

# 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

#### **Outline**

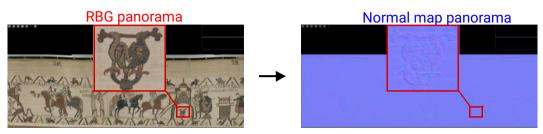


1. Case of the Bayeux tapestry

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 *embrodery*, 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





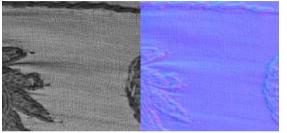
High-resolution ( $480,000\times6,000~px$ ) RGB panorama, created from 86 images acquired in 2017 by La Fabrique de patrimoines en Normandie

#### 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

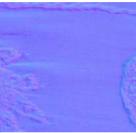
### Deep image-to-geometry learning

Input Ground truth image normal map





Estimated normal map



#### Proposed strategy for 3D-digitization

- 1. Store the RGB spatial registration parameters
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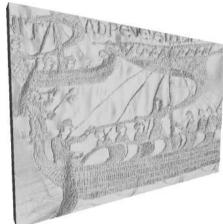
### **Ground truth geometry acquisition campaign**





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





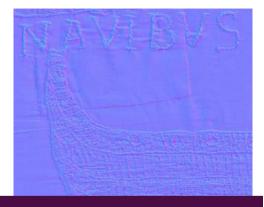
Left: three input images, taken from the same viewing angle but varying lighting Right: output high-resolution mesh (5M triangles)

### **Ground truth geometry acquisition campaign**









We have  $\approx$  30 couples (RGB,normals) of size  $3000 \, \text{px}^2$ 

ightarrow Thousands of  $128\,\mathrm{px^2}$  patches for learning the mapping RGB  $\mapsto$  geometry

### **Ground truth geometry acquisition campaign**







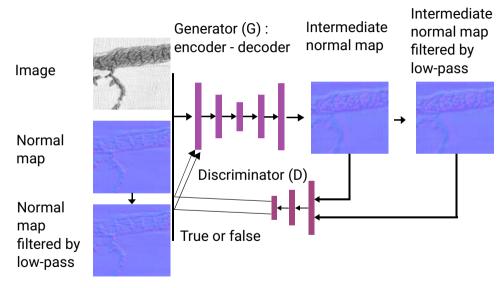


We have  $\approx$  30 couples (RGB,normals) of size  $3000 \, \text{px}^2$ 

 $\rightarrow$  Thousands of 128 px<sup>2</sup> patches for learning the mapping RGB  $\mapsto$  geometry

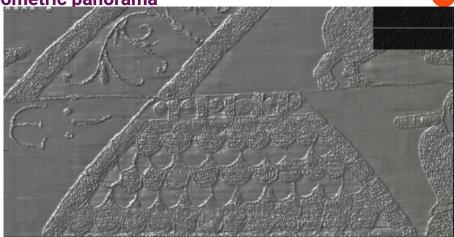
### Deep image-to-geometry learning





### Geometric panorama







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

#### **Outline**



1. Case of the Bayeux tapestry

2. Case of the Chauvet cave

#### Case of the Chauvet-Pont-d'Arc cave





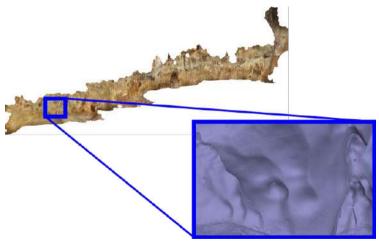


"Panneau des chevaux" (Chauvet-Pont-d'Arc cave, Ardèche, France)

### **Photogrammetry in Chauvet**







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

### **Needs for photometric stereo**







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

### Classic photometric stereo case





#### 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)

### **Accessibility constraints in the Chauvet cave**



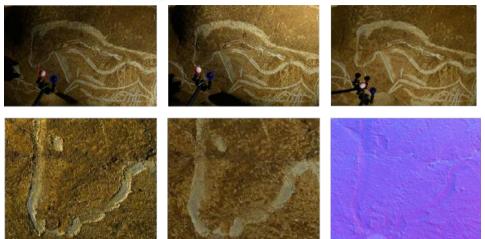




- ► Spheres are positioned at the end of a pole
- Position of the sphere in the image differs from one image to another
- Automatic detection with DETR network

### **Automatic neural lighting calibration**



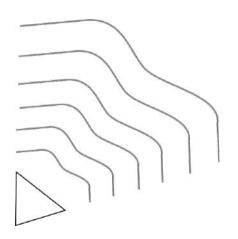


Top: three pictures (out of 16) with calibration spheres on a pole Bottom: zoom on a picture, albedo and normal map

## Combining photogrammetry and photometric stereo 🚥 😘







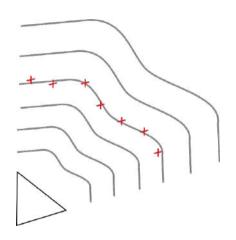
### Ongoing work

Depth deduced from normals, up to a scale factor

### Combining photogrammetry and photometric stereo (1977)







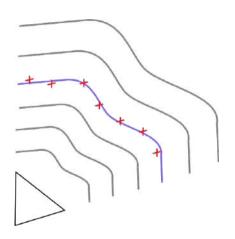
### Ongoing work

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

### Combining photogrammetry and photometric stereo (1977)







### 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

