

Texturing Computed Tomography 3D Models Using Multimodal 3D Reconstruction

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AND BUSINESS

- Non-destructive acquisition
- Acquisition of accurate geometry
- Representation of materiality and surface texture

Achieving all three **simultaneously** remains challenging

Problem: Geometry vs Appearance?

CT reconstruction:



Highly reliable geometry



No surface color or texture

Photogrammetry:



Captures surface color and appearance in detail



Unreliable geometry for reflective / translucent / thin objects

No **single** modality captures **both** effectively

Problem: Geometry vs Appearance?

Volumetric Mesh adaptation
(*Operculum specimen*)

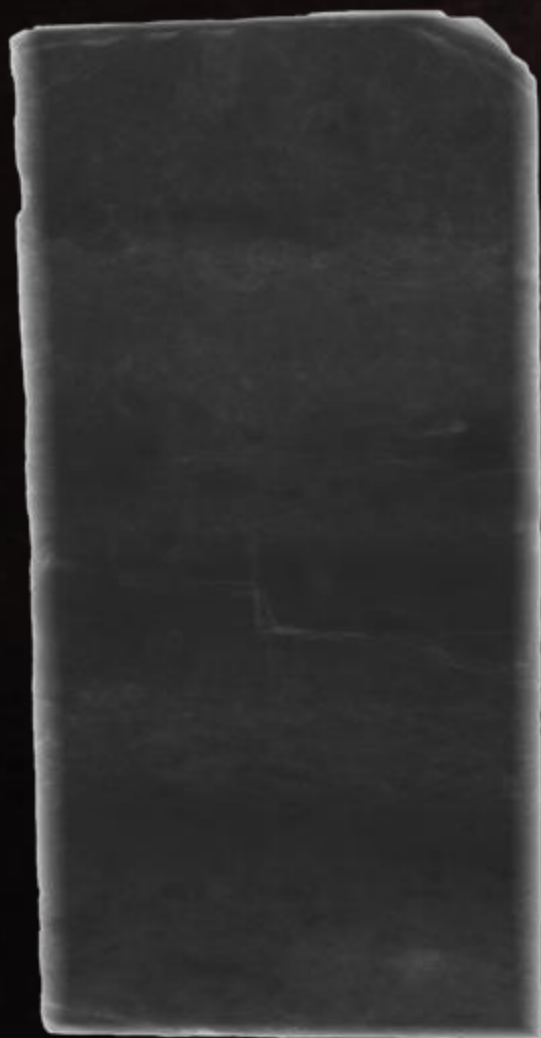


Textured Model adaptation
(*Operculum specimen*)

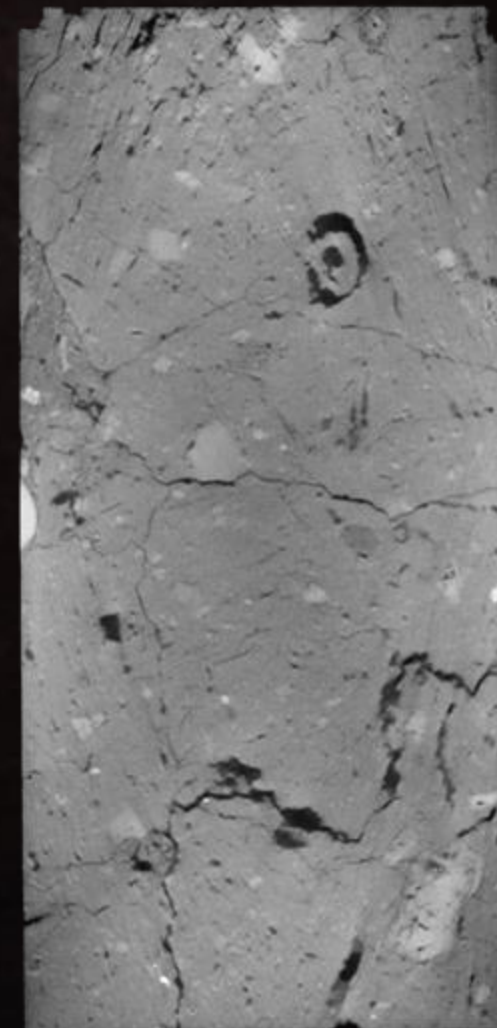


Accurate geometry can still look visually **incomplete**

Micro-CT projection
(external view)

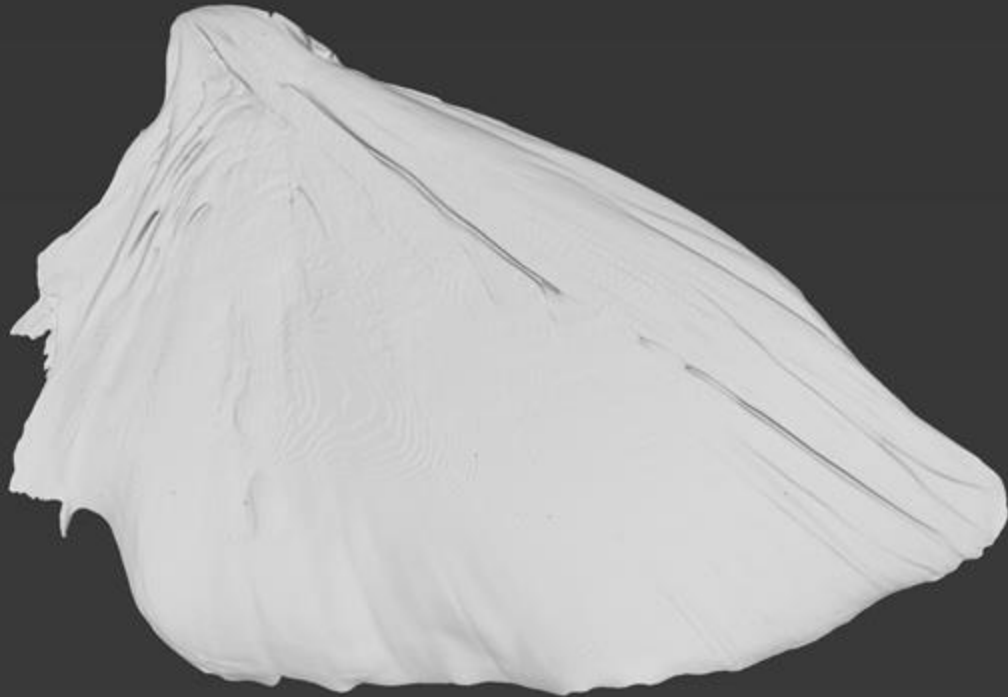


Slice Projection
(internal structure)



Computed Tomography enables:

- Non-destructive investigation
- High-accuracy digital documentation and measurement
- Internal structural information otherwise inaccessible



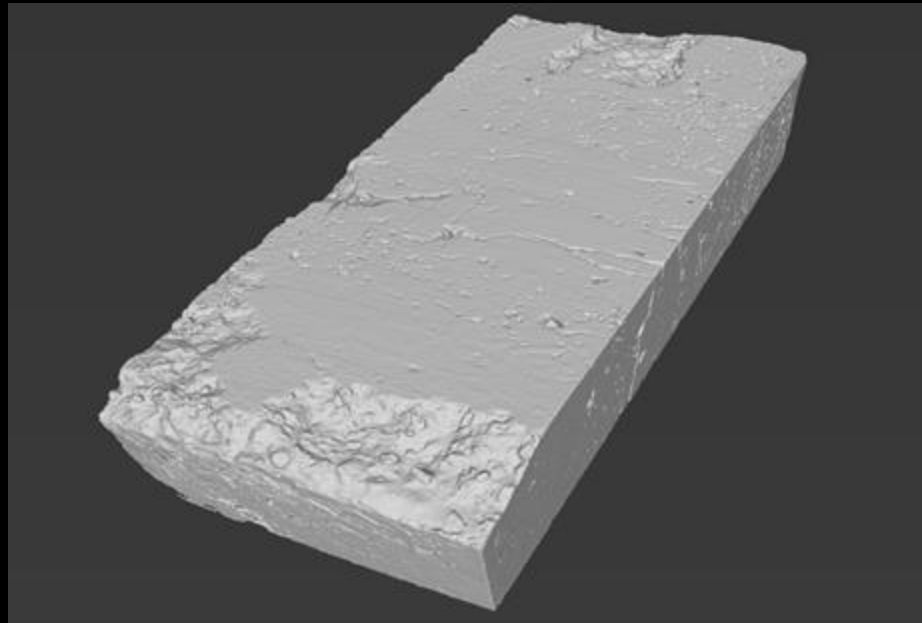
CT isosurface reconstruction
via Marching Cubes

- Reconstruction is derived from X-ray attenuation values stored as voxels
- Surface geometry is extracted as an isosurface from volumetric data
- Geometry reconstruction is independent of surface color, gloss, or translucency

But **what is lost** when geometry replaces appearance?



Volumetric reconstructions **lack color** and **surface texture information** as voxel values represent only density



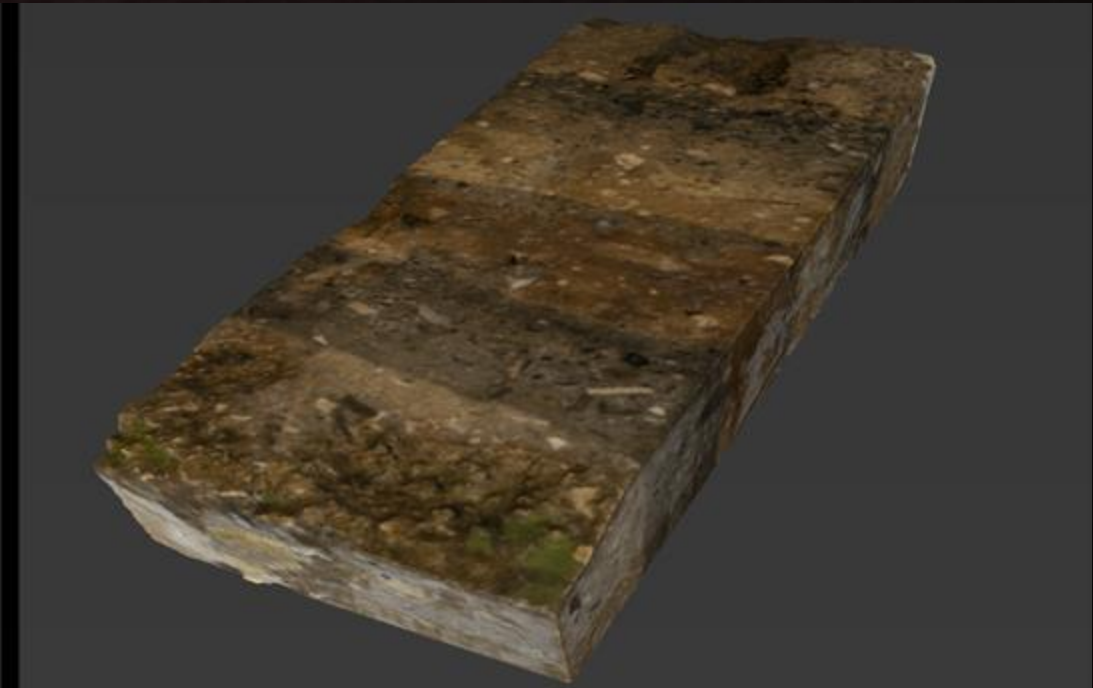
Is this trade-off acceptable?

Strengths:

- ✓ Captures detailed surface appearance and color (average reflectance + scattering)
- ✓ Produces high-resolution textures

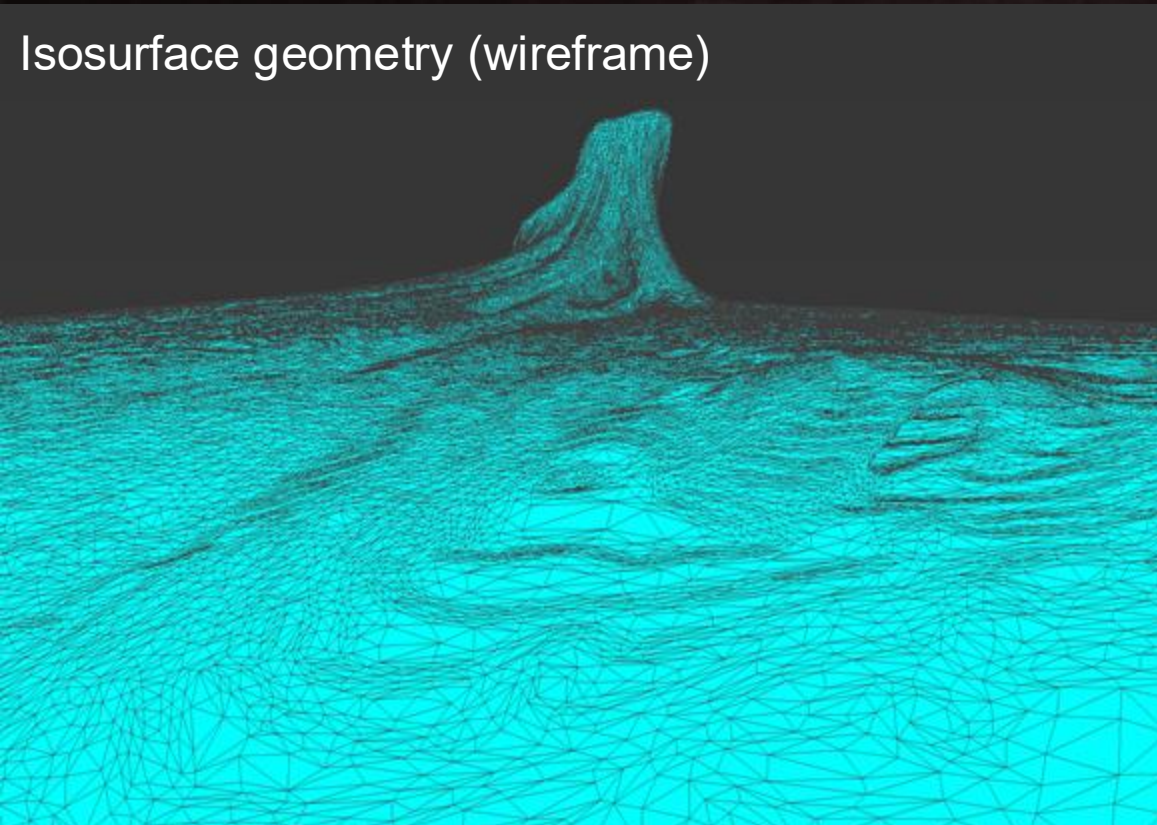
Limitations:

- ✗ Requires images with feature-rich content across multiple views
- ✗ Reflective or translucent materials introduce significant errors

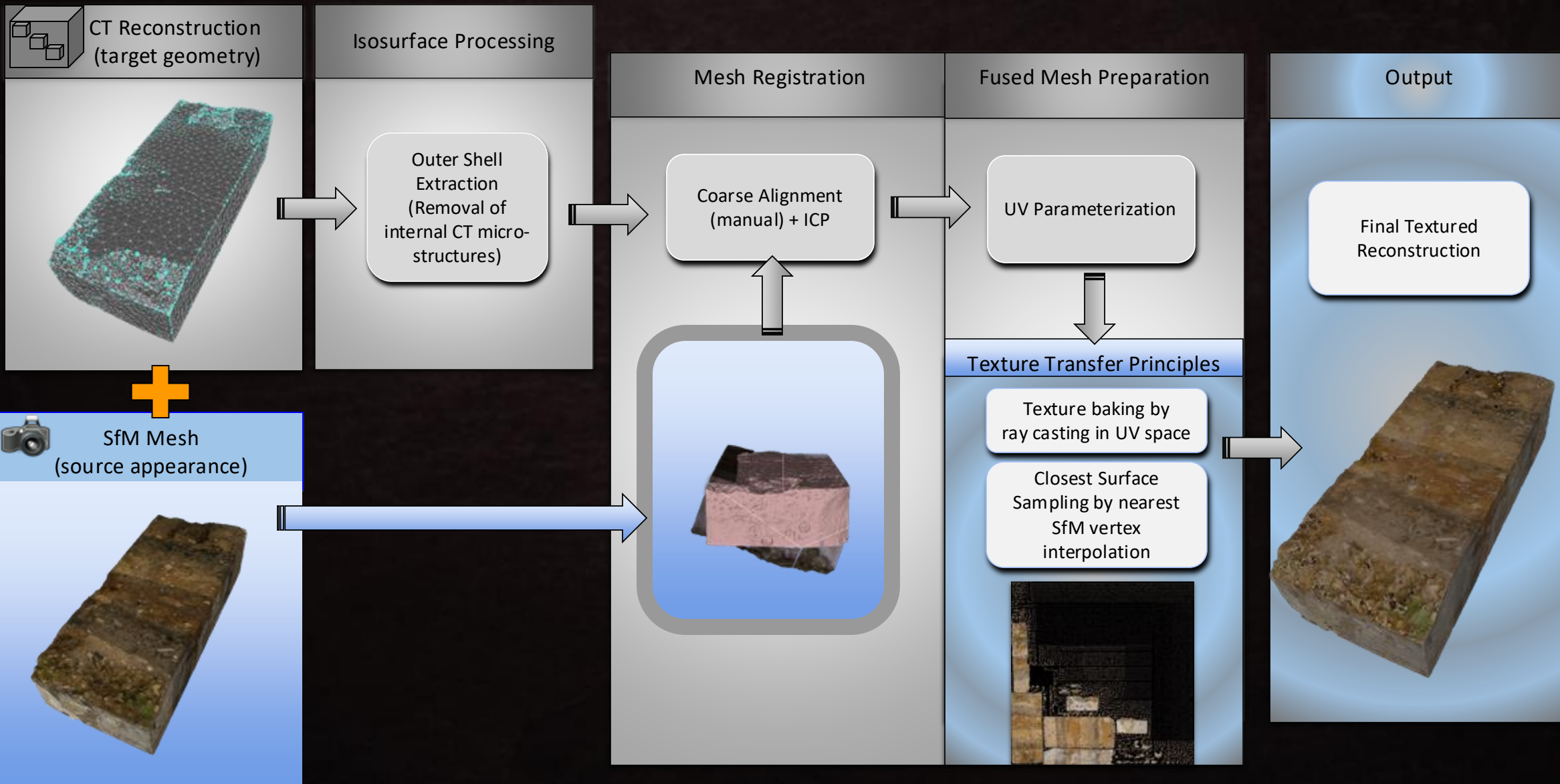


Our Approach

We combine both modalities to produce accurate and visually rich models




Multimodal Texture Transfer Workflow



Reconstructing 3D Geometry from CT Volumes

- CT produces volumetric scalar data represented as voxels
- Surface geometry is extracted using isosurface reconstruction

This results in:

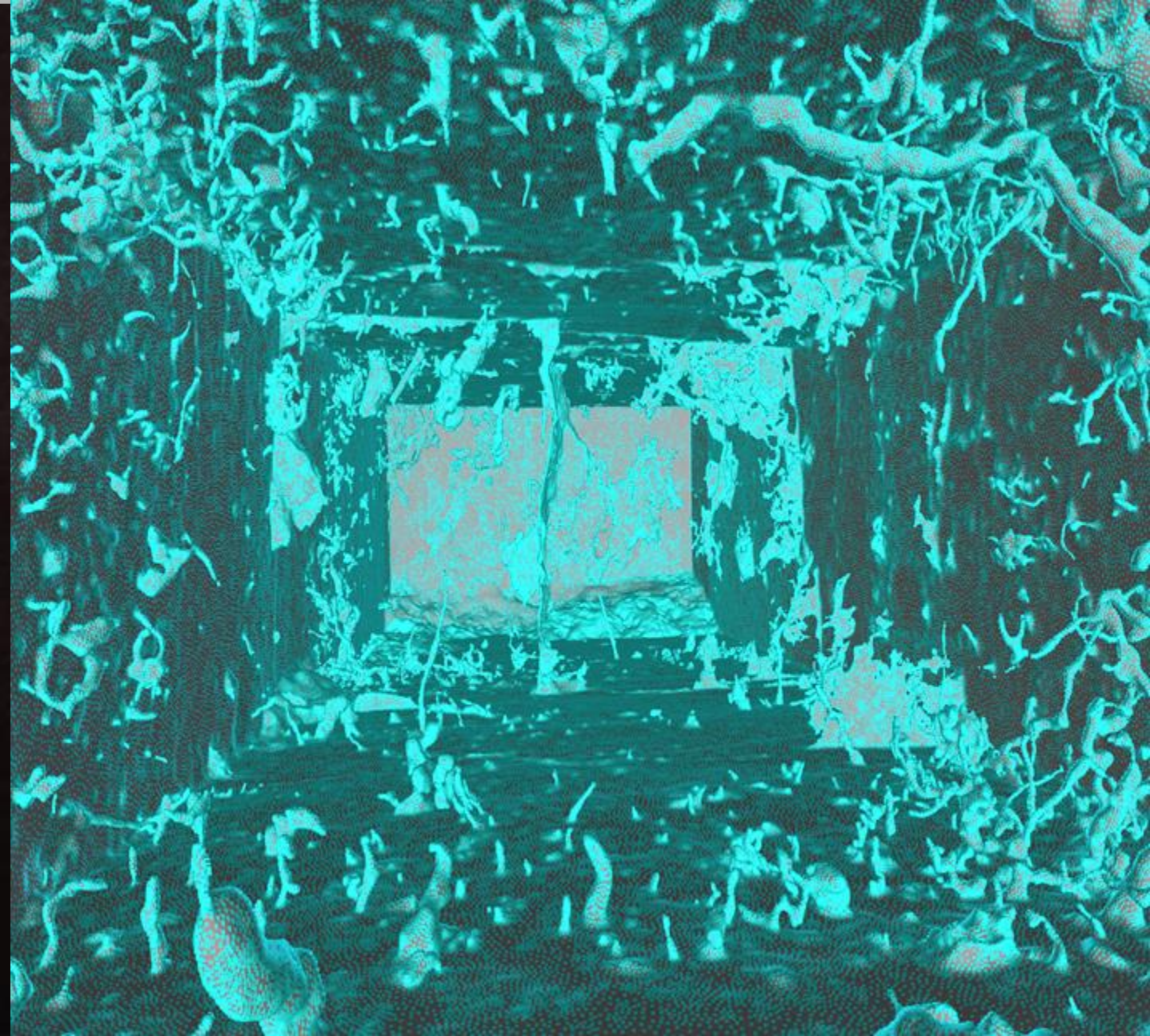
 A geometrically accurate model suitable for documentation and analysis



Concept of layers of stacked CT
slices (volumetric data)

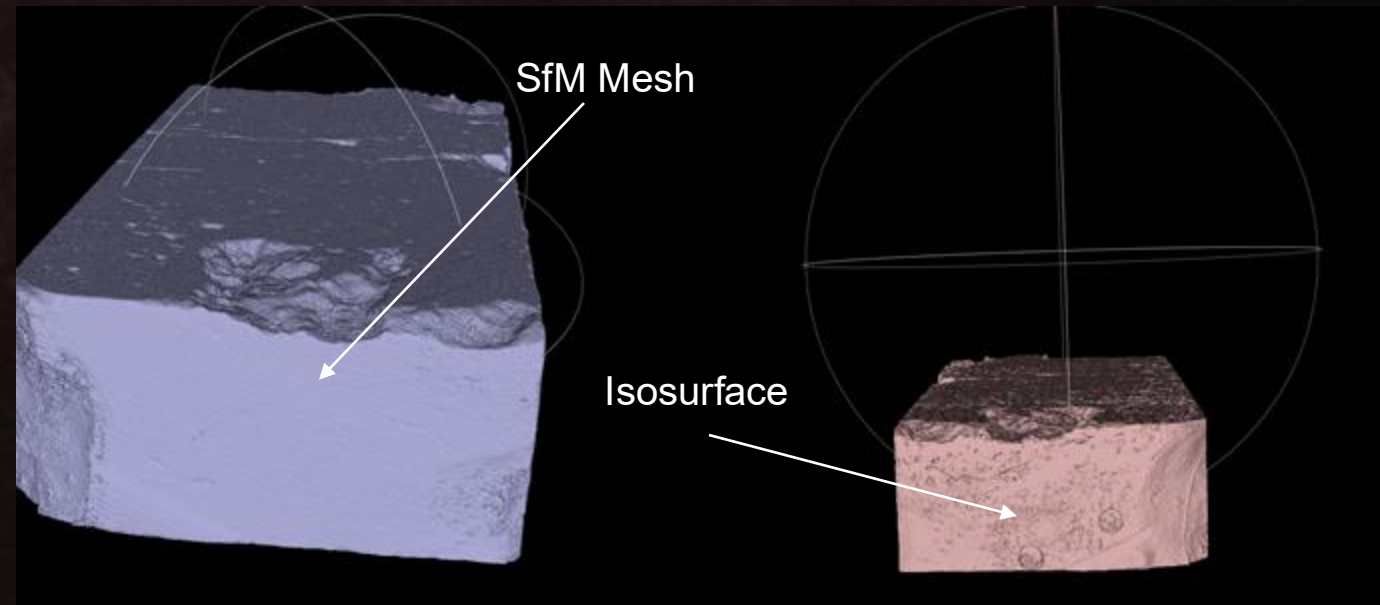
Mesh optimization is required:

- Efficient handling is important
- Isosurface meshes often contain millions of triangles
- Keep only the visible outer shell (if mesh is watertight)



Preprocessing - Cross Alignment

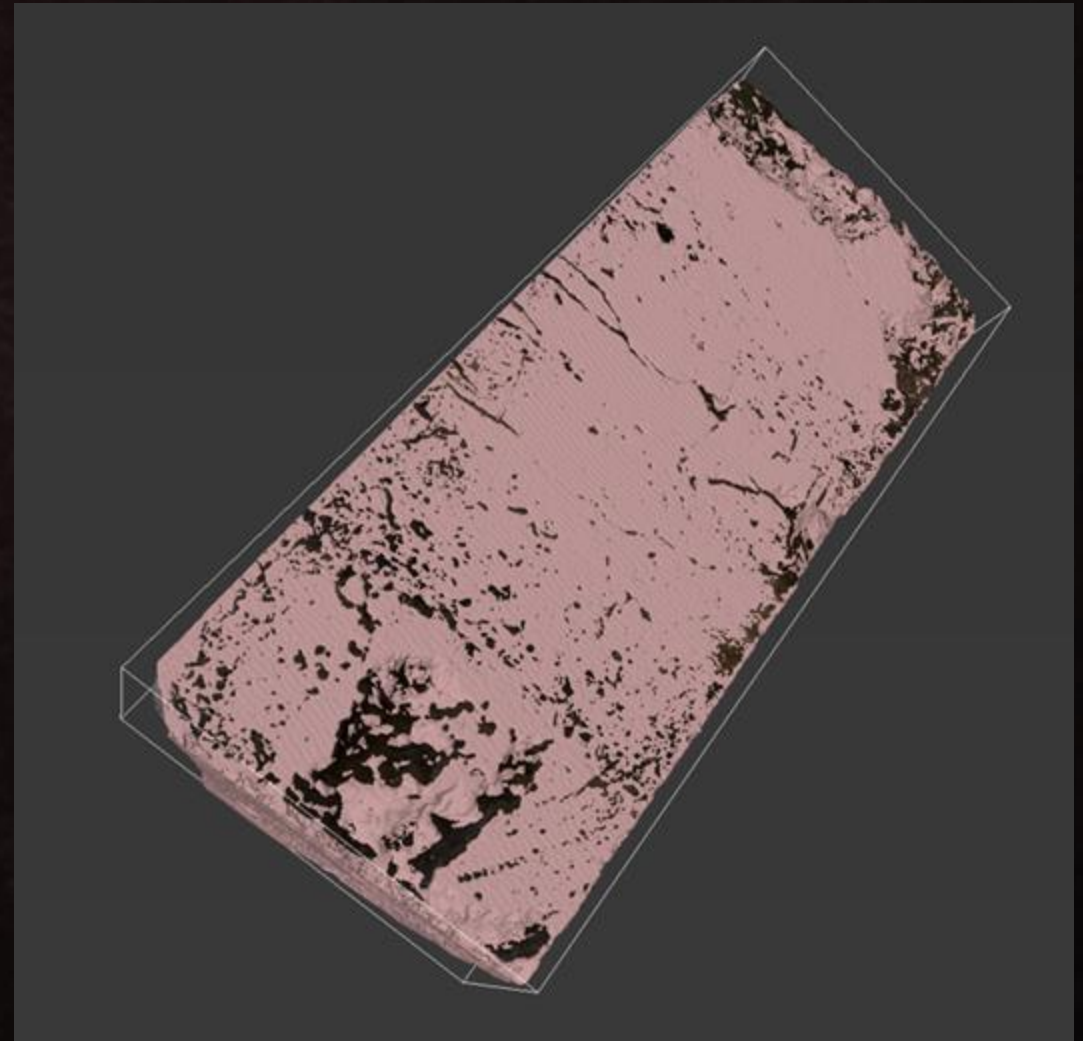
- Models acquired with different methods belong to different coordinate systems
 - CT and SfM models initially do not line up
 - Each has its own position, orientation, and scale
 - They must be aligned into a shared coordinate space



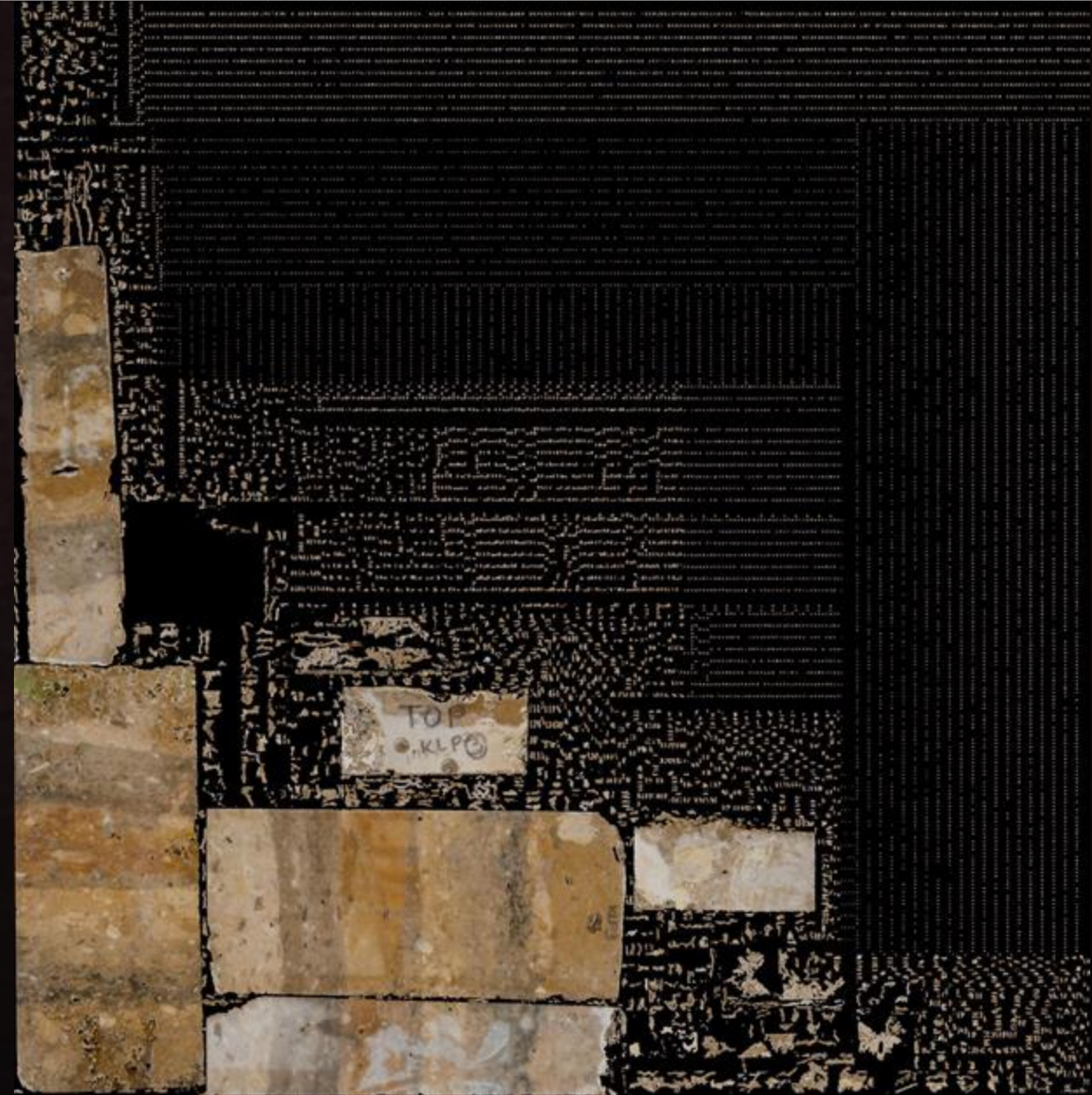
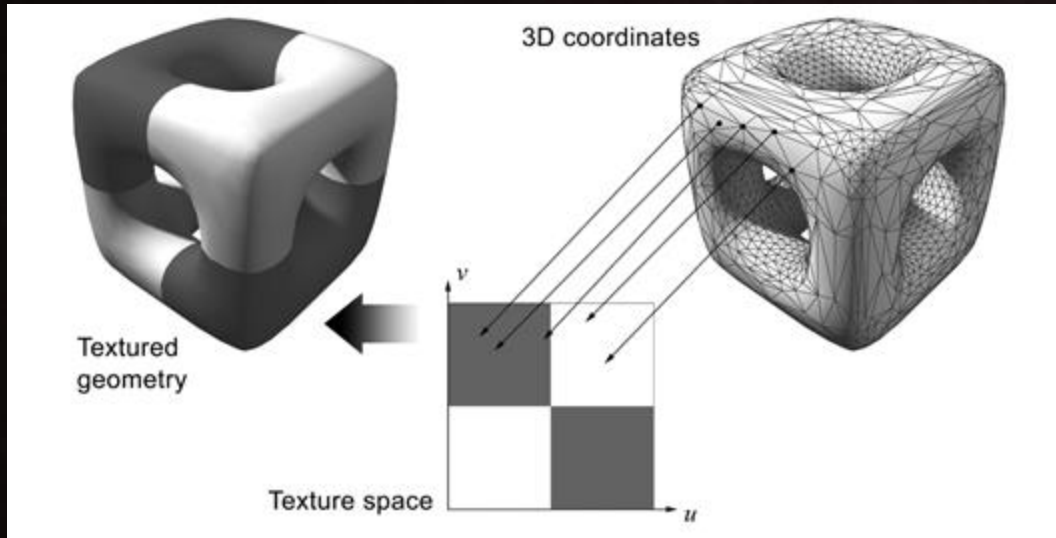
Preprocessing - Dual Model Integration

- Semi-automatic registration
- Manual coarse alignment
- ICP-based alignment

We transform both models into the *same* coordinate space



Preprocessing - UV Parameterization



- The mesh surface is unwrapped into a 2D UV domain
- UV coordinates map 3D surface vertices to locations in texture space
- Transferred texture is **applied** to the CT surface

■ Ray-casting texture baking

- Rays are cast from the CT surface
- They intersect the SfM mesh
- Colour is written to the texture map

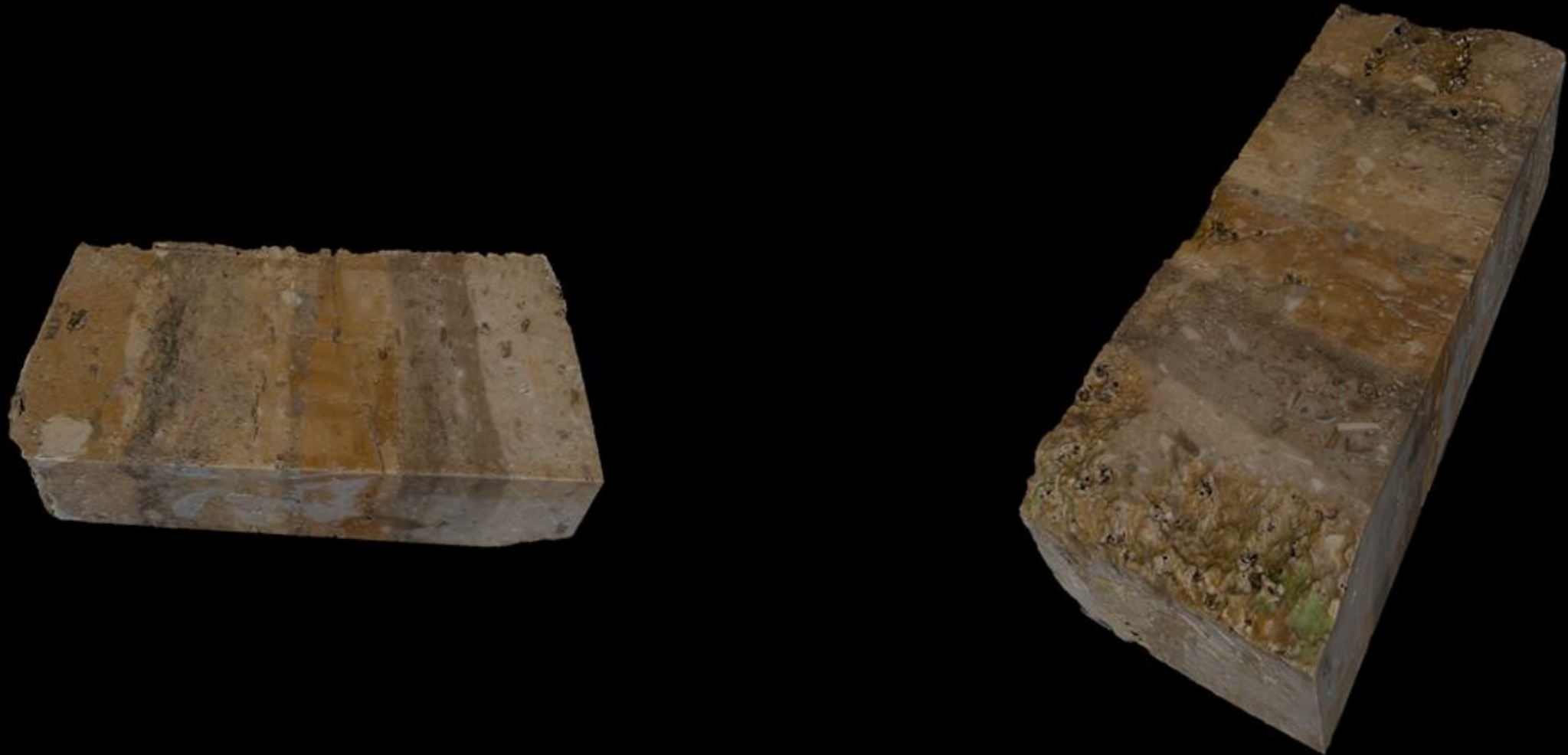
■ Closest-surface sampling

- For each CT surface point
- The nearest SfM surface point is found
- Colour is copied and interpolated onto the CT surface

Once both models share the same coordinate space, we can transfer appearance to the target geometry

Multimodal Texture Transfer

The fused model **keeps** the CT geometry while **restoring** the surface appearance from photogrammetry



Multimodal Texture Transfer

The fused model **keeps** the CT geometry while **restoring** the surface appearance from photogrammetry



- Two specimens were used to test the workflow under different acquisition challenges
 - Semi-translucent material
 - Low surface contrast
 - Thin and irregular geometry
 - Partial translucency
 - Glossy resin surface with strong reflections
 - Heterogeneous material composition



- CT scanning and SfM photogrammetry (Agisoft Metashape) were used to acquire the data
- CT provides the geometry of the models, while photogrammetry provides the surface appearance used for texture transfer

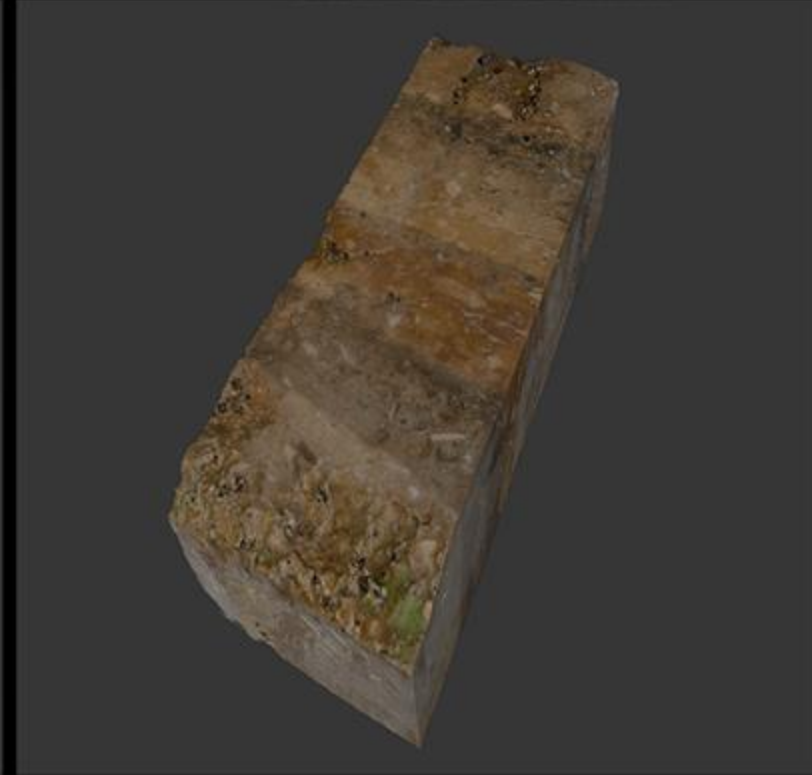
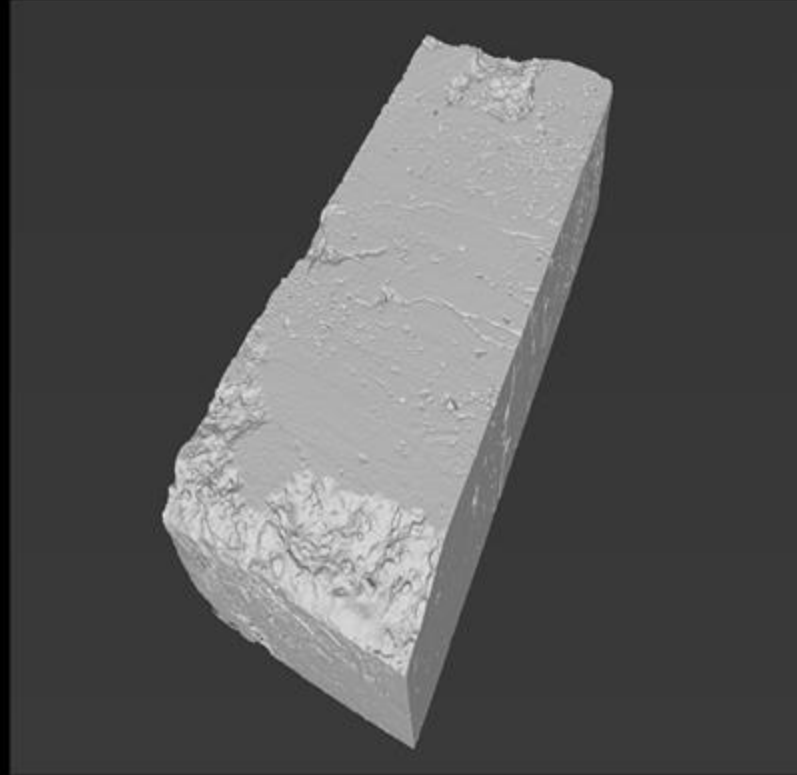


Photogrammetry model

Isosurface model

Textured isosurface

Sediment block



Results

Photogrammetry model



Isosurface model



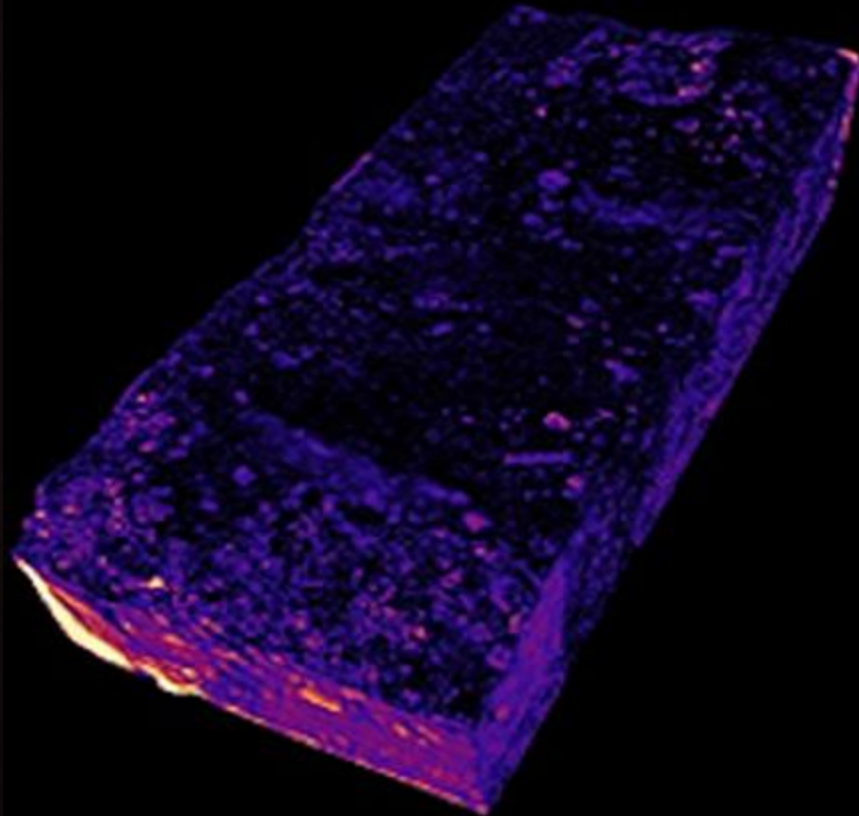
Textured isosurface



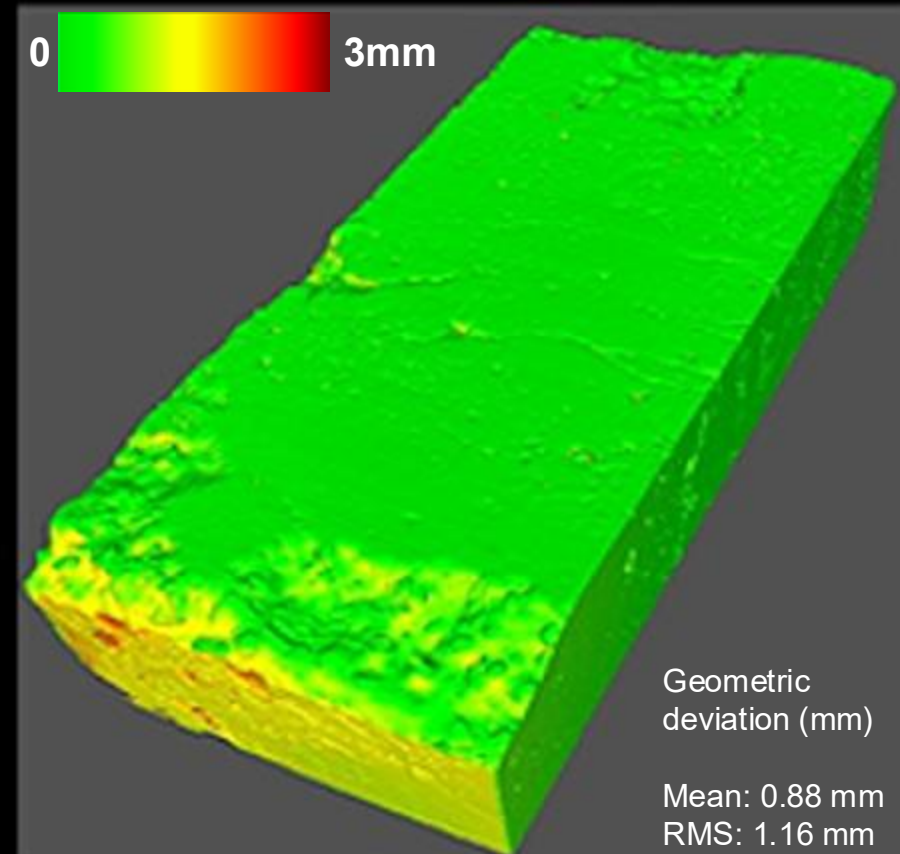
Operculum bone

Results - Perceptual and Geometric Differences

FLIP perceptual error



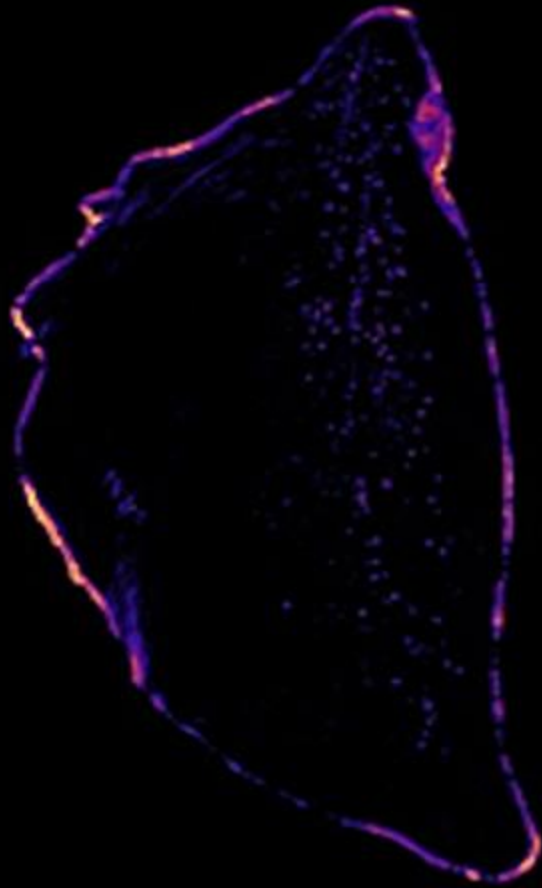
Geometric deviation



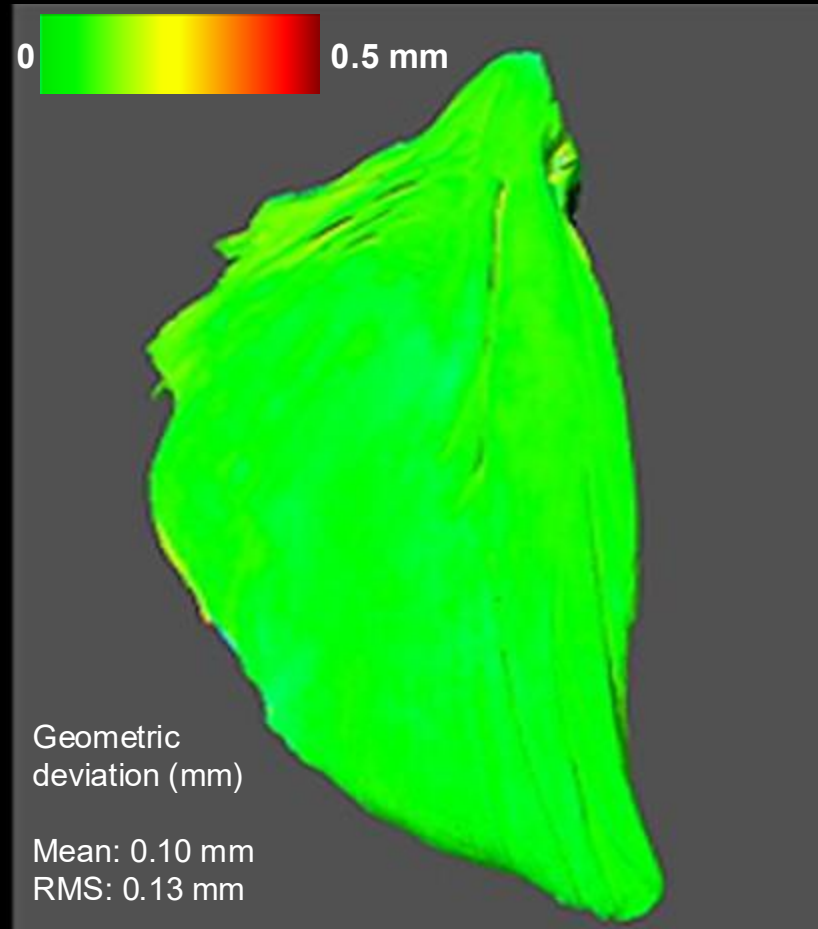
Verification of perceptual and geometric differences between SfM model and fused Model

Results - Perceptual and Geometric Differences

FLIP perceptual error



Geometric deviation



Verification of perceptual and geometric differences between SfM model and fused Model

- Volumetric texture transfer to full 3D volume via ML methods.



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Thank you!