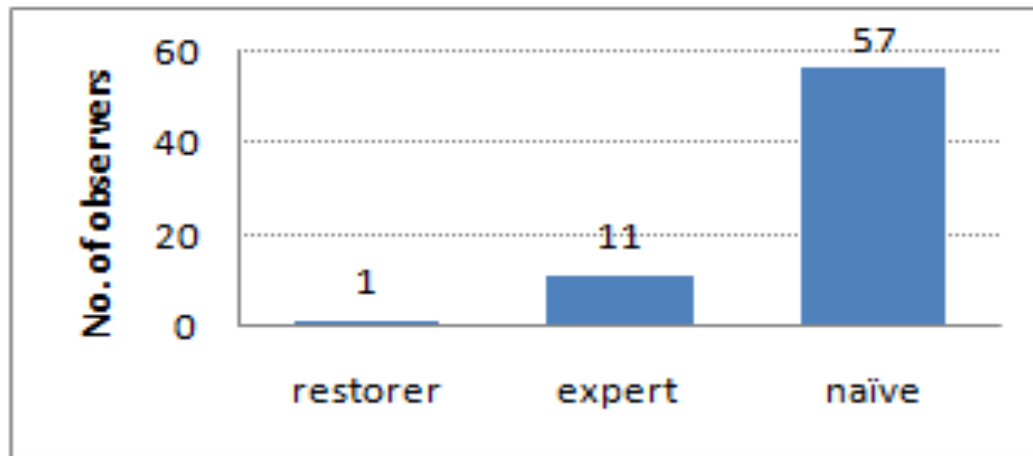
The overall quality of the right-sided image is:

- Excellent
- Good
- Fair
- Poor
- Bad

You have rated 8 image(s) out of 54. [Next image](#)



Evaluation method

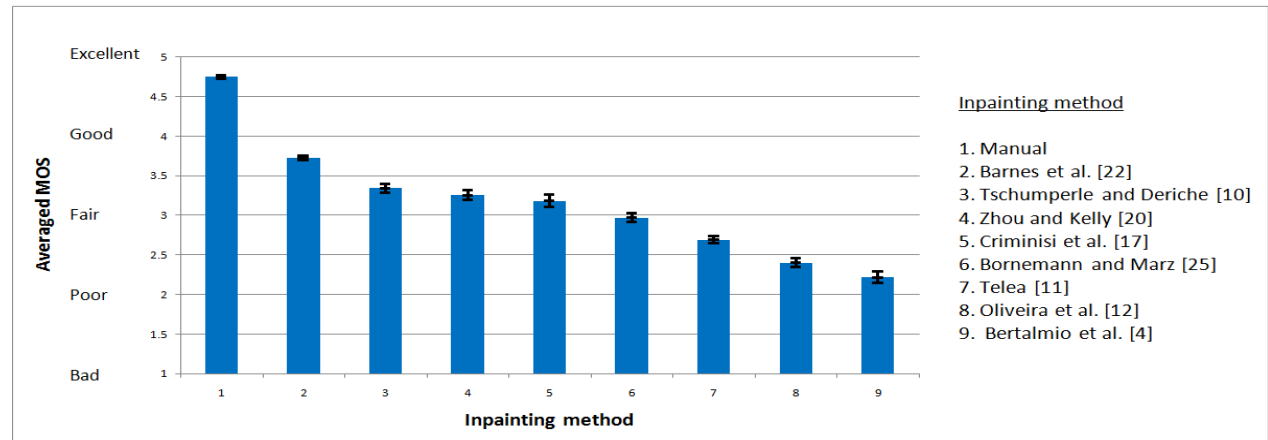


- Experts are familiar to image quality and digital image inpainting (Faculty staff from the colourlab)
- Restorer **Radu Tataru** from the Brasov Art Museum in Romania

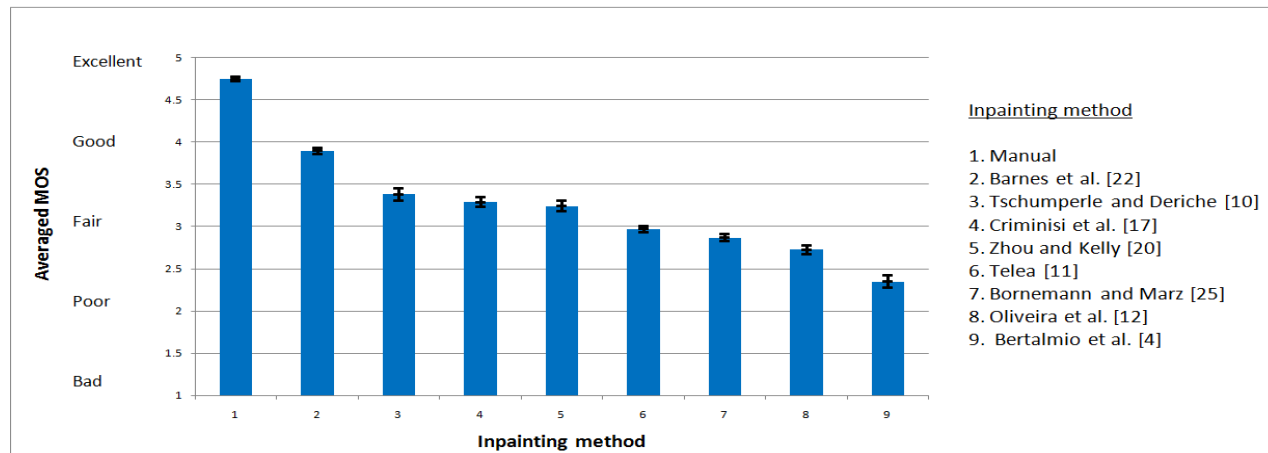


Results

naïve observers



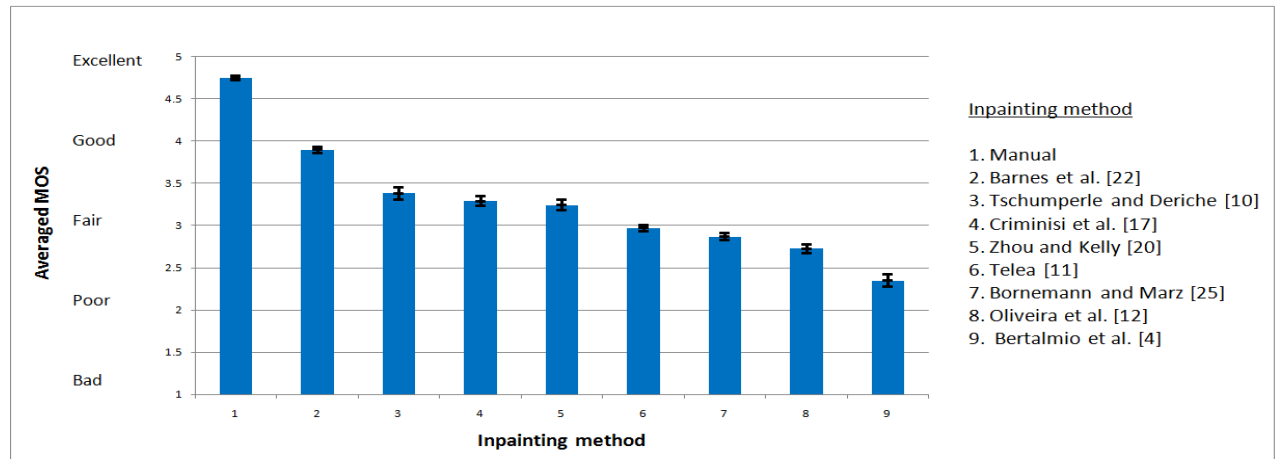
expert observers



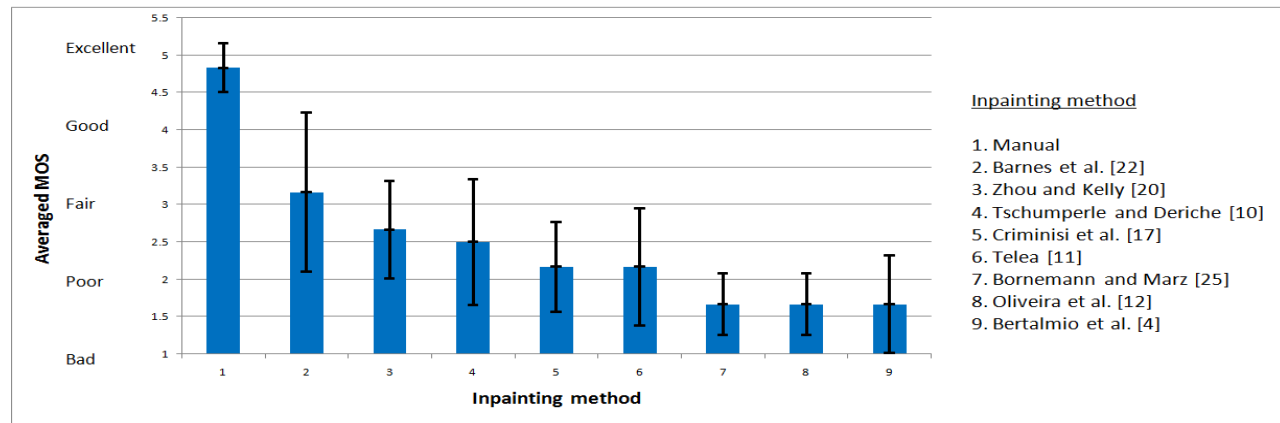


Results

expert observers



professional
restorer





Results overview

- Manual restoration as a „benchmark“, with almost perfect score independently of the expertise of the observer.
- More elaborated inpainting approaches perform better than PDE-based inpainting.
- **Discrepancy** between manual and digital inpainting is perceived largest by the professional restorer. Marginal differences between expert and naïve observer.



Quality metrics

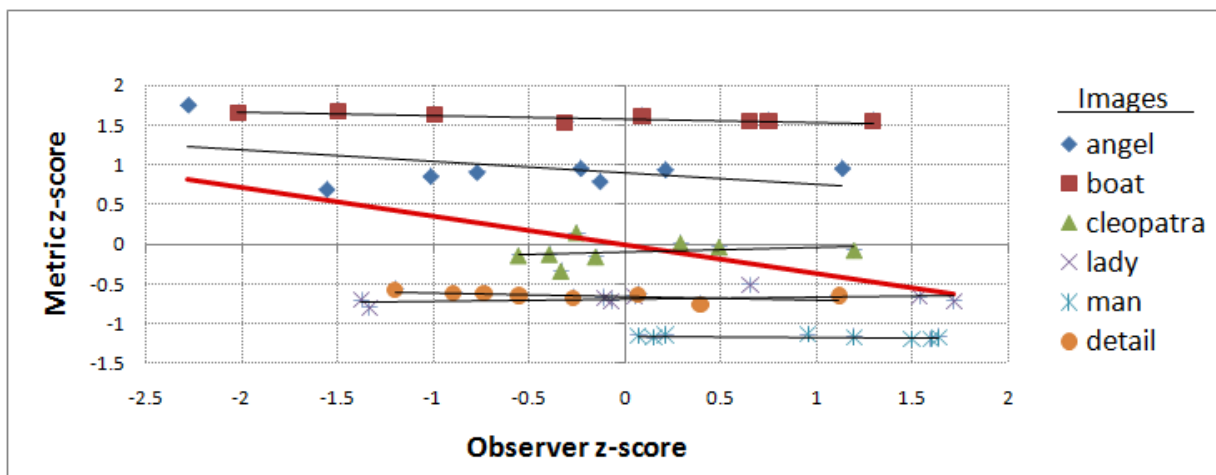
- Evaluations are labour-intensive, and might be substituted by image quality metrics.
- Different classes of quality metrics:
 - Mathematically based metrics (e.g. PSNR, MSE)
 - Low-level metrics (e.g. spatial-CIELAB)
 - High-level metrics (e.g. SSIM)
- Image quality for inpainting metrics should take the Human Visual System (HVS) into account.
- High level image quality metrics for inpainting based on saliency (Average Squared Visual Saliency (ASVS) and Degree of Noticeability (DN))



High level quality metrics for inpainting

- Degree of noticeability (DN) = identifies noiseless areas + areas where the saliency changes:

$$(1 / (\|\Omega\| + \|\Phi\|)) ((\sum_{\Omega} (S'(p))^2) + (\sum_{\Phi} (S'(p) - S(p))^2))$$



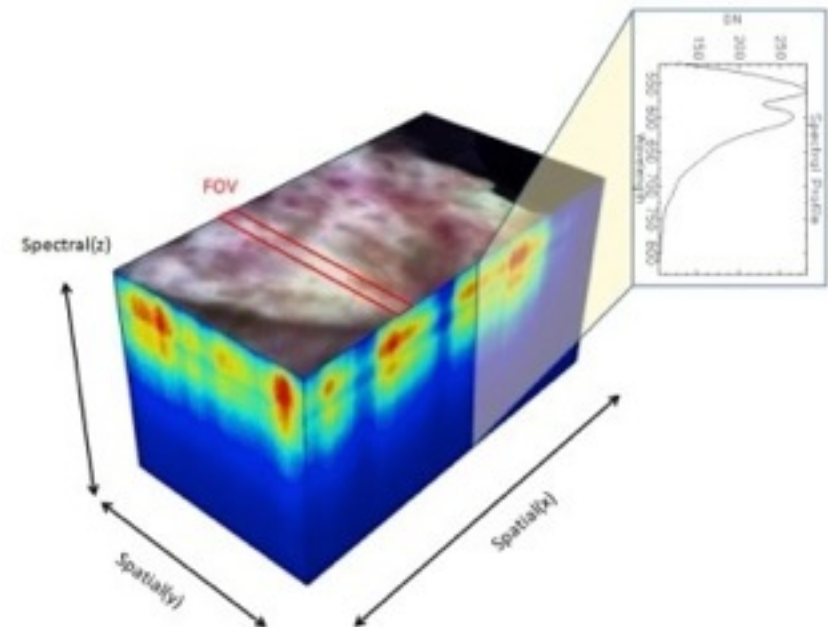


B. Inpainting in hyperspectral image documentation



Hyperspectral imaging

- Origins as a remote sensing tool.
- Imaging spectroscopy.
- Instead of an image it captures a physical property of the surface (its reflectance factor)





Hyperspectral imaging for art documentation

- Documentation -> invariant to the illumination.
- Helping Restorers -> Identifying Pigments (Non-destructive/semi-automatic)
- Art history -> Hyperspectral analysis might constrain the time when the painting was created.
- Virtual museum -> Apply different illuminations/ false colours.
- Art Reproduction and printing.



Hyperspectral data acquisition

- Noise reduction
- Geometric pixel normalisation
- Illumination normalisation
 - Non-uniformity of light + absolute illumination
 - Recover spectral reflectance
- Mosaicking and stitching
- Error concealment
 - Spectral highlights
 - Overexposed pixels



Error concealment

- Local areas are affected - spatially and spectrally.
 - Interpolation ?
 - Inpainting ?
- Variational based framework adapted to hyperspectral datacube (work in progress)



Real hyperspectral inpainting

- Future work
- Possibilities in combination with pigment identification. E.g. Additional restoration steps could be simulated.
- Using additional information e.g. underpaintings
- Framework needs to be open for the expertise of art restorers (used pigments, similar paintings)



Merci

