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Thin Details Meet Large-Scale 3D-Reconstruction: Photometric Stereo for Cultural Heritage

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THIN DETAILS MEET LARGE-SCALE 3D-RECONSTRUCTION

Photometric Stereo for Cultural Heritage

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ANR IMG



Digitizing two cultural heritage masterpieces



The Bayeux tapestry
XIth century, 70 m long



The Chauvet cave
36,000 years ago, 500 m long

Aim of the project

Develop AI tools for helping the 3D-digitization of these fragile, large-scale artifacts

When thin details meet large-scale



The artworks are **large-scale**, yet exhibit extremely **thin details**:

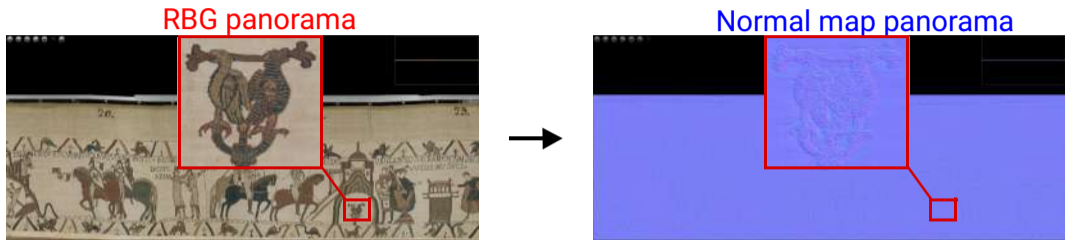
- ▶ Wool strings on a linen canvas
- ▶ Engravings on limestone

Challenge: digitize both the low and high geometric frequencies, while not deteriorating the artifacts

1. Case of the Bayeux tapestry

2. Case of the Chauvet cave

3D-digitization of the Bayeux tapestry



Goal: construct a 2.5D panorama of this 70 m-long medieval wool and linen embroidery, telling the conquest of England by William, Duke of Normandy, in 1066

- ▶ An **RGB panorama** is already available: <https://www.bayeuxmuseum.com/en/the-bayeux-tapestry/discover-the-bayeux-tapestry/explore-online/>
- ▶ Can we convert it to **3D**?

Redon et al., *3D surface Approximation of the Entire Bayeux Tapestry for Improved Pedagogical Access*, Proc. ICCV 2023 workshop on e-heritage

From an RGB panorama to a 2.5D one



High-resolution ($480,000 \times 6,000$ px) RGB panorama, created from 86 images acquired in 2017 by La Fabrique de patrimoines en Normandie

Proposed strategy for 3D-digitization

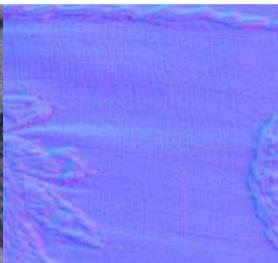
1. Store the RGB spatial registration parameters
2. Turn each RGB image to 2.5D using deep learning
3. Apply the same spatial registration to the 2.5D images

Deep image-to-geometry learning

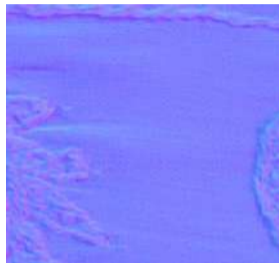
Input
image



Ground truth
normal map



Estimated
normal map



Proposed strategy for 3D-digitization

1. Store the RGB spatial registration parameters
2. Turn each RGB image to 2.5D using deep learning
3. Apply the same spatial registration to the 2.5D images

Ground truth geometry acquisition campaign

3D-reconstruction of 12 scenes, based on photometric stereo:



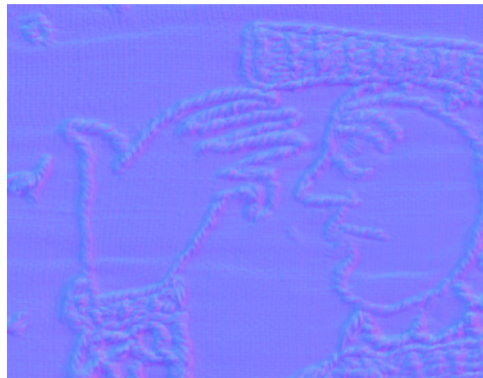
Left: three input images, taken from the same viewing angle but varying lighting

Right: output high-resolution mesh (5M triangles)



We have ≈ 30 couples (RGB, normals) of size 3000 px^2

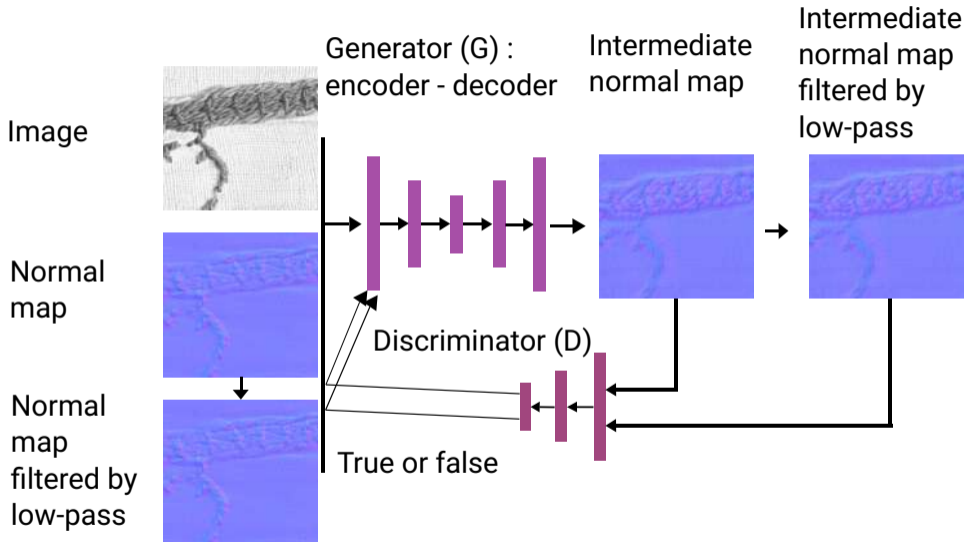
→ Thousands of 128 px^2 patches for learning the mapping $\text{RGB} \mapsto \text{geometry}$



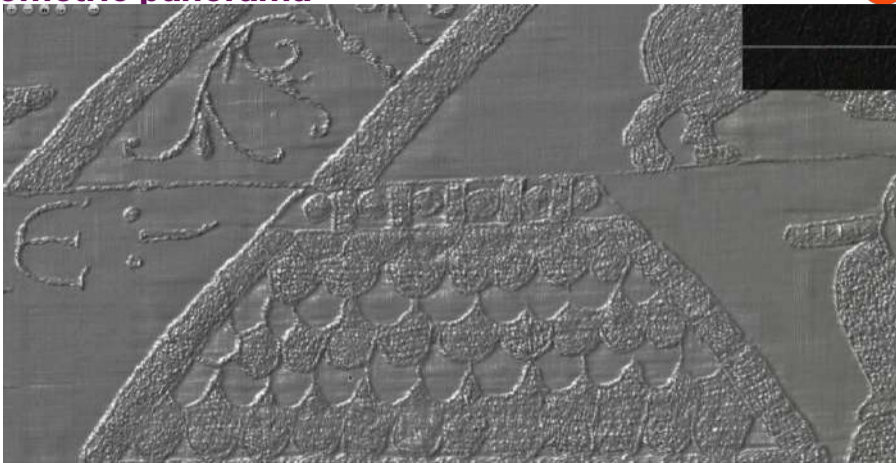
We have ≈ 30 couples (RGB, normals) of size 3000 px^2

→ Thousands of 128 px^2 patches for learning the mapping $\text{RGB} \mapsto \text{geometry}$

Deep image-to-geometry learning



Geometric panorama



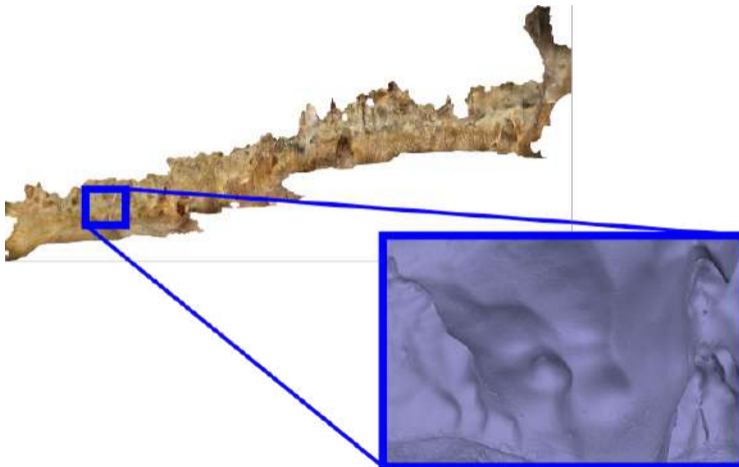
<https://redonmarjorie.github.io/projects/BayeuxPanorama.html>

1. Case of the Bayeux tapestry

2. Case of the Chauvet cave



“Panneau des chevaux” (Chauvet-Pont-d’Arc cave, Ardèche, France)



3D model of the Chauvet cave. Thin details are not reconstructed



Zoom on the “Panneau des chevaux”

Needs

- ▶ Precision: capturing digitized tracings, fine engravings, etc.
- ▶ Separate the relief from the color: analysis of the antero-posteriority

Photometric methods

- ▶ Have a pixel-size precision
- ▶ Separate light, geometry and color

Lighting calibration with a sphere

- ▶ Matte or glossy sphere placed in the scene
- ▶ Algorithm adapted to each type of sphere
- ▶ Sphere can be manually defined

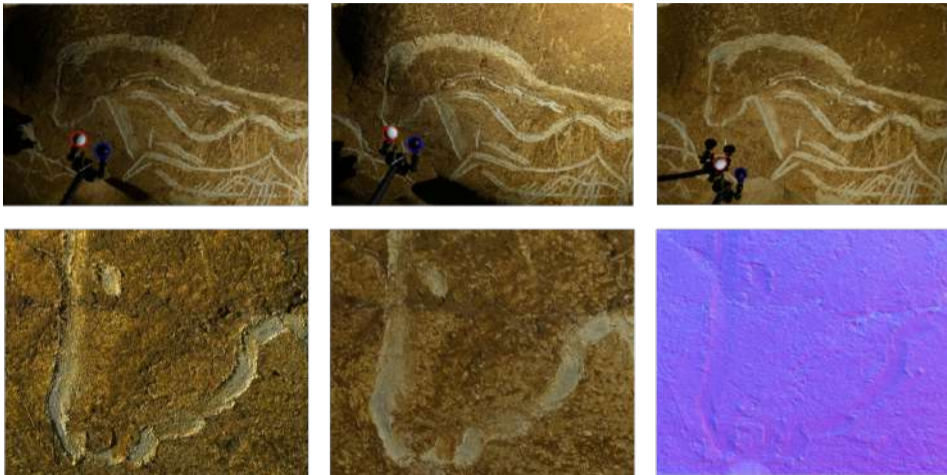


PS on the “Panneau des mammouths raclés”. From left to right: one of the 13 pictures, zoom on three pictures and results of PS (albedo and normal map)

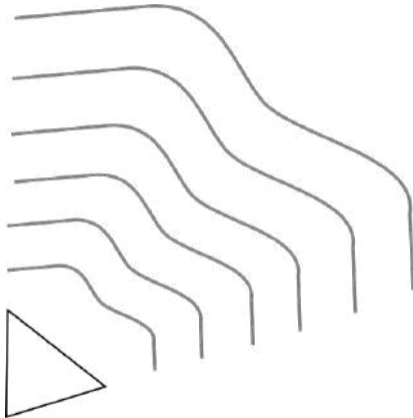


- ▶ Spheres are positioned at the end of a pole
- ▶ Position of the sphere in the image differs from one image to another
- ▶ Automatic detection with DETR network

Automatic neural lighting calibration

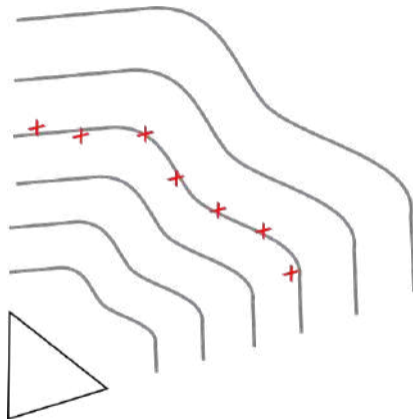


Top: three pictures (out of 16) with calibration spheres on a pole
Bottom: zoom on a picture, albedo and normal map



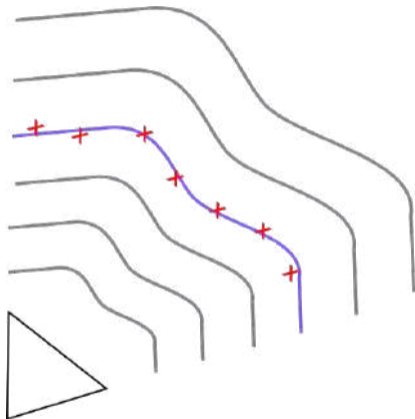
Ongoing work

- ▶ Depth deduced from normals, up to a scale factor



Ongoing work

- ▶ Depth deduced from normals, up to a scale factor
- ▶ Idea: use the photogrammetric cloud to determine the right scale



Ongoing work

- ▶ Depth deduced from normals, up to a scale factor
- ▶ Idea: use the photogrammetric cloud to determine the right scale

Thank you



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<https://alicevision.org/labcom-alicia/>
<https://redonmarjorie.github.io/projects/BayeuxPanorama.html>

