

DIGITAL EPIGRAPHY TOOLBOX

A web-based application that facilitates the preservation, study, and dissemination of ancient inscriptions.

Angelos Barmpoutis, Eleni Bozia, Robert Wagman

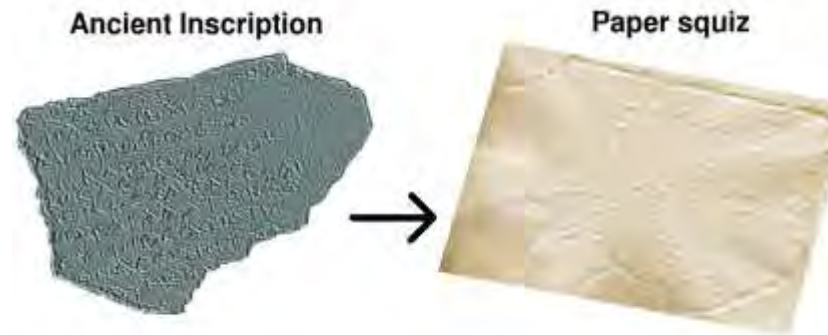
Funded by: NEH

Outline

- Motivation
- Computer Methods in Epigraphy
- Digitizing squeezes
- Automated epigraphic analysis
- DEMO – Experimental Results
- Conclusions



Motivation

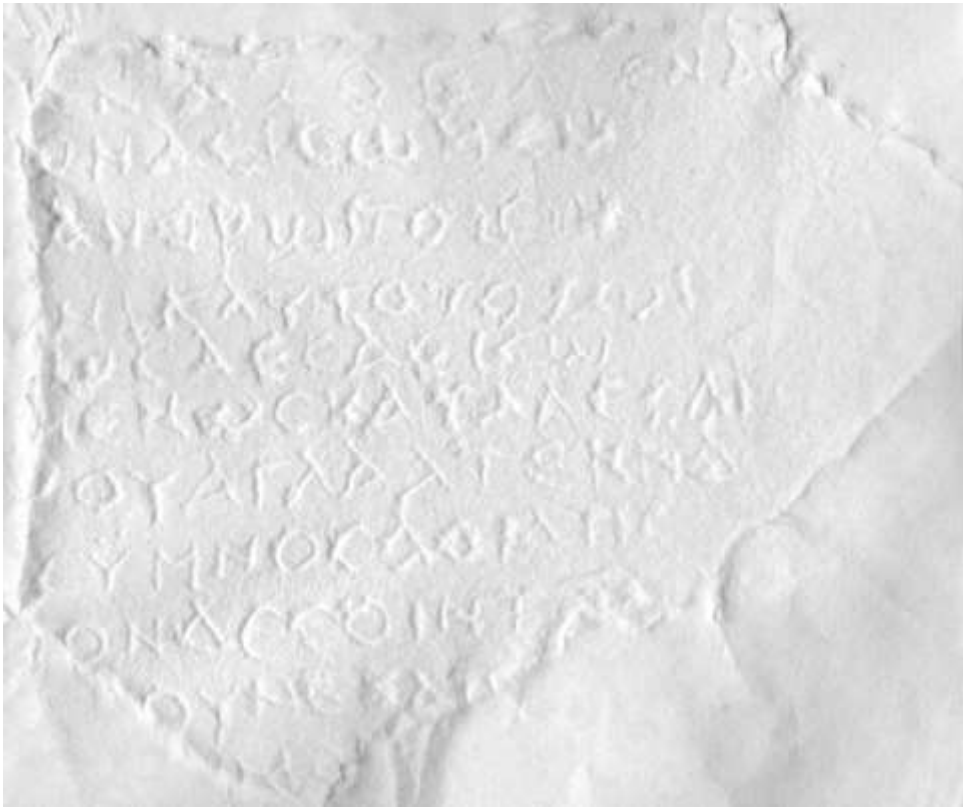


- There are several collections of squeezes in various institutions around the world
- Possible damage of squeezes
- Distribution difficulties
- Difficulties to read with naked eye
- ...

Challenges: How can we efficiently digitize squeezes?
Computer assisted study?

Computer Methods

- Take pictures of squeezes.



- Easy and inexpensive
- 3D information is not depicted
- Problems

Computer Methods

- Take several pictures of an inscription using a device with different light sources.
- HP labs, Tom Malzbender, 2001
- Good relighting results.



Computer Methods

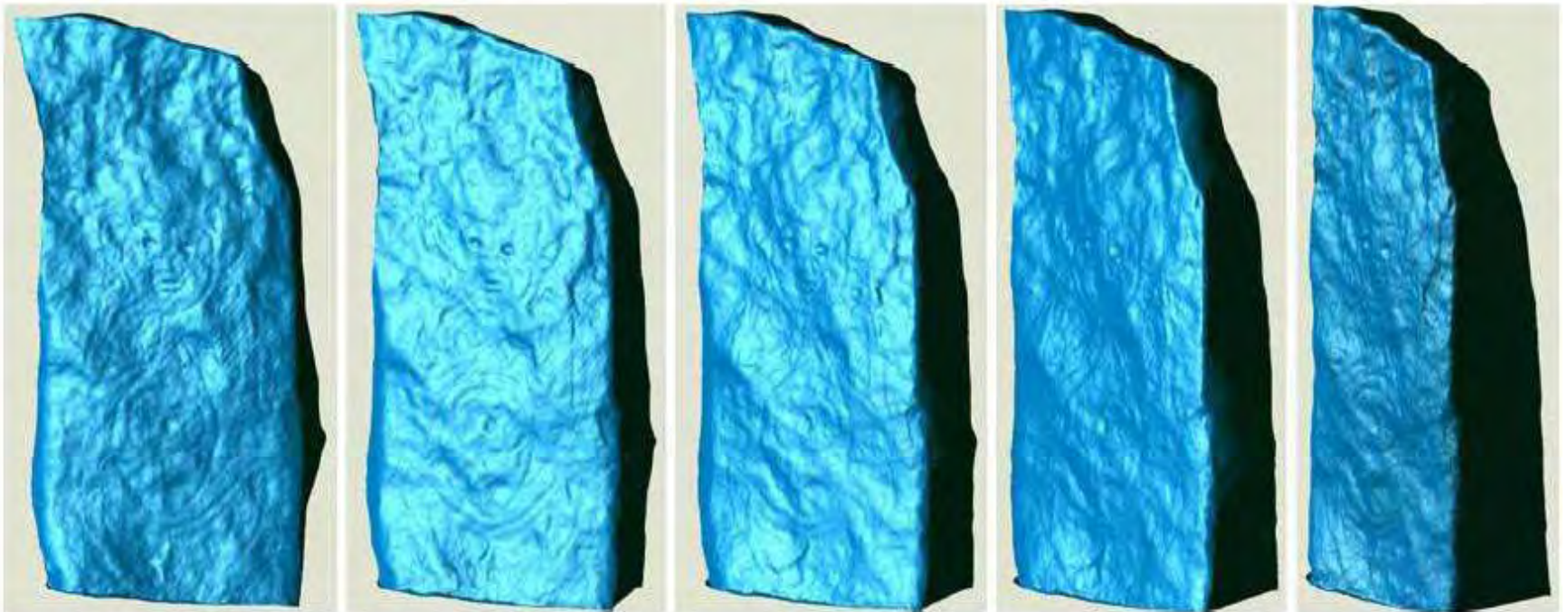
- Take several pictures of an inscription using different light sources.



- An expensive device is needed.
- Must be carried to the site.

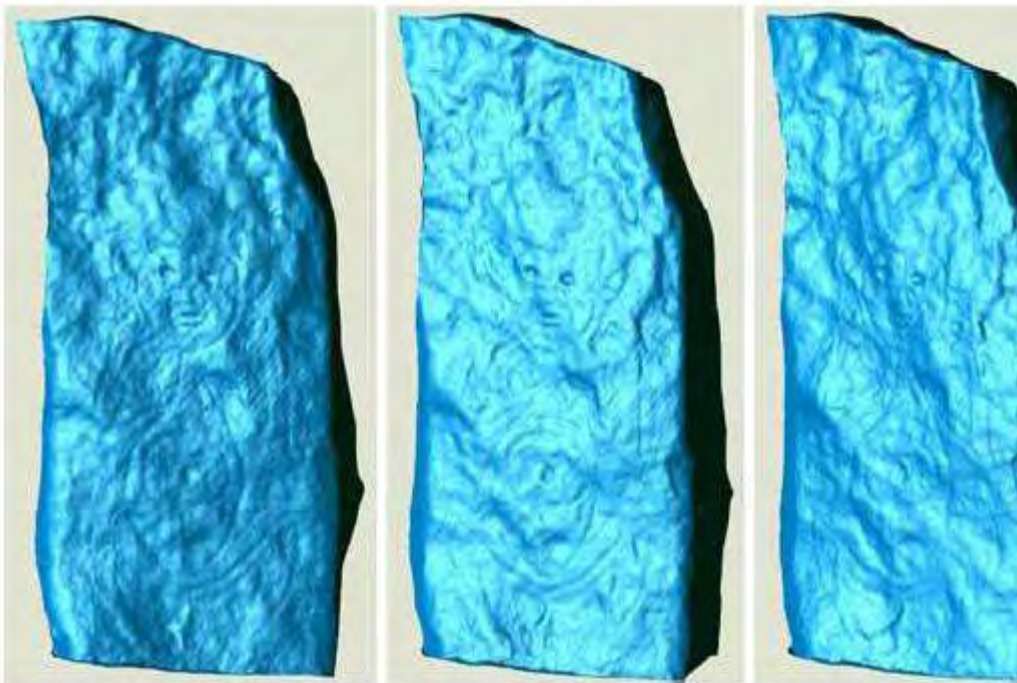
Computer Methods

- Petroglyph digitization using laser scanners
- George Landon et al., Machine Vision and Applications 2006



Computer Methods

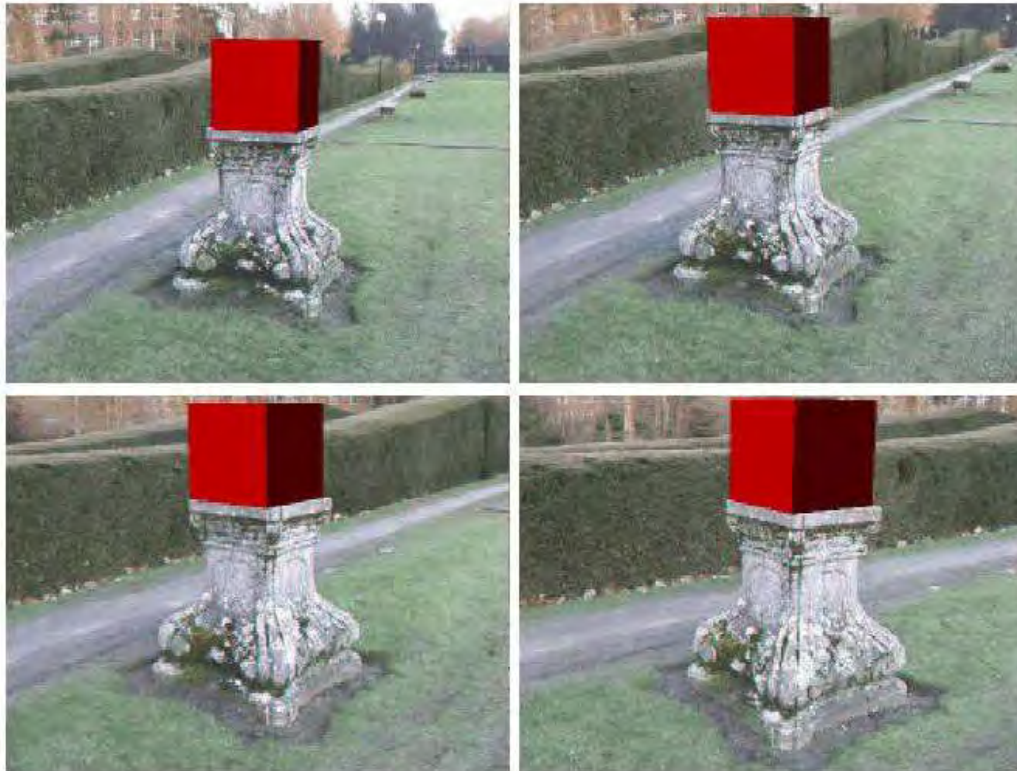
- Petroglyph digitization using laser scanners
- George Landon et al., Machine Vision and Applications 2006



- Accurate results
- Very expensive.
- Must be carried to the site.

Computer Methods

- Reconstruct 3D scene from video.
- Kurt Cornelis et al. 2000



- Needs only a camera!
- Good for large objects
- Inaccurate for details
- Cannot recover inscribed details

Computer Methods

Our proposed method:

- Makes use of squeezes
- Needs only a conventional scanner
- Inexpensive
- No need to transfer equipment in site.



An efficient performing

Eleni Bozia, Ang

D
Dep

Segmenting letters



Grouping



Registration & Atlas construction



Statistical analysis



Fig. 3 Illustration of the steps followed for the statistical analysis of the basing technique in the reconstructed inscriptions.

inscriptions (Letter segmentation in 3.1, Grouping in 3.2, Registration and Atlas construction in 3.3 and Classification in 3.4). In Sec. 4 we present our experimental results and in Sec. 5 we conclude.

2 Surface reconstruction

Surface reconstruction using photometric stereo guidance has been studied extensively in computer vision literature [11]. In those methods the information of a 3D surface is recovered by using a set of flat-panel images of the subject taken under different known illumination conditions. The disadvantage of the aforementioned methodologies is the fact that the results depend on the Uniform Reflectance Distribution Function (BRDF) of each face's material. For instance, non-Lambertian surfaces with specularities require a large number of acquired images in order to lead to realistic results [1,22]. In our application the depicted subject is a paper square (a type of filter paper), whose specular component is approximately zero and therefore its BRDF can be well represented by the diffuse parameter of the Phong reflectance model (also known as Lambertian model [1]). Thus, accurate results can be obtained by applying a shape-from-shading method (presented in this section) using only two scanned images of each square, which are sufficient to reconstruct the unknown parameters in this reflectance model.

Assume that the normal vector of the underlying surface S at the (i, j) location is given by $[p(i, j), q(i, j), 1]$ where $p(i, j) = \frac{\partial z(i, j)}{\partial x}$ and $q(i, j) = \frac{\partial z(i, j)}{\partial y}$ are the x, y gradients of the surface respectively.

Each scanned image of the surface can be modeled using the Phong reflectance model. In this model the reflectance of a Lambertian surface (non-specularly) is given by

$$R(i, j) = k_0 I_0 + k_d I_0 (\mathbf{L} \cdot \mathbf{N}(i, j)) \quad (1)$$

where \mathbf{L} is the 3-dimensional vector of the direction of the light beam at (i, j) , $\mathbf{N}(i, j)$ is the normal vector of the surface at (i, j) , I_0 and I_d are the ambient and diffuse components of the light and finally k_0 and k_d are the ambient and diffuse components of the surface material respectively.

Given a set of N scanned images I_1, I_2, \dots, I_N associated with light source directions L_1, L_2, \dots, L_N respectively we need to estimate the unknown surface gradients p and q by minimizing the following energy

$$E(p, q) = \sum_{i,j} \int_{L_1}^N ((I_0 - R) \sqrt{p^2 + q^2 + 1})^2 - \sum_{i,j} \int_{L_1}^N ((I_0 - R) \sqrt{p^2 + q^2 + 1} - c_0 [p L_1^x + q L_1^y + L_1^z])^2 \quad (2)$$

where $c_0 = k_0 I_0$, $c_d = k_d I_0$, and L_1^x, L_1^y , and L_1^z are the x, y, z components of the direction of the i th light source. Note that I_0, R, p and q are all 2-dimensional functions and in Eq. 2 are being integrated over their domain. Equation 2 is minimized when R comes close to I_0 and the role of the factor $\sqrt{p^2 + q^2 + 1}$ is to maintain numerical stability of the functional minimization method.

In Eq. 2 we can also add a regularization term for smoothing of p and q across the lattice. The regularization term can be expressed by

$$\int_{i,j} \left(\frac{\partial p}{\partial x} \right)^2 + \left(\frac{\partial p}{\partial y} \right)^2 + \left(\frac{\partial q}{\partial x} \right)^2 + \left(\frac{\partial q}{\partial y} \right)^2 \quad (3)$$

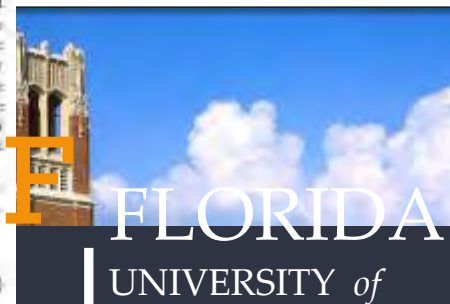
The standard role of the regularity term (Eq. 3) is to remove part of the high frequencies from the data. In our case, these frequencies correspond to fine details of the square, which more often than not are considered noise on the surface of the paper. However, some of the useful details in the data may also be faded out due to regularization. Hence one needs to estimate carefully the desired degree of smoothness or incorporate a more sophisticated noise removal technique (i.e. anisotropic smoothing). In our experiments we acquired data which did not contain these artifacts and therefore we did not impose any regularization constraints.

Given the surface gradients p and q , we can reconstruct the unknown surface S by minimizing the following energy

$$E(S) = \int_{i,j} \left(\frac{\partial S}{\partial x} - p \right)^2 + \left(\frac{\partial S}{\partial y} - q \right)^2 \quad (4)$$

ezes and
lysis

), 2010, pp. 989-998



- Use a regular scanner
- Grayscale option
- Scan squeezes twice

1.



2.

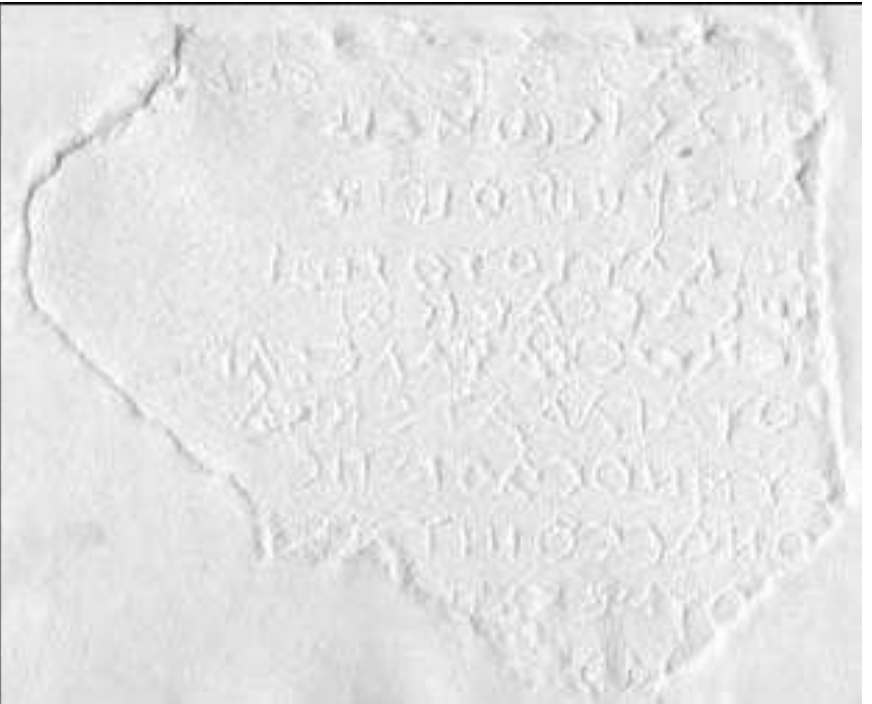


- This will produce a set of images like that:

Light from the top



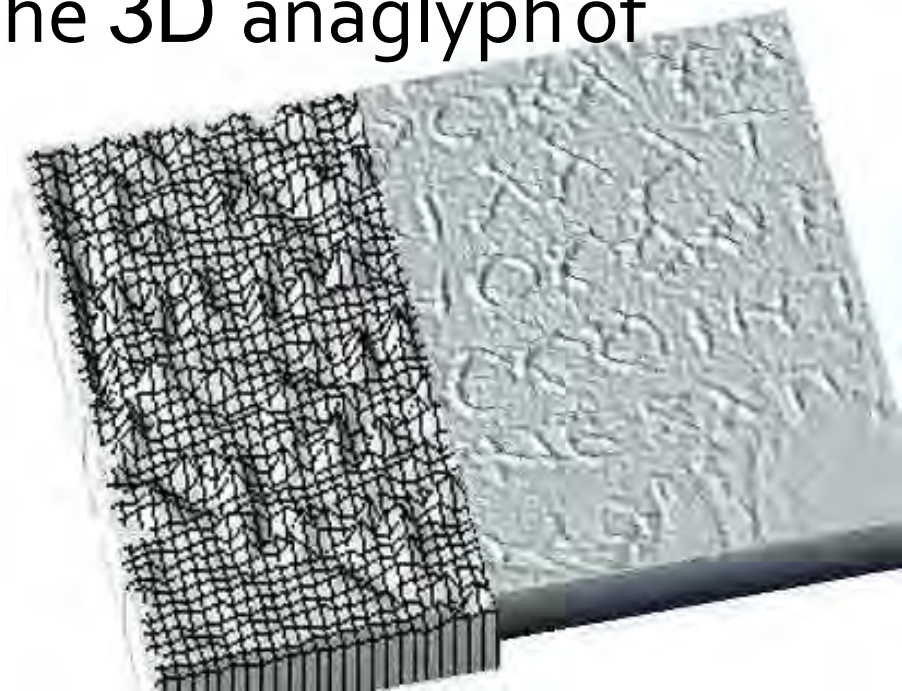
Light from the left



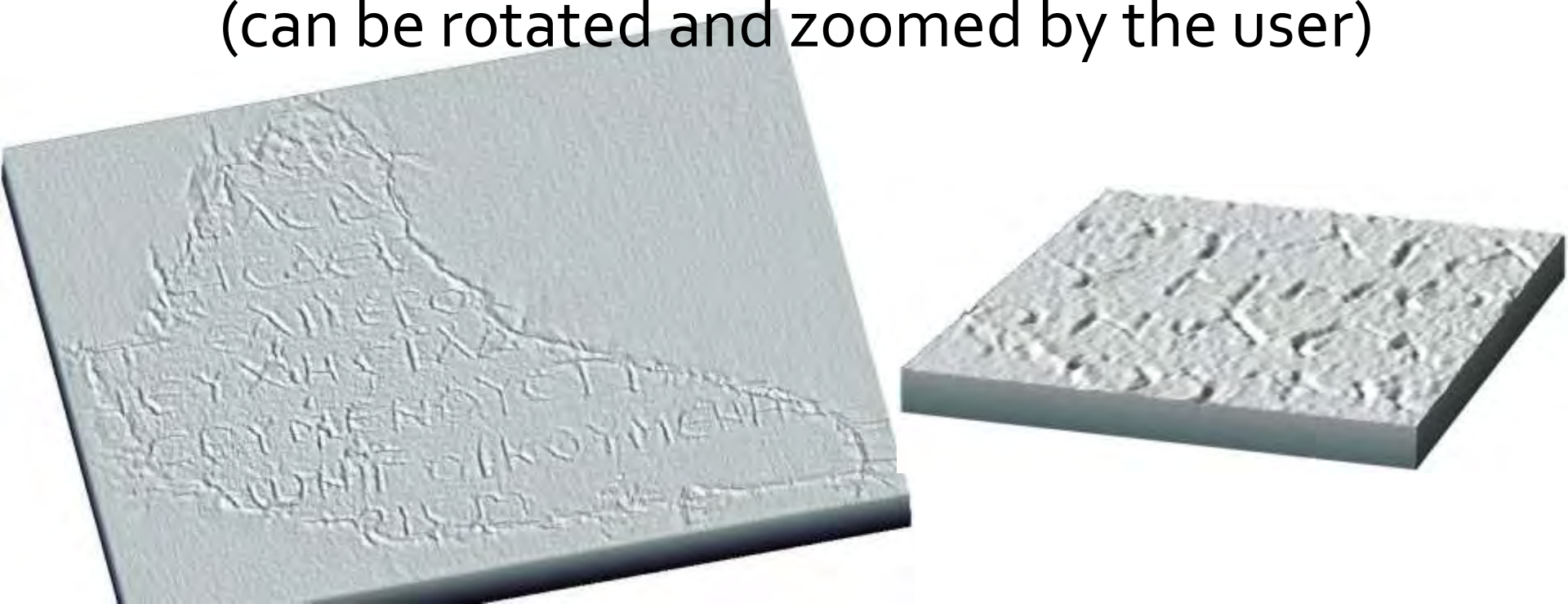
- These images contain all the shading information needed to understand the local curvature of the paper.



- By combining:
 - Knowledge about the reflectance model of a paper
 - The shading provided from the two scans
- A computer can recover the 3D anaglyph of the squeeze
 - This is known as “shape from shading”



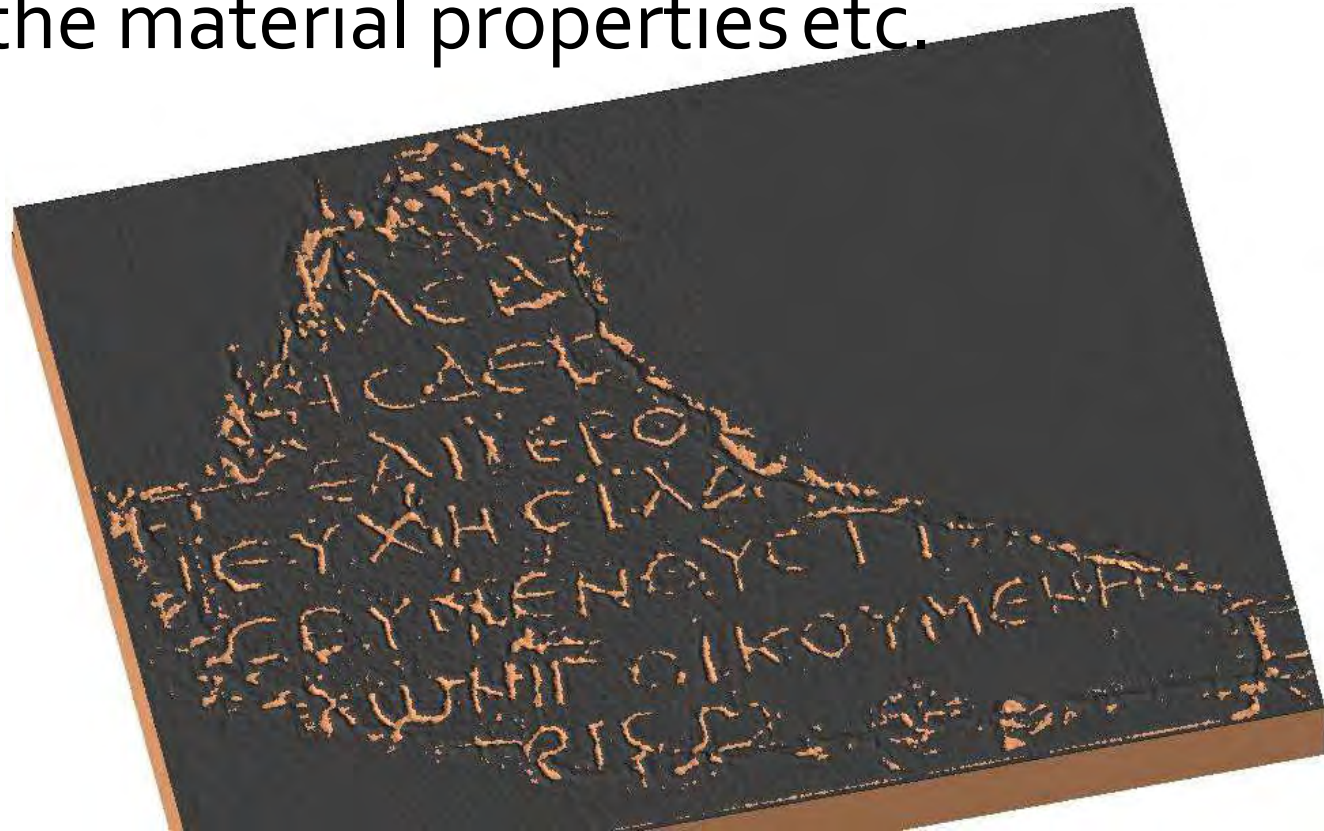
- There are several ways to visualize the reconstructed 3D surfaces
- 1) Plot the 3D surface
(can be rotated and zoomed by the user)



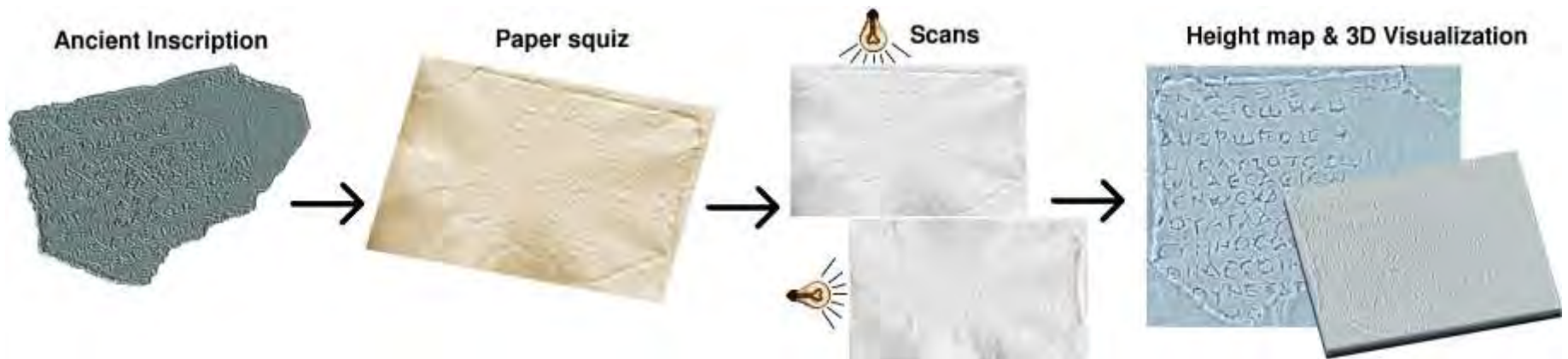
- There are several ways to visualize the reconstructed 3D surfaces
- 2) Plot the height-map
(dark intensities=deeper locations)



- There are several ways to visualize the reconstructed 3D surfaces
- 3) Change the material properties etc.



- So far, the steps of our method:



- Then we can perform post-processing steps for automated analysis

- For each reconstructed inscription, we can automatically segment each letter or symbol

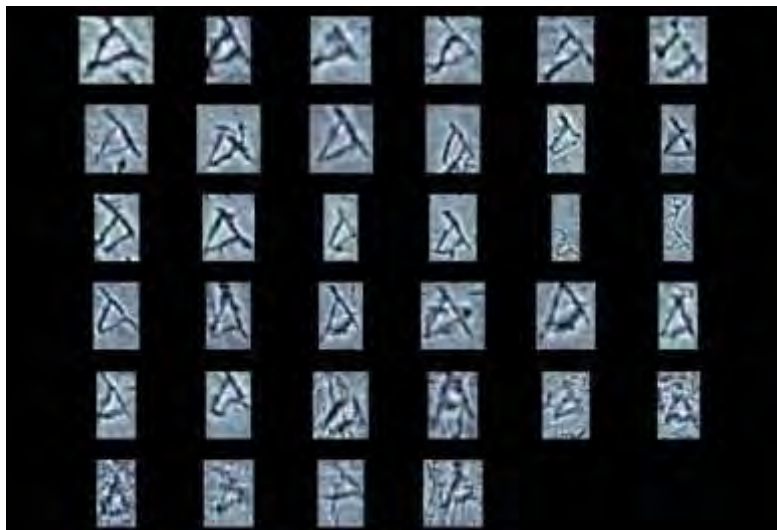


The process is fully automated.

A box is placed around each symbol.

There may be few errors which can be discarded by the user.

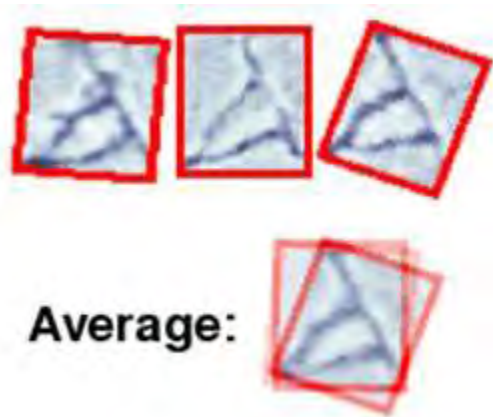
- The segmented symbols can be automatically clustered into groups.
- Example:
all 'alpha' characters are grouped together



This process can be first done partly by the user.

Then the computer can continue automatically by finding letters similar to those chosen by the user.

- The symbols from each group are rotated and scaled automatically in order to overlap each other as much as possible.

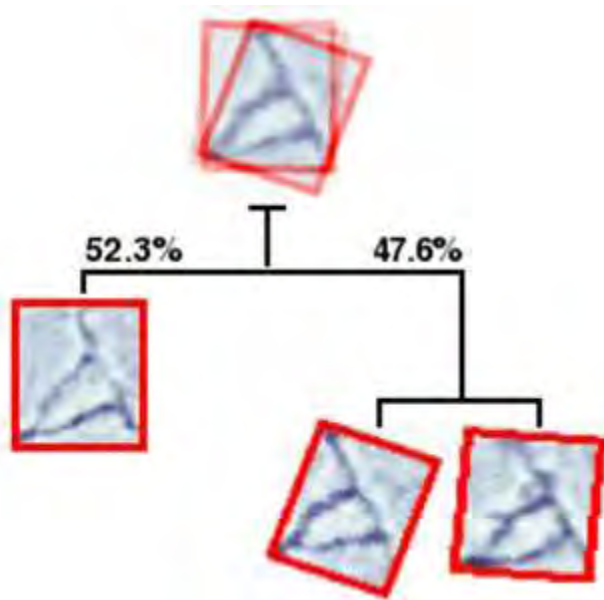


This process is fully automated and it is known as 'group-wise registration'.

The average character is also computed during this process.

The average depicts useful information about the letterforms.

- Finally, the registered characters can be compared to each other by measuring the affinity between them.



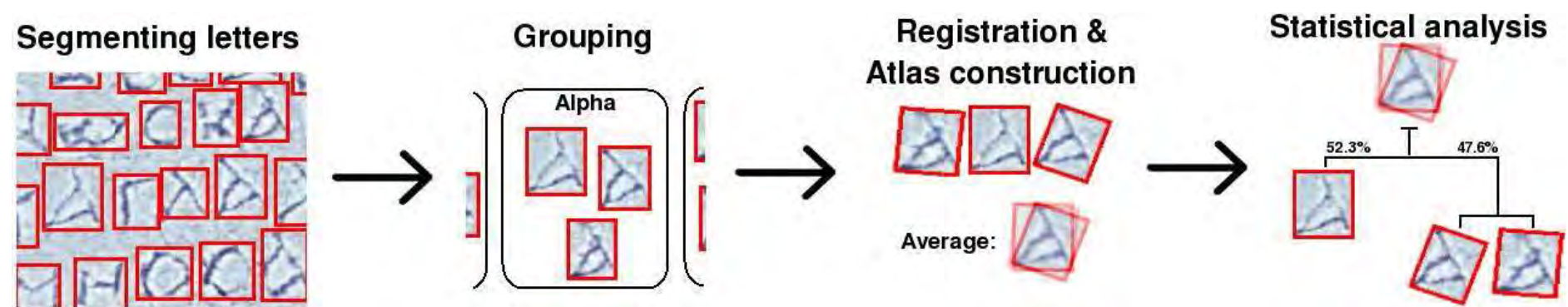
The computed affinities can be further used to construct a dendrogram.

The method is known as:
Agglomerative hierarchical clustering

The computed dendrogram shows groups of letters with similar characteristics.

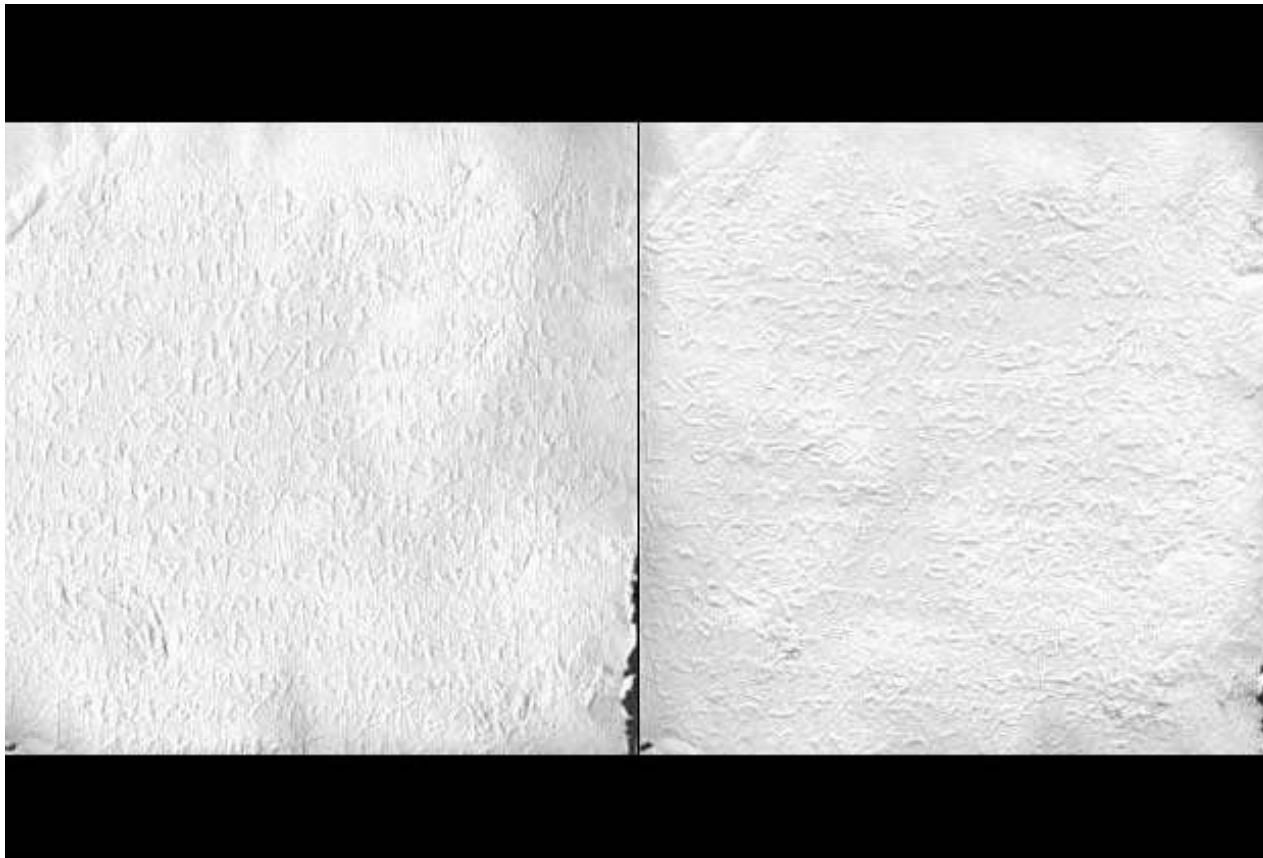
Useful for automated analysis.

- The post-processing steps of our method:

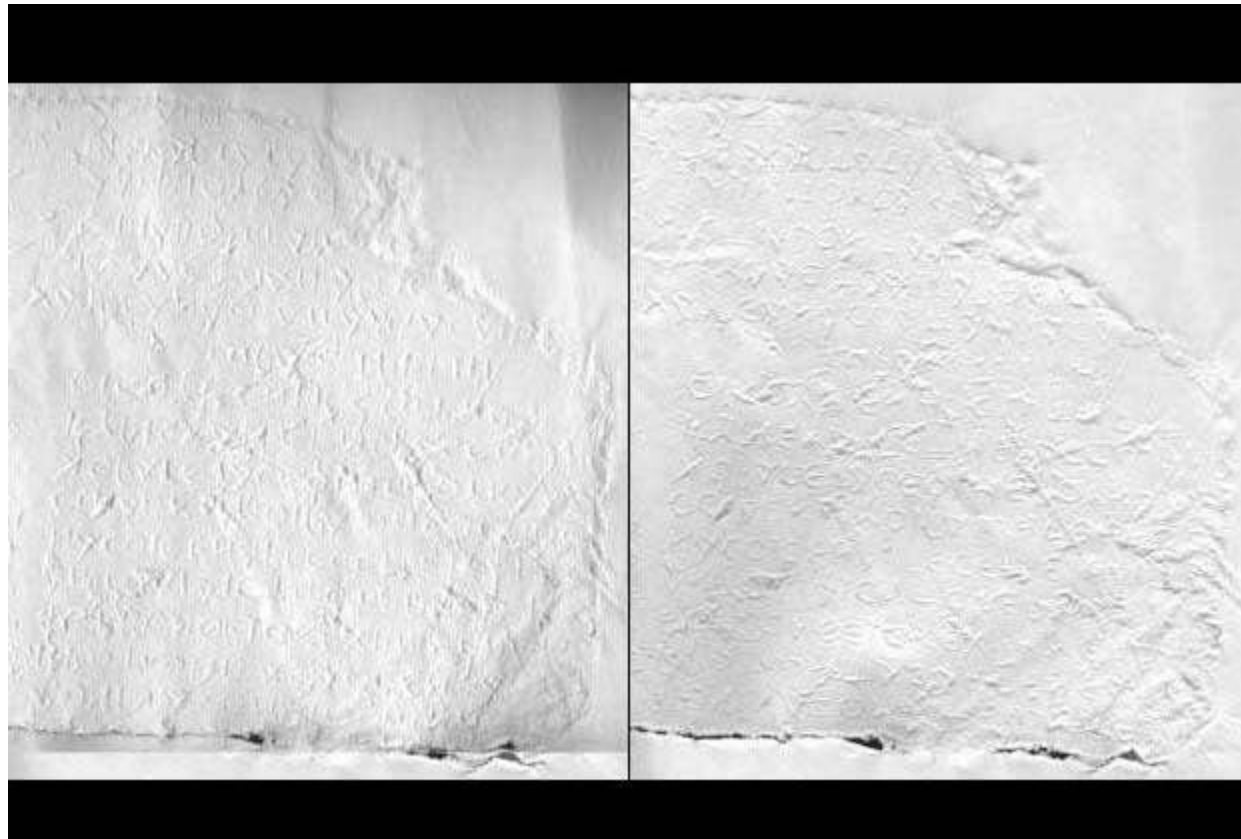


- We applied the proposed framework to:
- 5 squeezes from five inscribed fragments (archaeological site of Epidauros)
- contain religious hymns for Asclepius and other deities
- IG IV I 2, 129-135; SEG 30, 390 in R. S. Wagman. *Inni di Epidauro. Biblioteca di Studi Antichi*, Pisa, 1995

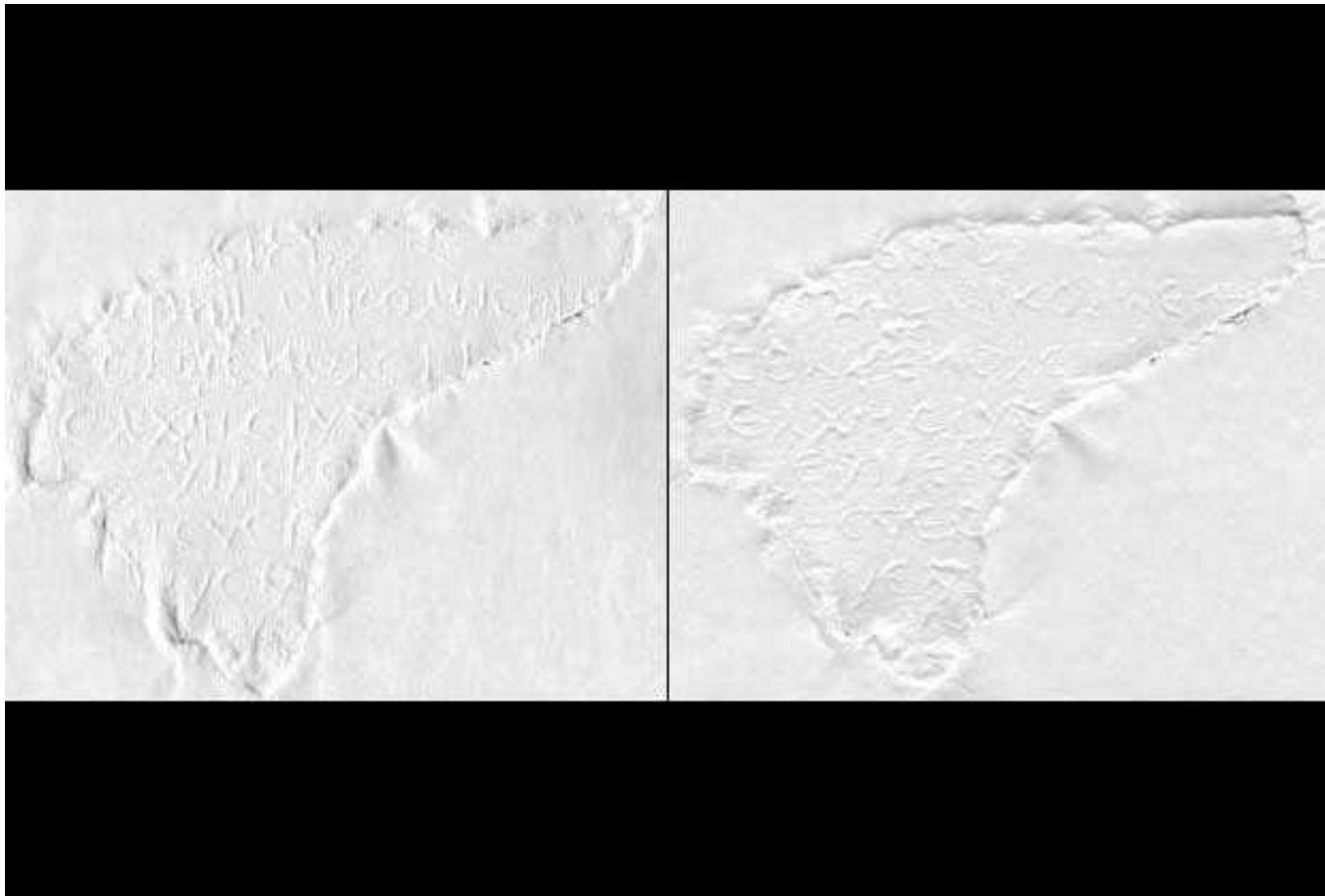
- Example of the two scanned images:



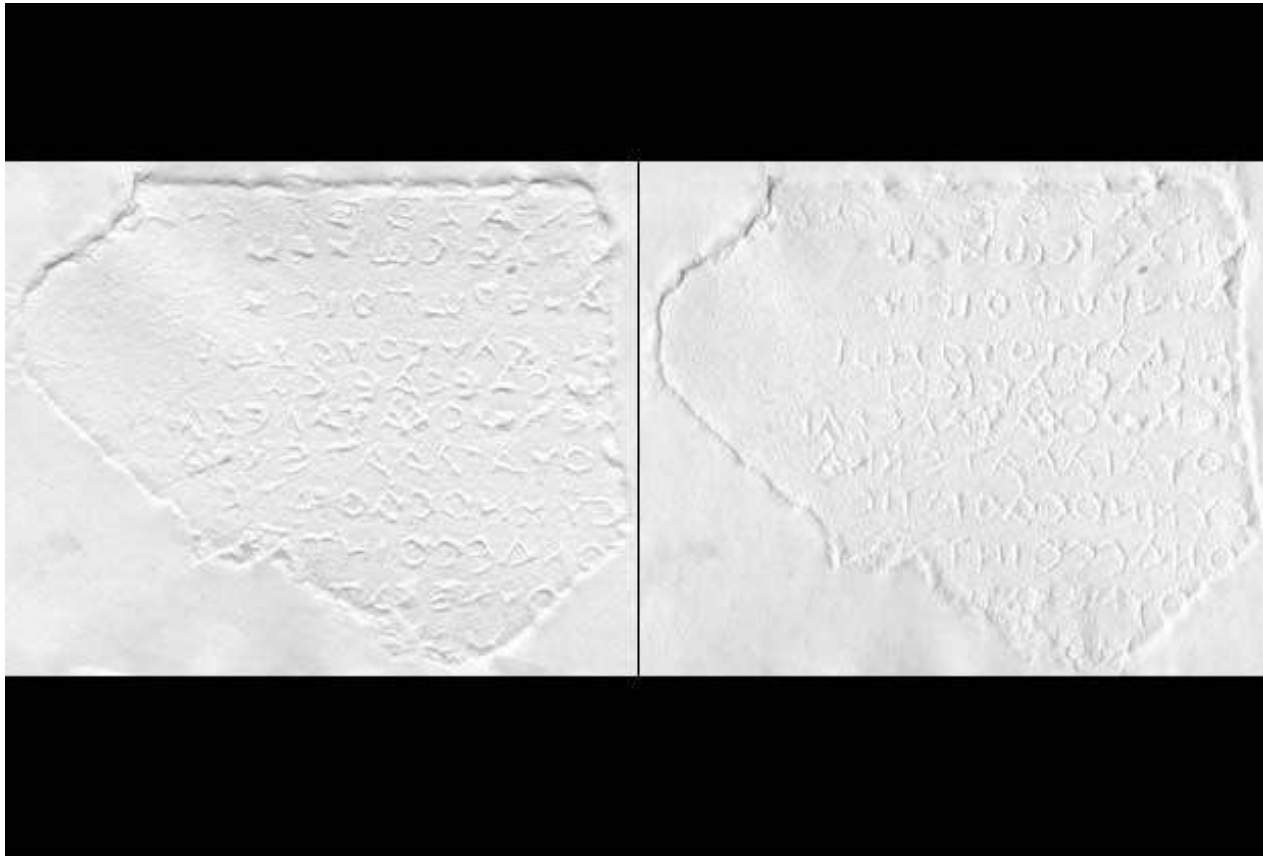
- Example of the two scanned images:



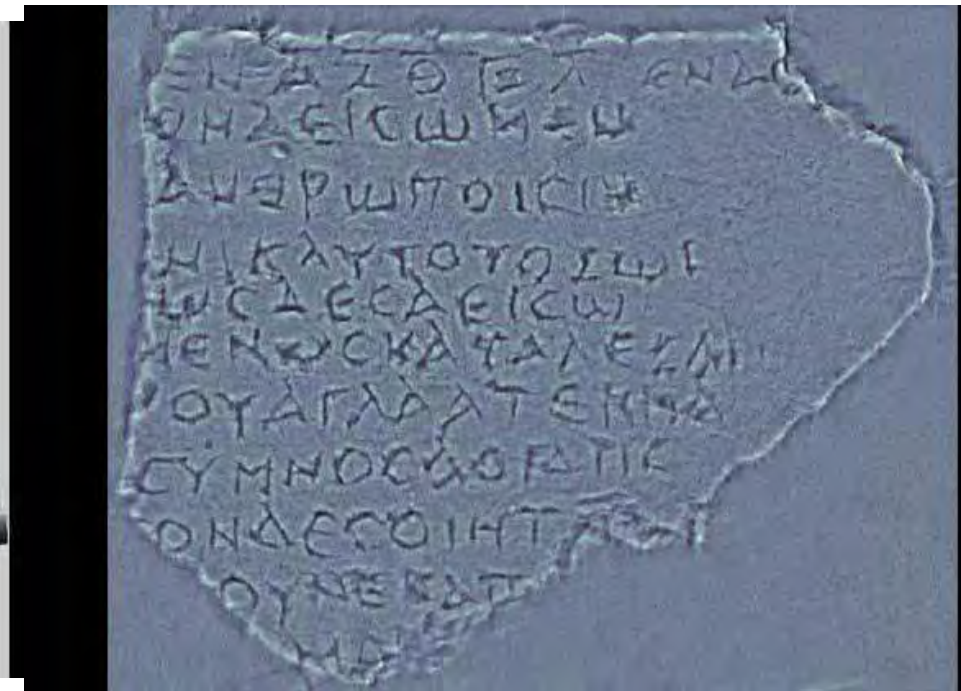
- Example of the two scanned images:



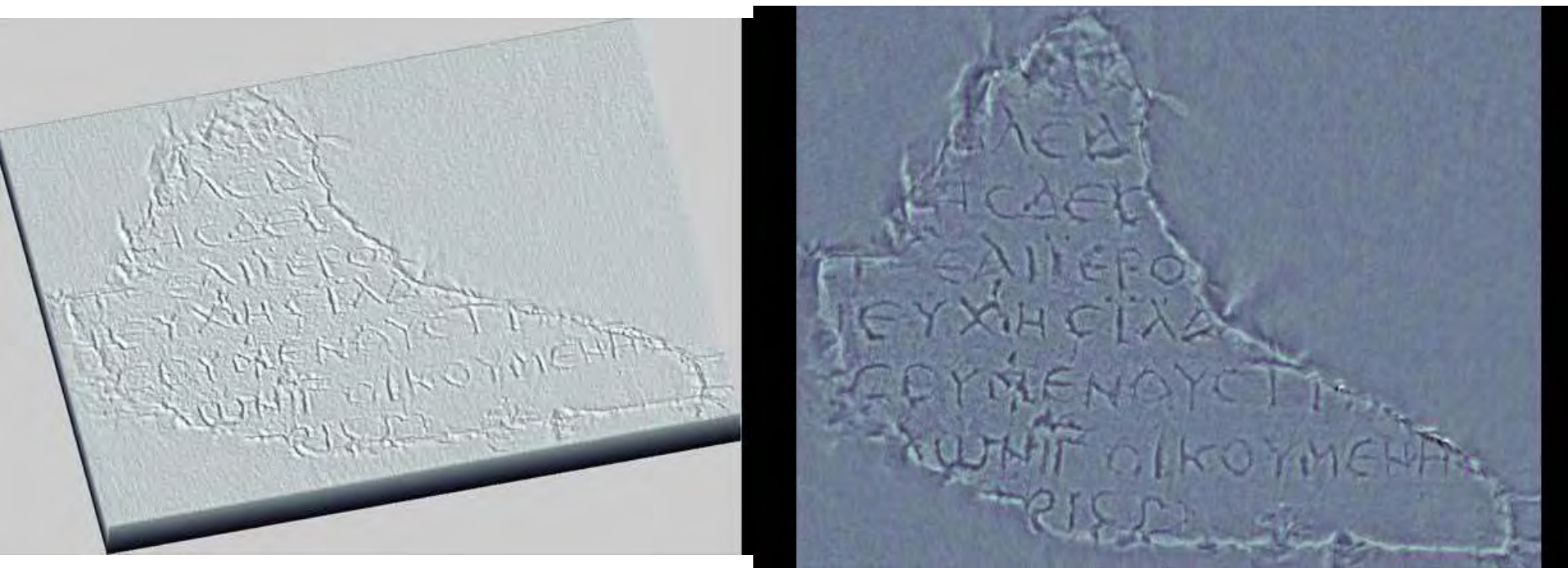
- Example of the two scanned images:



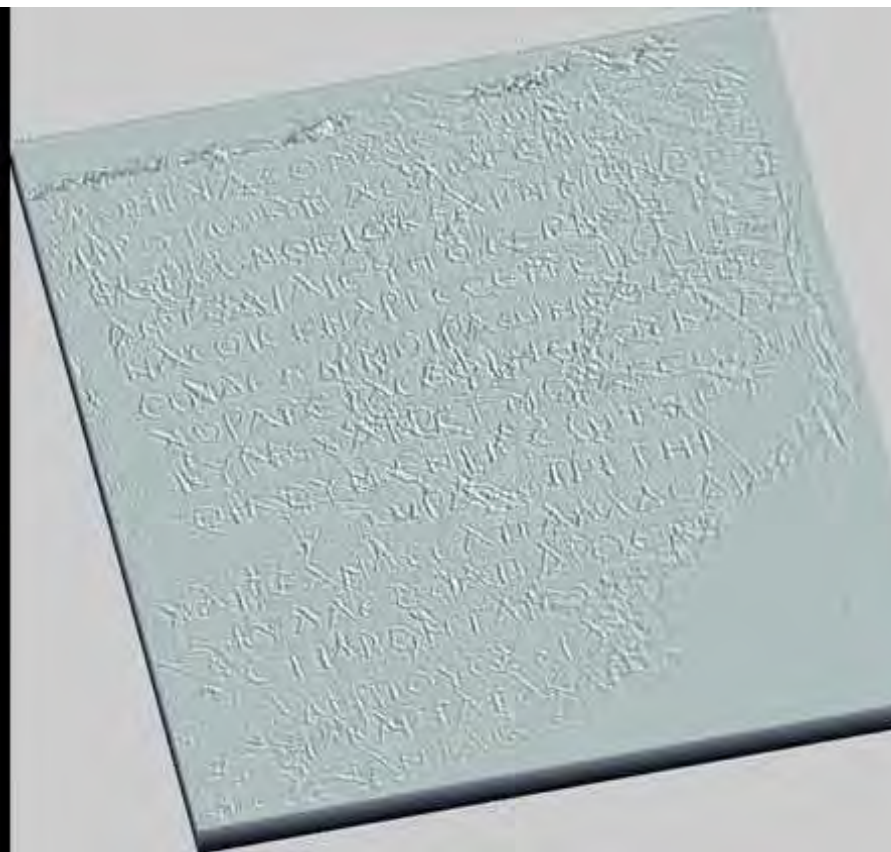
- Example of the 3D reconstruction



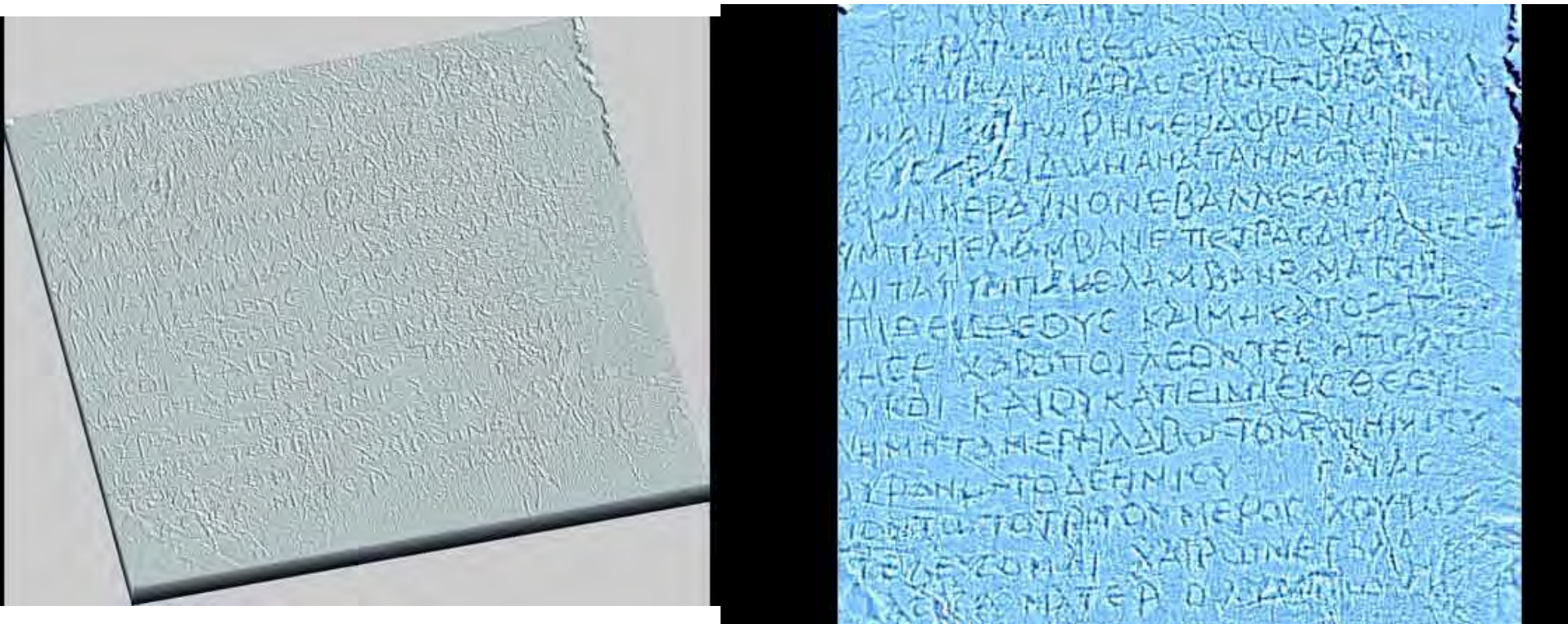
- Example of the 3D reconstruction



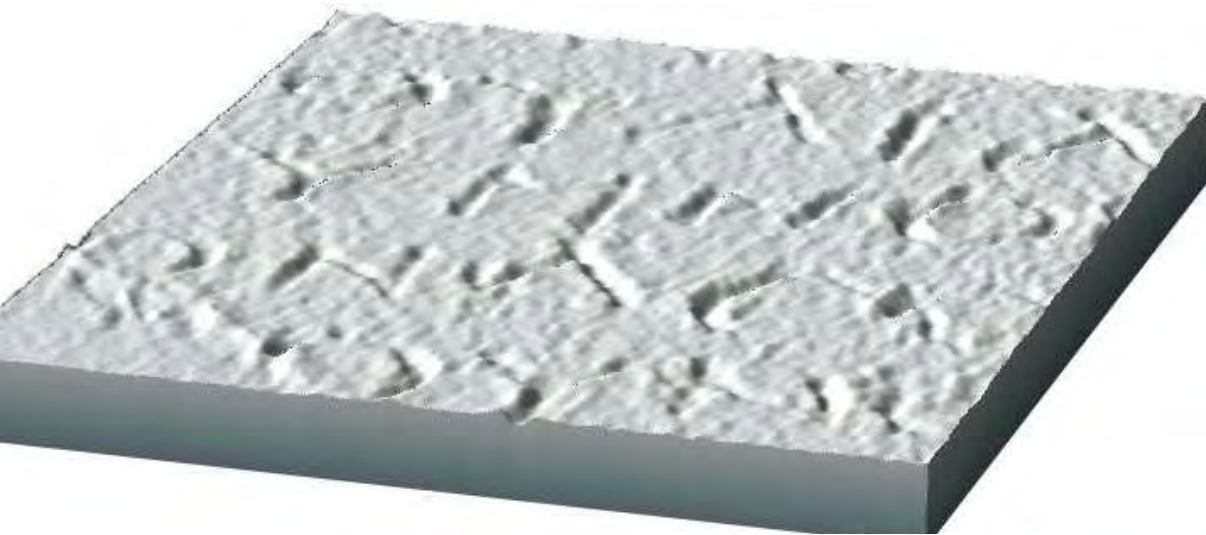
- Example of the 3D reconstruction



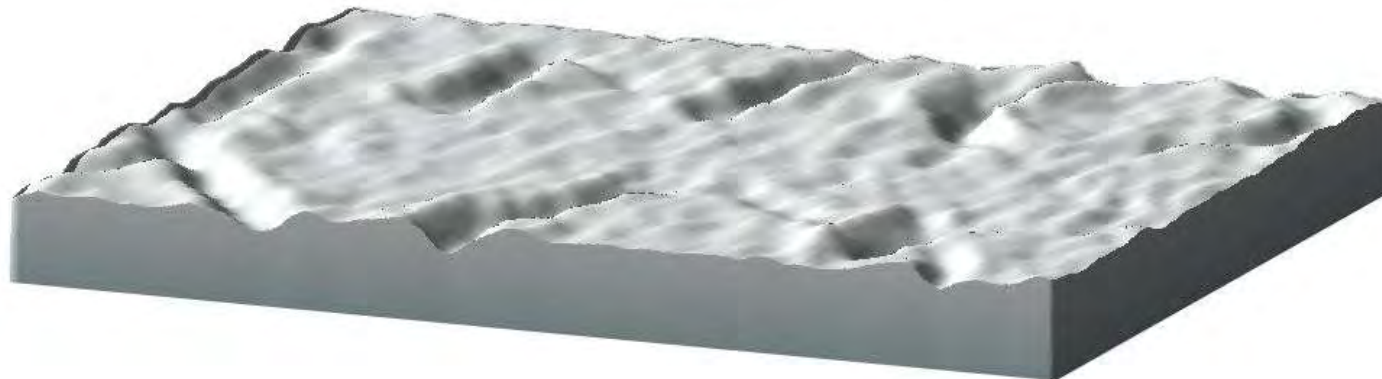
- Example of the 3D reconstruction



- Example of the 3D reconstruction



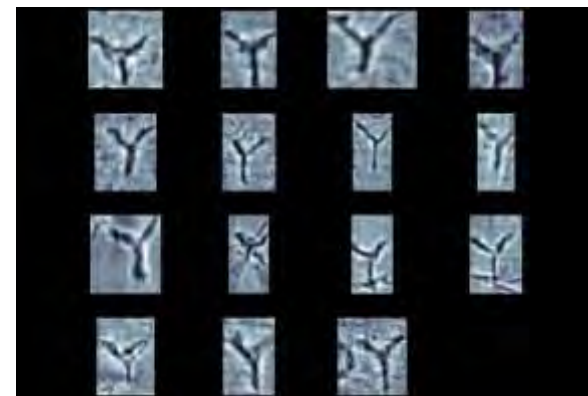
Details from the
reconstructed surfaces



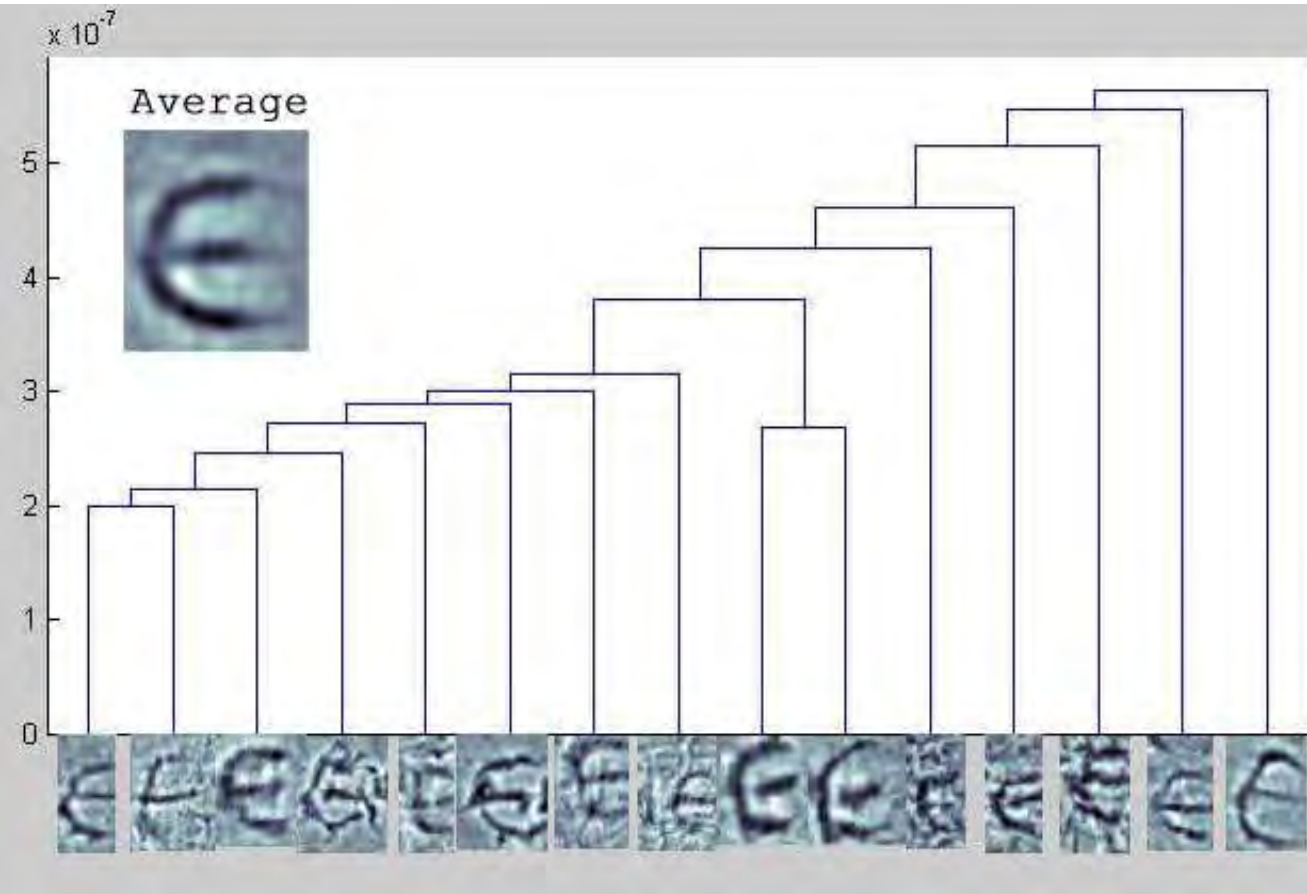
- Examples of letter segmentation



- Examples of letter grouping



■ Dendrogram of 'epsilon'

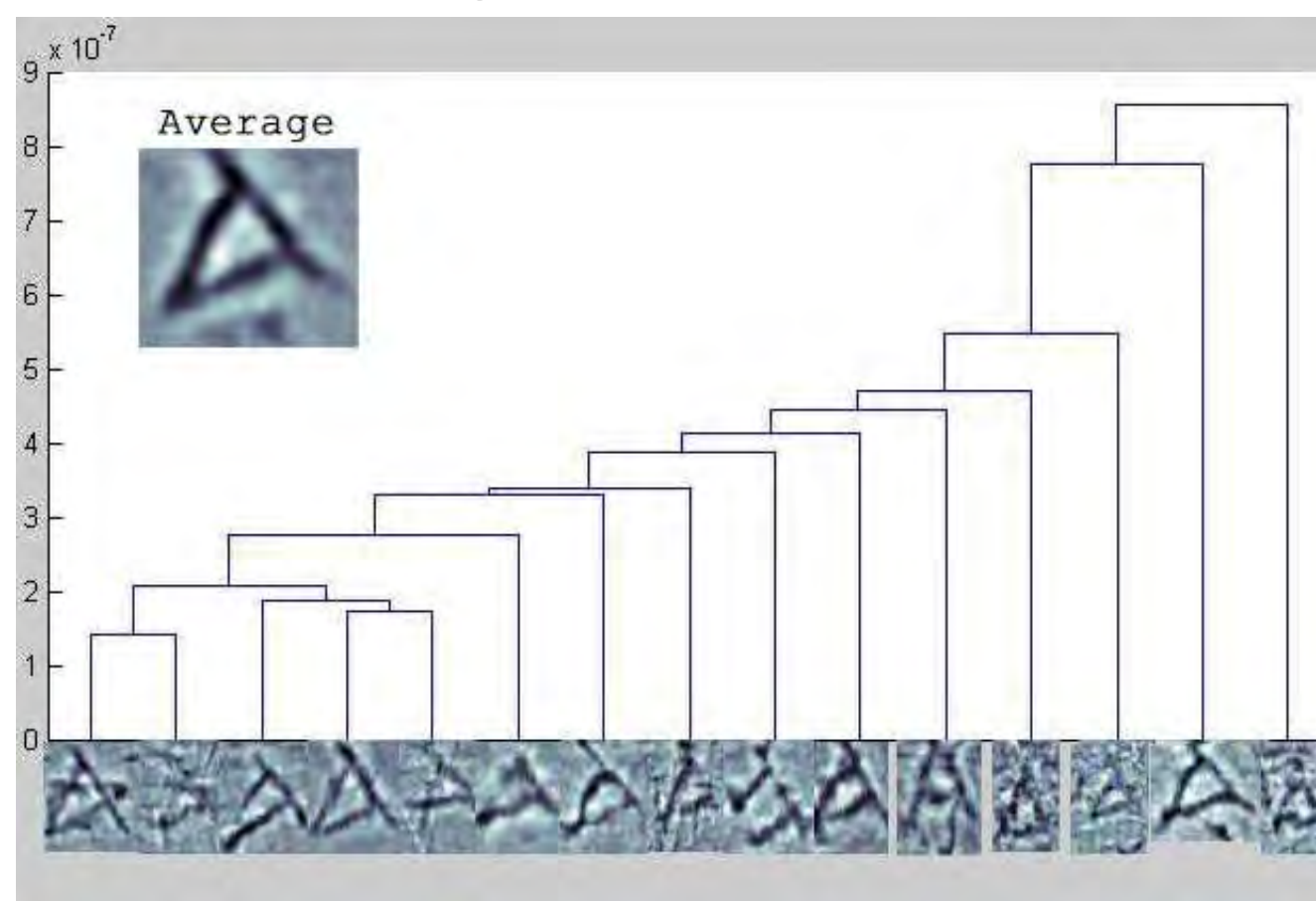


Notice line extensions in the average image.

Notice a small group in the dendrogram with two 'epsilons' whose middle line is not touching the vertical one.

No other significant sub-groups were formed.

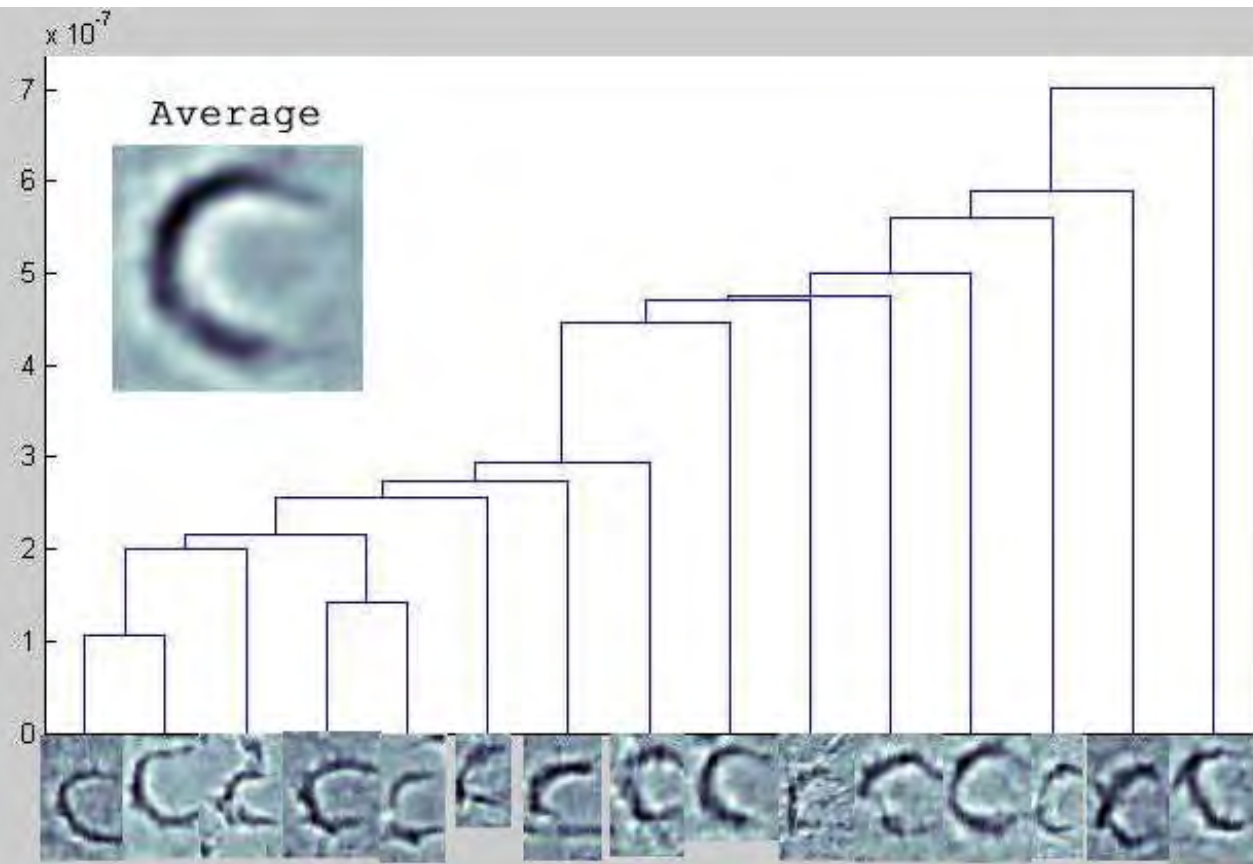
■ Dendrogram of 'alpha'



Look at the shape of the computed average.

No significant sub-groups were formed.

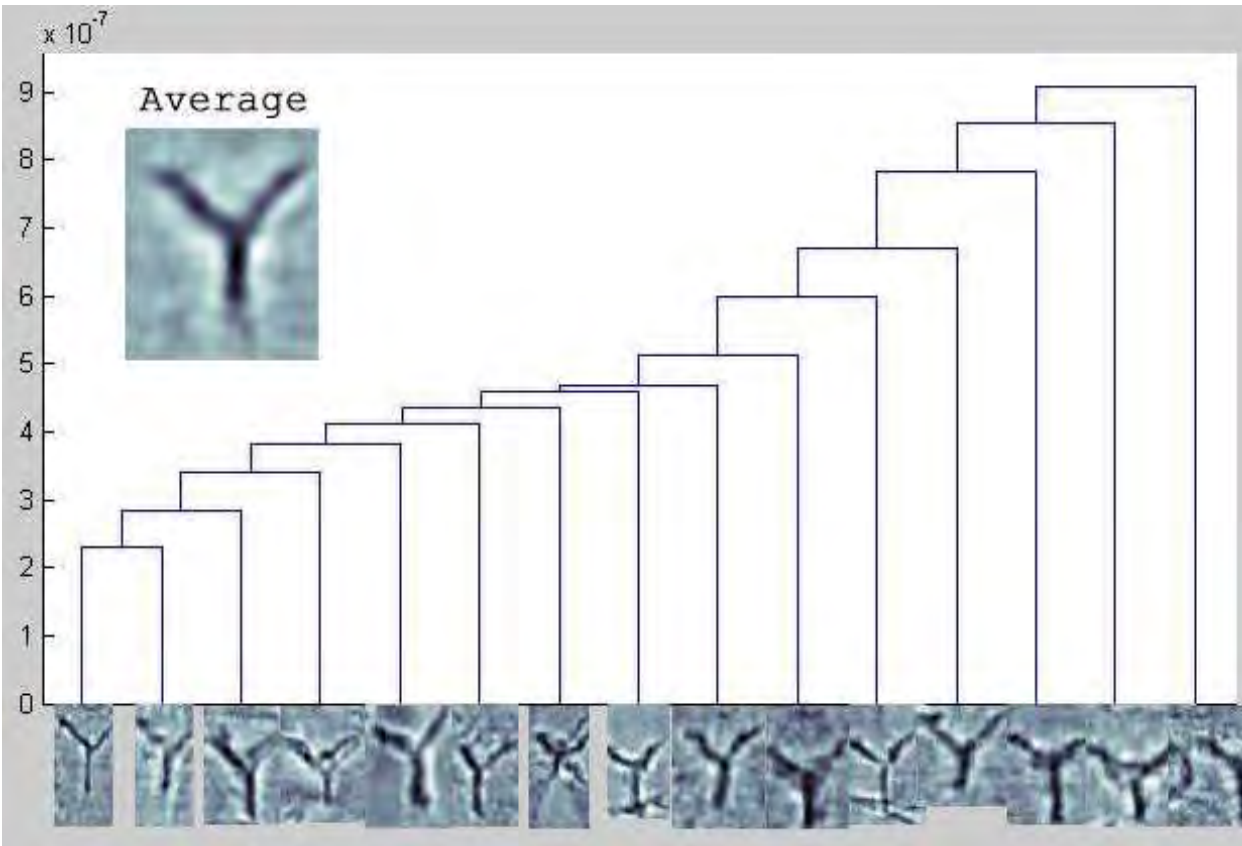
■ Dendrogram of 'sigma'



Look at the shape of the computed average.

No significant sub-groups were formed.

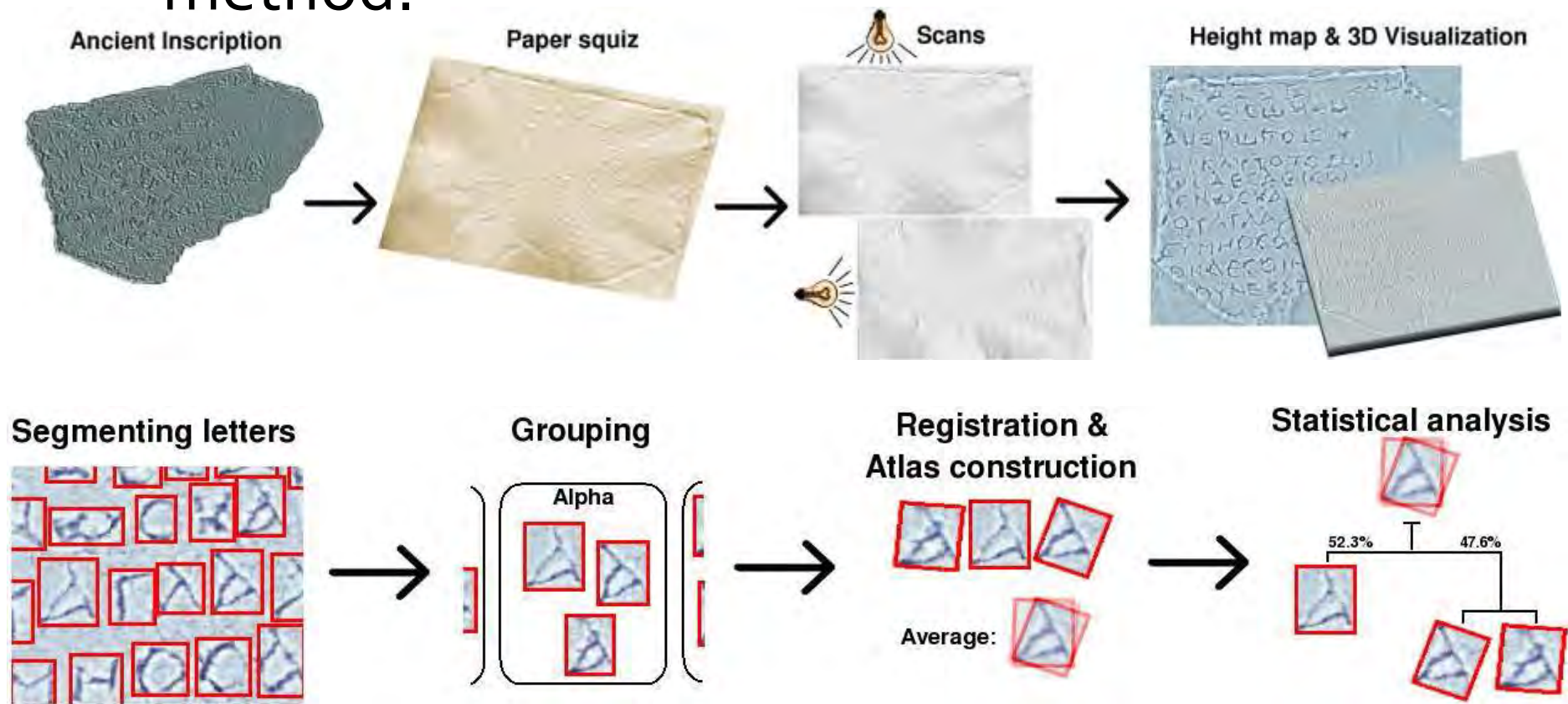
■ Dendrogram of 'ypsilon'



Look at the shape of the computed average.

No significant sub-groups were formed.

- To conclude, here is a diagram of our method.



Advantages:

- Convert paper squeezes into a digital format
- Easy copy and distribution of the squeezes
- Create libraries of 3D squeezes
- Use different viewing angles and shadings
- Compare letters and compute statistics

Drawbacks:

- Some details of the inscriptions are not captured by the squeezes, such as depth.
- Very large squeezes are hard to be scanned.

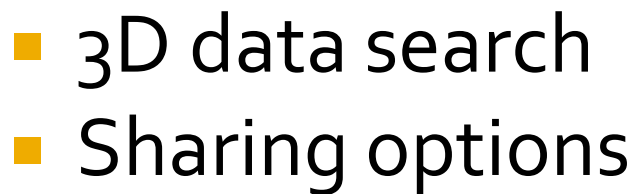
Future uses:

- Build an on-line library of 3D squeezes
- Other uses e.g. Create fonts from inscriptions

Other challenges:

- Automated dating
- Automated classification of inscriptions made from the same workshop

- 3D data search
- Sharing options



NATIONAL ENDOWMENT FOR THE
Humanities

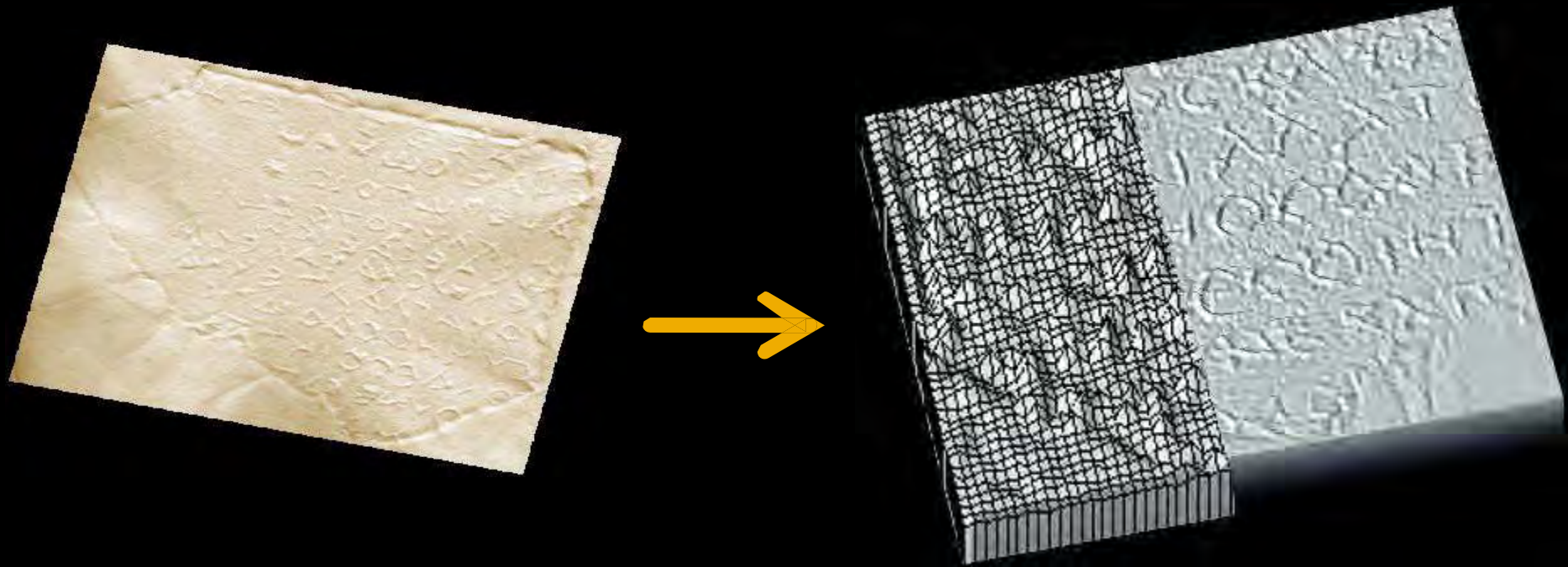
On-line Demo

<http://plaza.ufl.edu/bozia/epigraphy>

The image shows a screenshot of a web browser displaying the Digital Epigraphy Project website. The browser window is titled "Digital Epigraphy Project - Mozilla Firefox" and shows the URL <http://plaza.ufl.edu/bozia/epigraphy>. The website content includes the title "Digital Epigraphy Project - University of Florida" and the authors "Angelos Barmpoutis [1], Eleni Bozia [2], Robert S. Wagman [2]". Below this, it lists the affiliation: "Information Science and Engineering Department, University of Florida, Gainesville FL 32611, USA" and "Department, University of Florida, Gainesville FL 32611, USA".

Overlaid on the bottom left of the browser window is a smaller window titled "Digital Epigraphy Project - On-line Demo". This window displays a 2x2 grid of images showing the results of an epigraphy process. The top-left image shows a segmented letter 'E' on a textured background. The top-right image shows a 3D visualization of the letter 'E'. The bottom-left image shows a 2D height map of the letter 'E'. The bottom-right image shows a 3D height map of the letter 'E'. Below the grid, there are three buttons: "Segment letters", "Show 3D visualization", and "Show 2D height maps".

At the bottom center of the slide, the word "one" is written.



Thank you