



Grafica 3D per i beni culturali: Dense Stereo Matching, Arc3D Web Service

Lezione 13: 3 Maggio 2013

Image-based 3D Reconstruction

□ Advantages:

- Automatic
- Fast (relatively to manual built)
- Good scalability (both small and huge model can be acquired)
- Non-expert users can create his/her 3D model.
- Cheap!

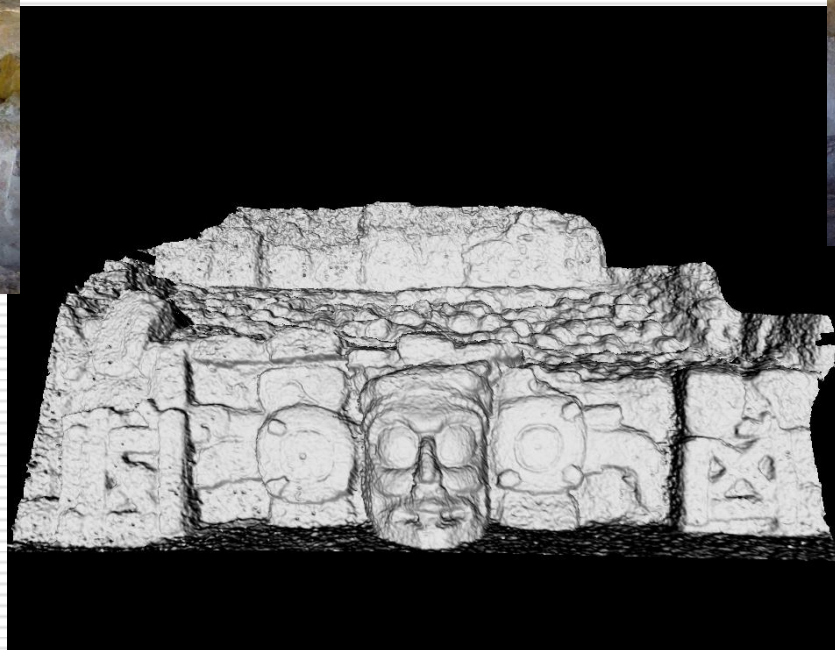
□ Disadvantages:

- Accuracy (not so accurate)
 - Not all the objects can be acquired
-

ARC3D Web Service

- ARC3D Web Service in a nutshell:
 - Register your account
 - Send your images (taken with your digital camera)
 - Get your 3D model
 - **Authors:** Martin Vargauwen and Luc Van Gool of University of Leuven (Belgium), in the ambit of EPOCH European Network of Excellence
 - **Web Site:** <http://arc3d.be>
 - **Further Information:** M. Vergauwen and L. Van Gool, *Web-based 3D Reconstruction Service*, in Machine Vision Applications (MVA), 17, pp. 411-426, 2006.
-

ARC3D Web Service

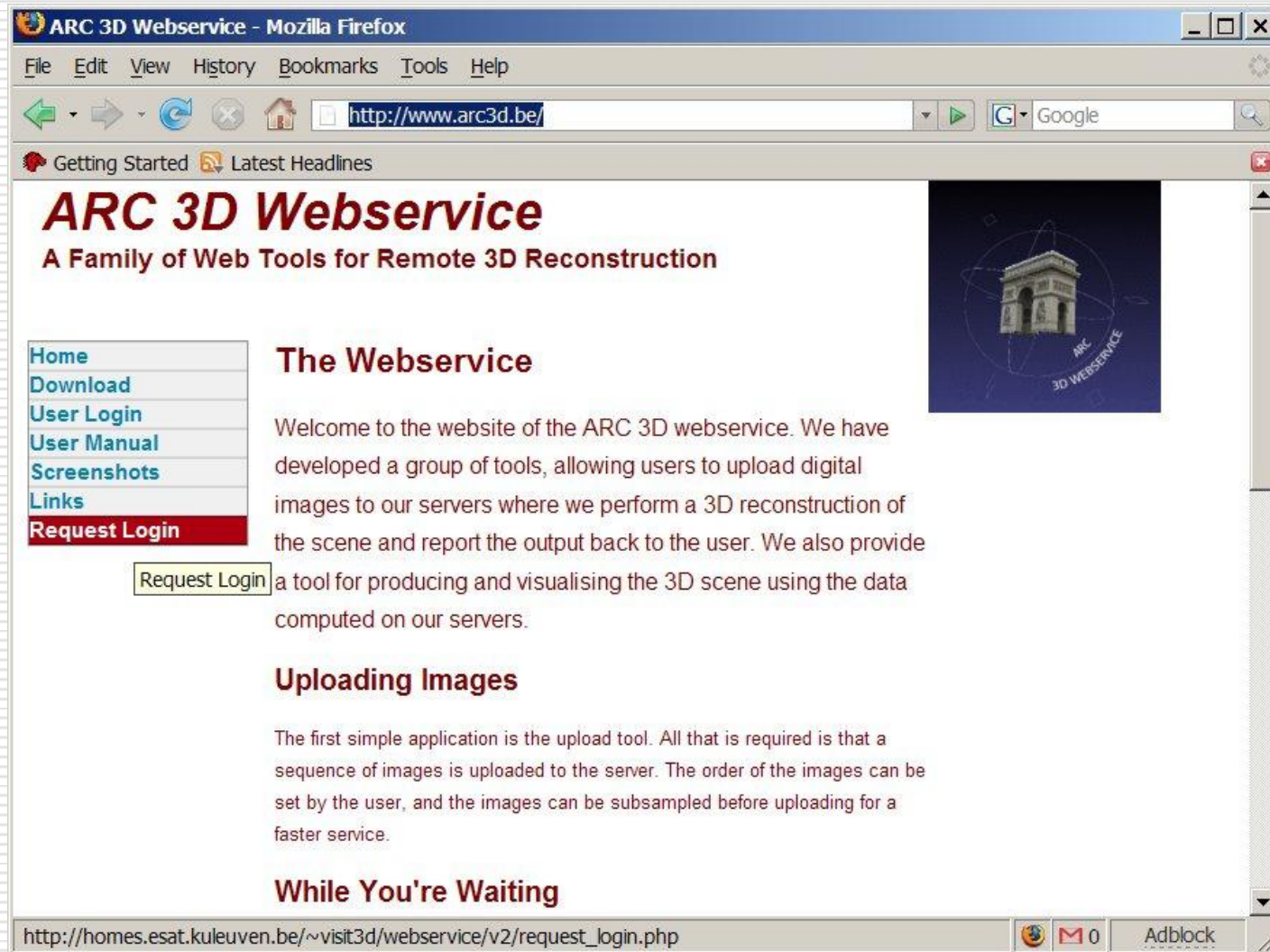


Images (C) by
Maurizio Forte
CNR, Rome

How do you use it?

- ❑ Obtain an account from the website
 - ❑ Download and install the software
 - ❑ Use the upload tool
 - Load your images
 - Upload them to the server
 - ❑ Have a coffee (the reconstruction could take also some hours...)
 - ❑ Download the results from the server
 - ❑ Visualize the results
-

Setup an account



The screenshot shows a Mozilla Firefox browser window displaying the ARC 3D Webservice website. The browser's address bar shows the URL `http://www.arc3d.be/`. The website's main heading is **ARC 3D Webservice**, with the subtitle **A Family of Web Tools for Remote 3D Reconstruction**. On the left side, there is a navigation menu with links for [Home](#), [Download](#), [User Login](#), [User Manual](#), [Screenshots](#), [Links](#), and [Request Login](#). The [Request Login](#) link is highlighted in red. The main content area features a section titled **The Webservice** with the following text: "Welcome to the website of the ARC 3D webservice. We have developed a group of tools, allowing users to upload digital images to our servers where we perform a 3D reconstruction of the scene and report the output back to the user. We also provide a tool for producing and visualising the 3D scene using the data computed on our servers." Below this is a section titled **Uploading Images** with the text: "The first simple application is the upload tool. All that is required is that a sequence of images is uploaded to the server. The order of the images can be set by the user, and the images can be subsampled before uploading for a faster service." At the bottom of the page, there is a section titled **While You're Waiting**. A small image on the right side of the page shows a 3D reconstruction of a classical building. The browser's status bar at the bottom displays the URL `http://homes.esat.kuleuven.be/~visit3d/websevice/v2/request_login.php` and includes icons for Firefox, a mail icon, and an Adblock extension.

Setup an account (2)

The screenshot shows a Mozilla Firefox browser window titled "Epoch 3D Webservice - Mozilla Firefox". The address bar contains "http://www.arc3d.be/". The page content includes a navigation menu on the left with links for Home, Download, User Login, User Manual, Screenshots, Links, and Request Login. The main heading is "ARC 3D Webservice" with the subtitle "A Family of Web Tools for Remote 3D Reconstruction". To the right is a logo featuring a classical building within a 3D wireframe sphere. The central section is titled "User Login Request" and contains the text "Please input your name and emailaddress in order to request a login." Below this are three input fields: "Name:", "Email:", and "Captcha letters and numbers:". The captcha image shows the number "3f499". A "Submit" button is located below the captcha field. The browser's status bar at the bottom shows "Done" and includes icons for Firefox, Mail, and Adblock.

Epoch 3D Webservice - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.arc3d.be/

Getting Started Latest Headlines

ARC 3D Webservice

A Family of Web Tools for Remote 3D Reconstruction

- Home
- Download
- User Login
- User Manual
- Screenshots
- Links
- Request Login

User Login Request

Please input your name and emailaddress in order to request a login.

Name:

Email:

Captcha letters and numbers:

3f499

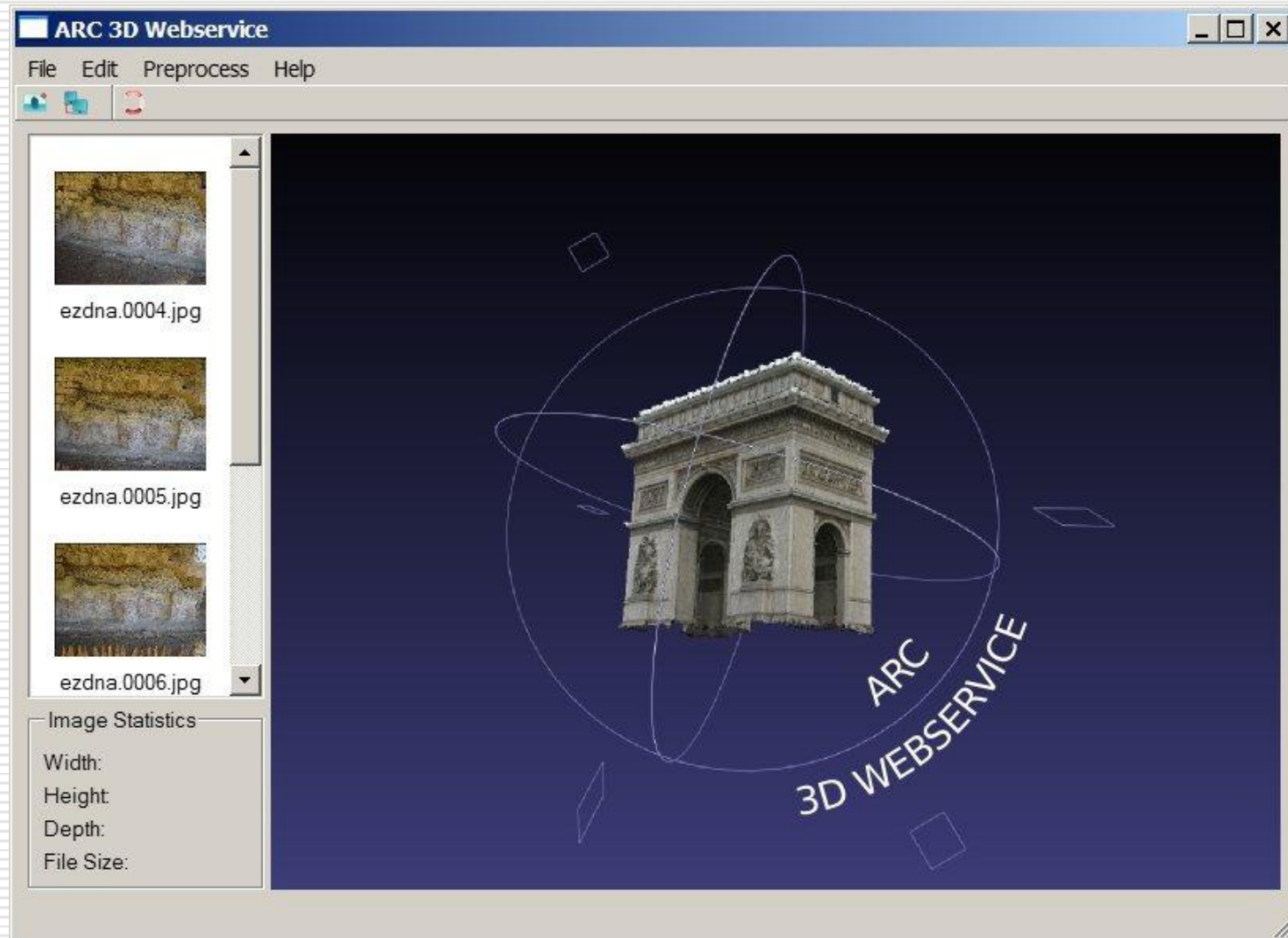
Done

Download and install

Be sure to be administrator of your machine (!)

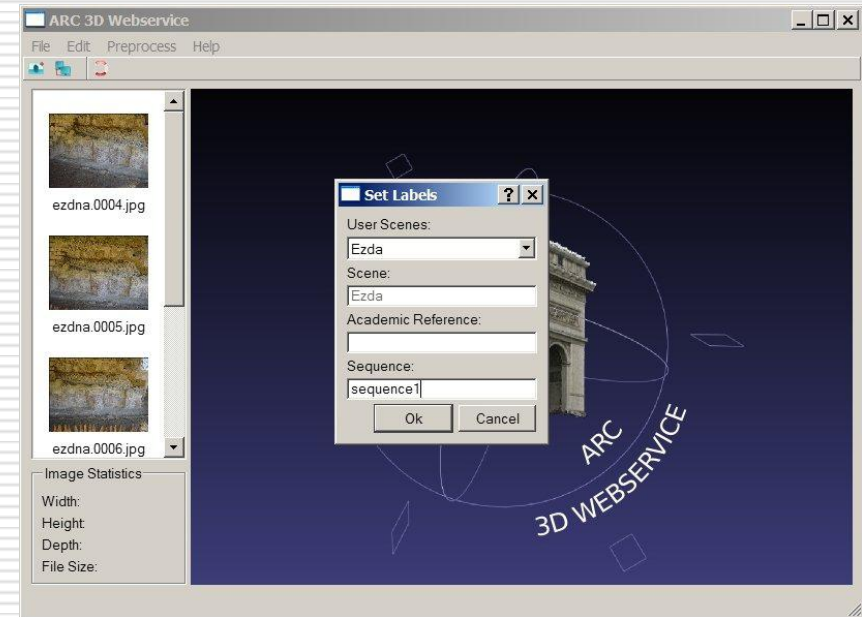


Upload Client



Upload Client (2)

- Images selected by user
- Subsample to smaller size for faster upload and computation
- Authentication with server
- Organization into scenes and sequences
 - Select or create a new scene
 - Supply a sequence label
 - Add academic reference (If ARC decides to use your images in a publication, it will add this reference. See conditions on the ARC homepage)

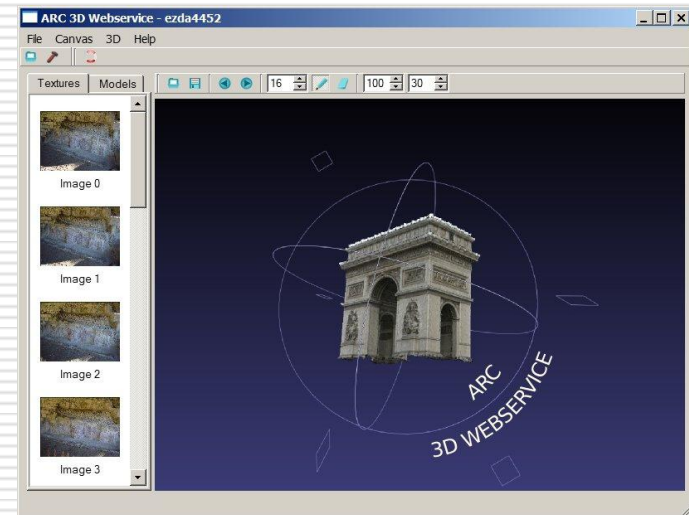
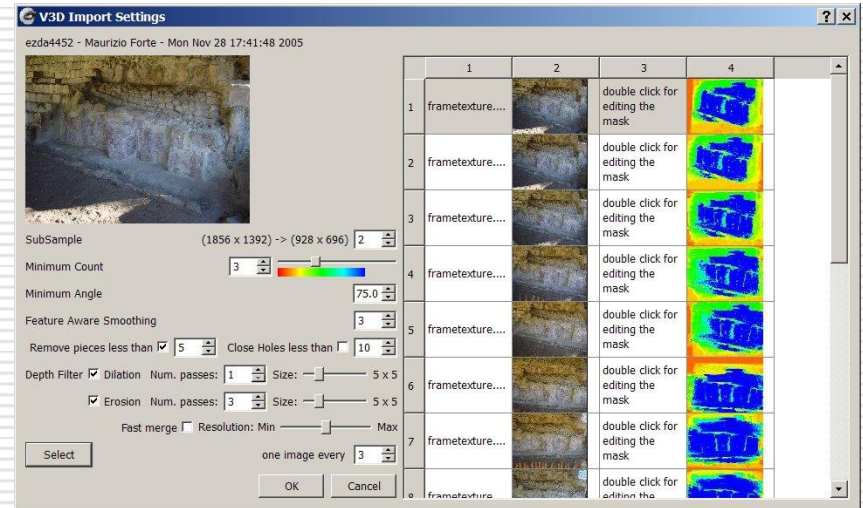


Get your 3D model

- ❑ The ARC service reports its result to you by email.
 - ❑ If the reconstruction has succeeded, a URL is specified from where you can download a zip file containing the results.
 - ❑ If the reconstruction failed, some more information is given, including tips on how to improve the result.
-

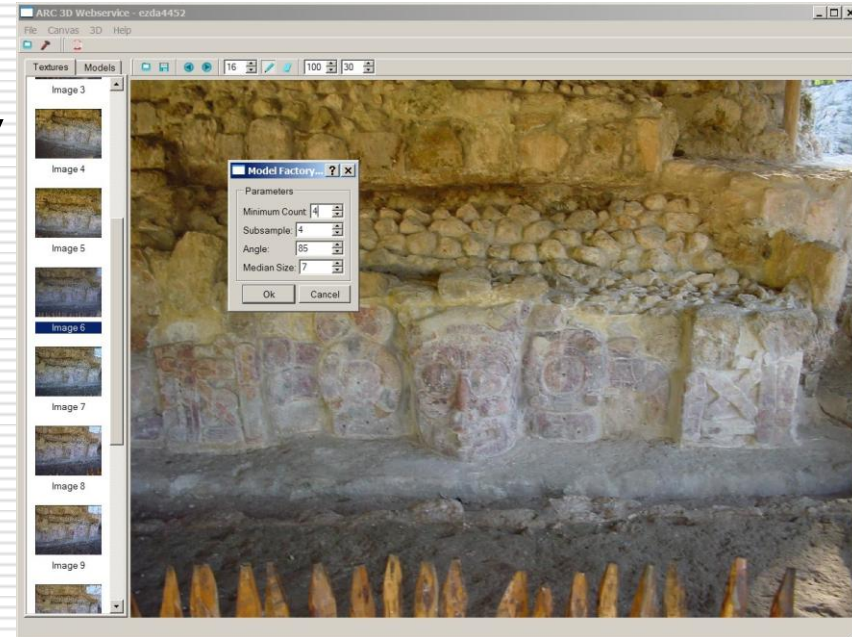
Visualize the Result

- Two tools are available for inspecting the results
- MeshLab, a tool developed by CNR-ISTI in Pisa, Italy (ARC3D Team recommends Meshlab)
- A simple model viewer comes with the ARC installer (ARC3D Model Viewer)



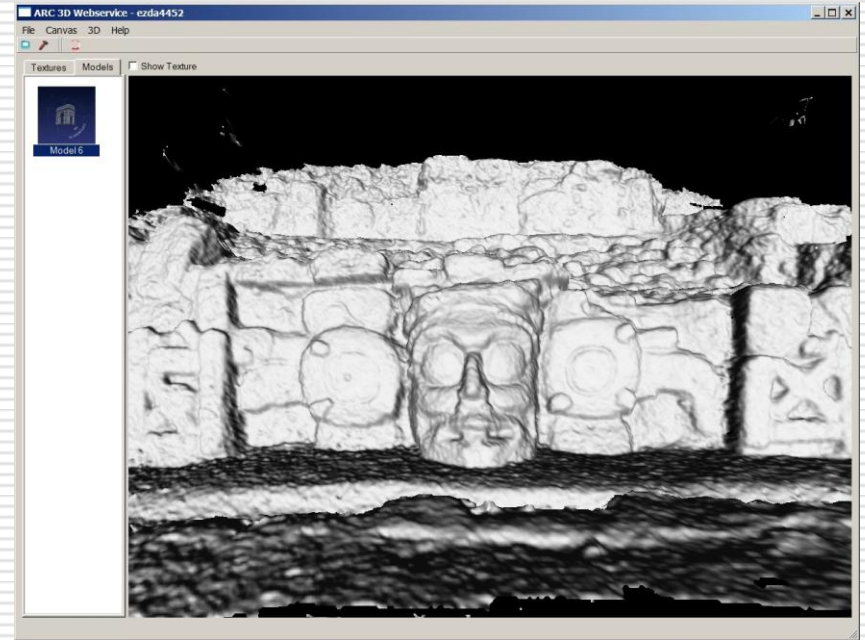
Visualize with ARC3D Model Viewer

- ❑ Download results from server
- ❑ Unzip file with images, cameras, depth and count maps
- ❑ Select one image on the left.
- ❑ Reconstruct 3D model for this specific depth map
- ❑ Parameters to tune:
 - Minimum quality (count)
 - Subsample for smaller models
 - Minimum angle w.r.t. viewing direction. This ensures that shearing angles are removed
 - Median filter size: larger filter for smoother (less noisy) models



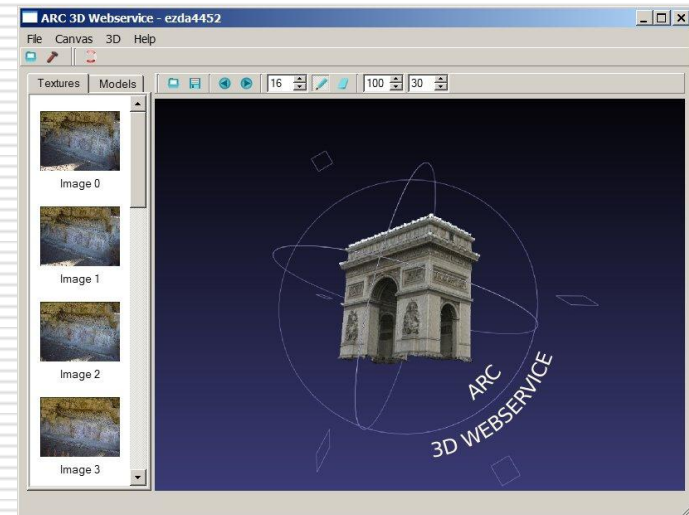
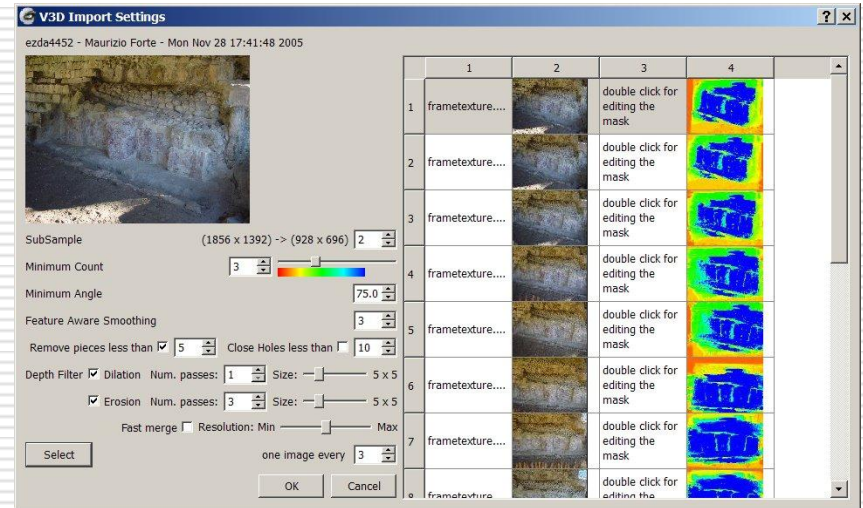
Visualize with ARC3D Model Viewer

- ❑ Select the model tab and view the result in a 3D widget
- ❑ Texture comes from the original image
- ❑ Export to different formats (X3D, PLY, OBJ, VRML) is possible



Visualize the Result

- Two tools are available for inspecting the results
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- A simple model viewer comes with the ARC installer (ARC3D Model Viewer)

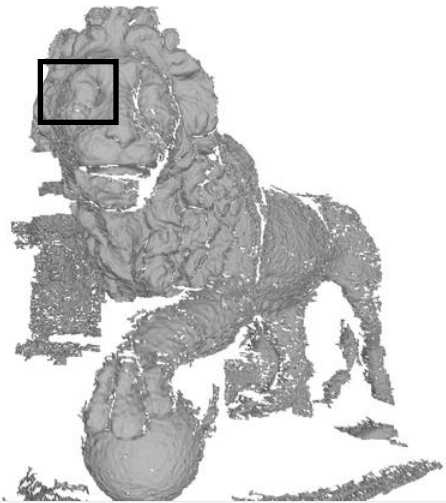
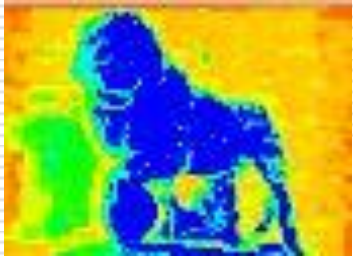


Manage ARC3D WebService Output

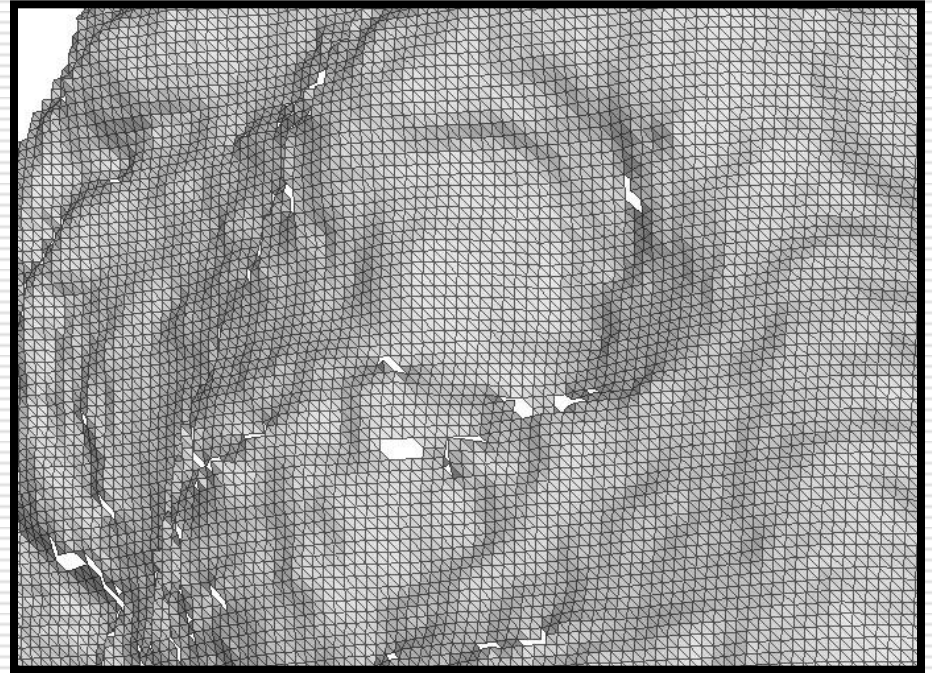
- ❑ ARC3D Web Service returns essentially **depth maps** for each input image
 - ❑ A *depth map* is an image with a value of depth associated for each pixel.
 - ❑ These depth maps have to be assembled together in order to create the final 3D model
 - ❑ ARC3D Web Service provides a model viewer to handle these data and obtain a final model
 - ❑ MeshLab can import and manage V3D files in order to produce the final 3D model or generate post-processed **range maps**.
 - ❑ A *range map* is the triangular mesh version of a depth map.
-

Depth Maps and Range Maps

Depth Map



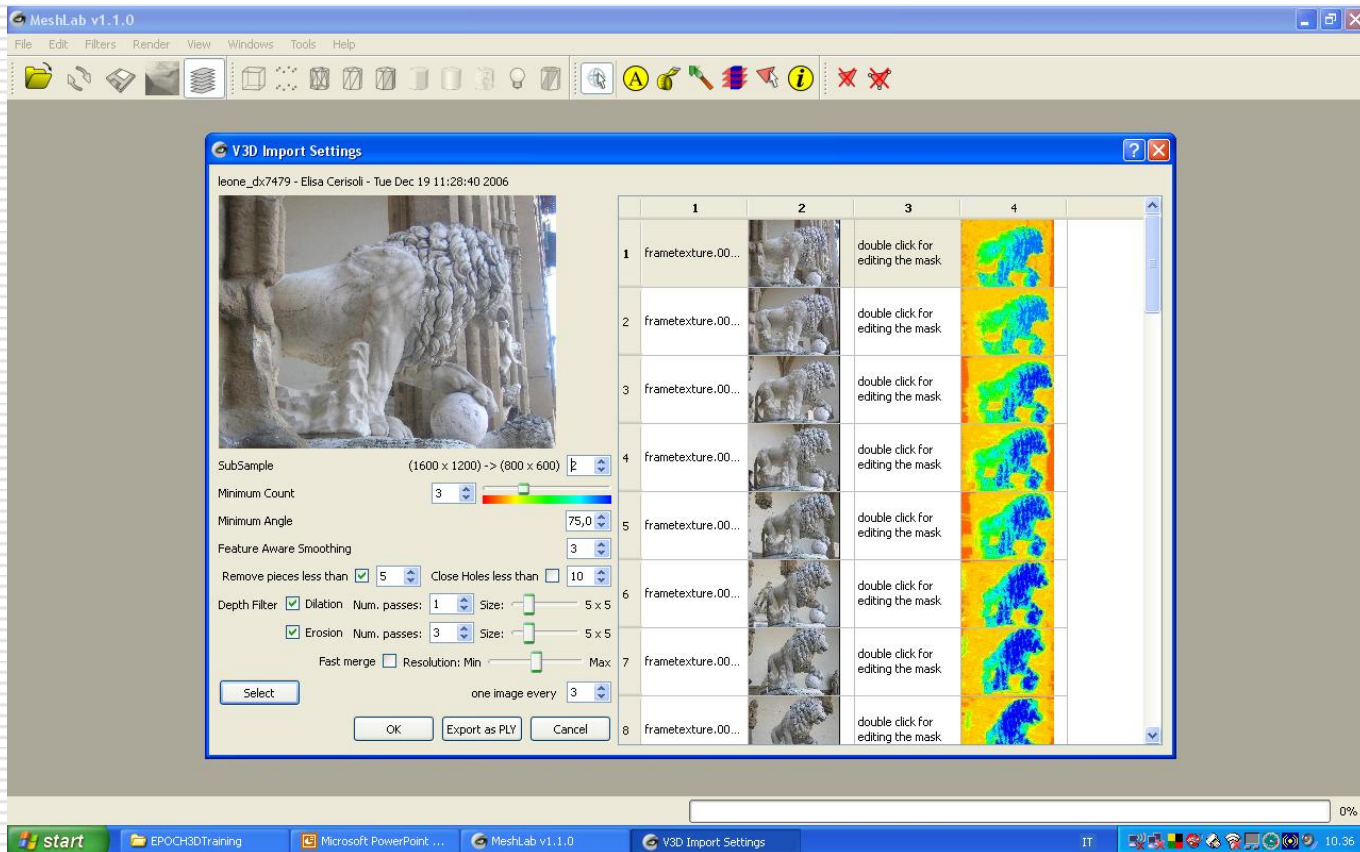
**Corresponding
Range Map**



Range Map (detail)

Import V3D Files


- ❑ V3D is the main data file
- ❑ We simply launch meshlab and open it through the arc3D tool...



Import V3D Files

V3D Import Settings

leone_dx7479 - Elisa Cerisoli - Tue Dec 19 11:28:40 2006



SubSample (1600 x 1200) -> (800 x 600) 2

Minimum Count 3

Minimum Angle 75,0

Feature Aware Smoothing 3

Remove pieces less than 5 Close Holes less than 10






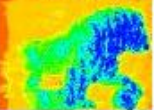

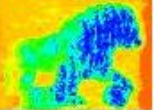



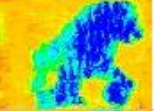

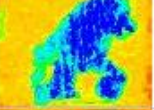

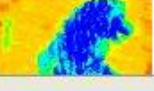
Depth Filter Dilation Num. passes: 1 Size: 5 x 5

Erosion Num. passes: 3 Size: 5 x 5

Fast merge Resolution: Min Max

Select one image every 3

OK Export as PLY Cancel

	1	2	3	4
1	frametexture.00...		double click for editing the mask	
2	frametexture.00...		double click for editing the mask	
3	frametexture.00...		double click for editing the mask	
4	frametexture.00...		double click for editing the mask	
5	frametexture.00...		double click for editing the mask	
6	frametexture.00...		double click for editing the mask	
7	frametexture.00...		double click for editing the mask	
8	frametexture.00...		double click for editing the mask	

V3D Import Settings Dialog

- ❑ The V3D Import Settings dialog is composed by two parts
 - ❑ Left part → processing parameters
 - ❑ Right part → table containing the summary of the EPOCH Web Service output
 - ❑ We start to describe the right part...
-

Summary Table

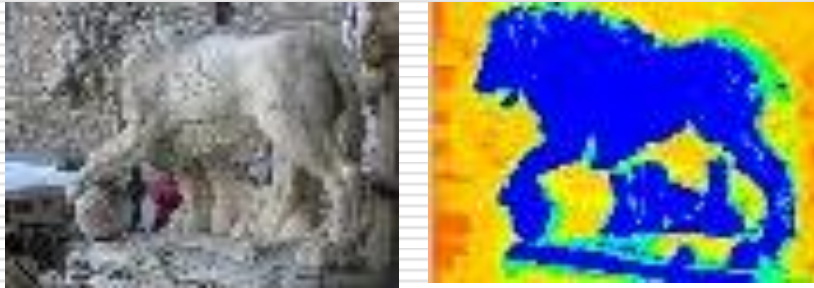
- ❑ The summary table contains a thumbnail for each photos uploaded and the depth map computed by the EPOCH Web Service
- ❑ The depth map is visualized in false color



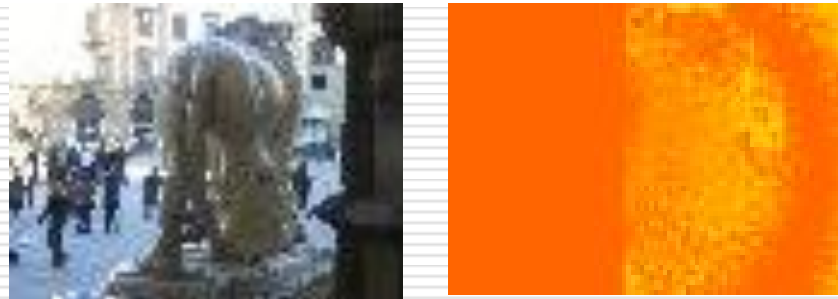
- ❑ These values represent the number of matching, i.e. the quality of the computed depth value
-

Depth Maps Quality

High-quality depth map



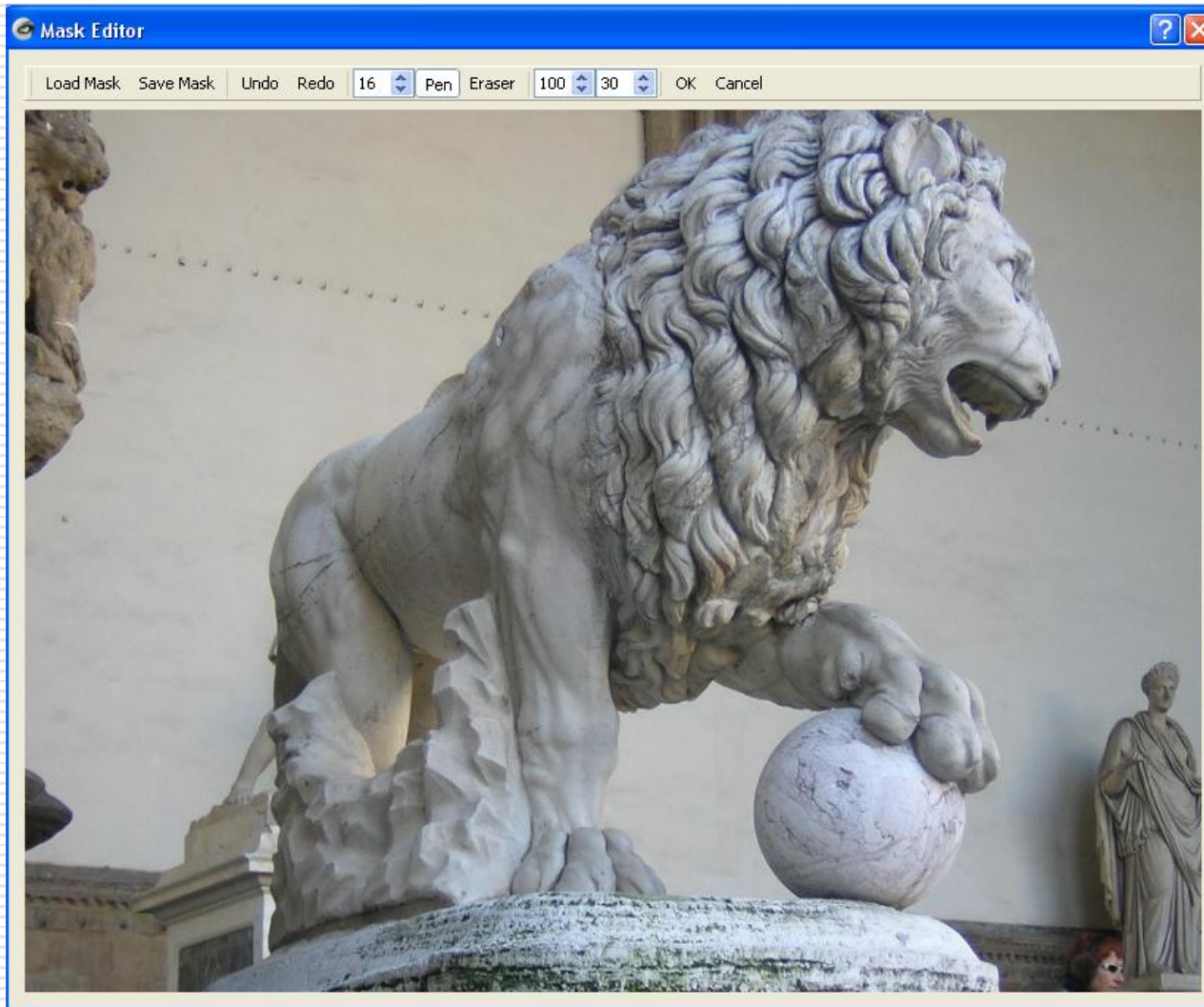
Poor quality depth map



Summary Table

- By double clicking the cell between the thumbnail and the depth map it is possible to set reconstruction mask to improve the final reconstruction
 - In other words we can indicate what is the model and what is the background in the photo
-

Mask Editor



**Let's go to do
some practice...**

Processing Parameters

V3D Import Settings

leone_dx7479 - Elisa Cerisoli - Tue Dec 19 11:28:40 2006

SubSample (1600 x 1200) -> (800 x 600) 2

Minimum Count 3

Minimum Angle 75,0

Feature Aware Smoothing 3

Remove pieces less than 5 Close Holes less than 10

Depth Filter Dilation Num. passes: 1 Size: 5 x 5

Erosion Num. passes: 3 Size: 5 x 5

Fast merge Resolution: Min Max

Select one image every 3

OK Export as PLY Cancel

	1	2	3	4
1	frametexture.00...		double click for editing the mask	
2	frametexture.00...		double click for editing the mask	
3	frametexture.00...		double click for editing the mask	
4	frametexture.00...		double click for editing the mask	
5	frametexture.00...		double click for editing the mask	
6	frametexture.00...		double click for editing the mask	
7	frametexture.00...		double click for editing the mask	
8	frametexture.00...		double click for editing the mask	

Processing Parameters

- **Subsample**: is the resolution used to build the range maps. Example: to use one depth value for each pixel of the depth map you have to use the original resolution. The default is the half of the original resolution.
- **Minimum Count**: is the minimum number of matching required to consider the depth value reliable. Unreliable values are not considered in the reconstruction.

SubSample (1600 x 1200) -> (800 x 600) 2

Minimum Count 0

Minimum Angle 75,0

Feature Aware Smoothing 3

Remove pieces less than 5 Close Holes less than 10

Depth Filter Dilation Num. passes: 1 Size: 5 x 5

Erosion Num. passes: 3 Size: 5 x 5

Fast merge Resolution: Min Max

one image every 3

Select OK Export as PLY Cancel

Processing Parameters

- **Minimum Angle:** faces that have their normal forming an angle with view direction larger than the indicated value (in degree) are deleted. The default value works in many cases.
- **Feature Aware Smoothing:** smoothing filter. Depth discontinuities are not filtered to avoid the introduction of artifacts.

The screenshot shows a software interface for processing parameters. The background is a light beige color. At the top left, the text "SubSample" is followed by "(1600 x 1200) -> (800 x 600)" and a spin box containing the number "2". Below this is "Minimum Count" with a spin box containing "0" and a horizontal color bar with a green-to-blue gradient. "Minimum Angle" is followed by a spin box containing "75,0". "Feature Aware Smoothing" is followed by a spin box containing "3". "Remove pieces less than" has a checked checkbox, a spin box containing "5", and "Close Holes less than" has an unchecked checkbox and a spin box containing "10". "Depth Filter" has a checked checkbox, followed by "Dilation" with a spin box containing "1" and "Size:" with a slider set to "5 x 5". Below that, "Erosion" has a checked checkbox, followed by "Num. passes:" with a spin box containing "3" and "Size:" with a slider set to "5 x 5". "Fast merge" has an unchecked checkbox, followed by "Resolution: Min" with a slider and "Max". At the bottom right, "one image every" is followed by a spin box containing "3". At the bottom left is a "Select" button. At the bottom center are "OK", "Export as PLY", and "Cancel" buttons.

Processing Parameters

- **Remove pieces less than:** After the meshing all the dangling pieces composed by a number of faces smaller than the indicated values are deleted. In this way you can automatically delete all the small floating pieces that in most cases are just noise.
- **Close holes less than:** this option controls the size of holes to close.

The screenshot shows a software interface for mesh processing parameters. The background is a light beige color. The parameters are arranged in a grid-like fashion. At the top right, there is a resolution change indicator: "(1600 x 1200) -> (800 x 600)" followed by a dropdown menu set to "2". Below this is a "Minimum Count" parameter with a dropdown set to "0" and a color gradient bar to its right. The "Minimum Angle" parameter has a dropdown set to "75,0". The "Feature Aware Smoothing" parameter has a dropdown set to "3". The "Remove pieces less than" parameter has a checked checkbox and a dropdown set to "5". The "Close Holes less than" parameter has an unchecked checkbox and a dropdown set to "10". The "Depth Filter" section includes "Dilation" with a checked checkbox, "Num. passes" set to "1", and "Size" set to "5 x 5". Below it, "Erosion" has a checked checkbox, "Num. passes" set to "3", and "Size" set to "5 x 5". The "Fast merge" parameter has an unchecked checkbox and a "Resolution" slider between "Min" and "Max". At the bottom right, there is a "one image every" dropdown set to "3". At the bottom, there are three buttons: "Select", "OK", and "Export as PLY", and a "Cancel" button on the far right.

SubSample (1600 x 1200) -> (800 x 600) 2

Minimum Count 0

Minimum Angle 75,0

Feature Aware Smoothing 3

Remove pieces less than 5 Close Holes less than 10

Depth Filter Dilation Num. passes: 1 Size: 5 x 5

Erosion Num. passes: 3 Size: 5 x 5

Fast merge Resolution: Min Max

one image every 3

Select OK Export as PLY Cancel

Processing Parameters

- ***Dilation and Erosion filter:***
Sometimes, the computed range maps are noisy, especially near high depth gradient. With these filters the user can reduce such undesired noise. The dilation filter is applied before the erosion one. The default parameters are good in most cases. The erosion reduce the reconstructed surface area, hence a detailed reconstruction require more photos. If the range maps still remains noisy after the filtering increase the erosion steps or size. Increase dilation steps or size in case of holes in the reconstructed surfaces.

The screenshot shows a software interface for processing parameters. The background is a light beige color. The settings are as follows:

- SubSample:** (1600 x 1200) -> (800 x 600) with a dropdown menu set to 2.
- Minimum Count:** A dropdown menu set to 0 and a horizontal color bar ranging from red to blue.
- Minimum Angle:** A dropdown menu set to 75,0.
- Feature Aware Smoothing:** A dropdown menu set to 3.
- Remove pieces less than:** A checked checkbox followed by a dropdown menu set to 5.
- Close Holes less than:** An unchecked checkbox followed by a dropdown menu set to 10.
- Depth Filter:** A checked checkbox. It contains two sub-sections:
 - Dilation:** A checked checkbox, Num. passes: 1, Size: 5 x 5.
 - Erosion:** A checked checkbox, Num. passes: 3, Size: 5 x 5.
- Fast merge:** An unchecked checkbox.
- Resolution:** A slider between Min and Max.
- one image every:** A dropdown menu set to 3.

At the bottom, there are four buttons: "Select", "OK", "Export as PLY", and "Cancel".

Processing Parameters

- ❑ **Fast merge:** This option active a fast merge process but produce a less accurate model. If high accuracy is not required or many range maps have to be processed this option should be active. **Selection:** we can select manually each depth map or push this button to select a subset (one image every **X**) of depth maps automatically.
- ❑ **Export as PLY:** single range maps are exported as single files for fusion with extern tools.

SubSample (1600 x 1200) -> (800 x 600) 2

Minimum Count 0

Minimum Angle 75,0

Feature Aware Smoothing 3

Remove pieces less than 5 Close Holes less than 10

Depth Filter Dilation Num. passes: 1 Size: 5 x 5

Erosion Num. passes: 3 Size: 5 x 5

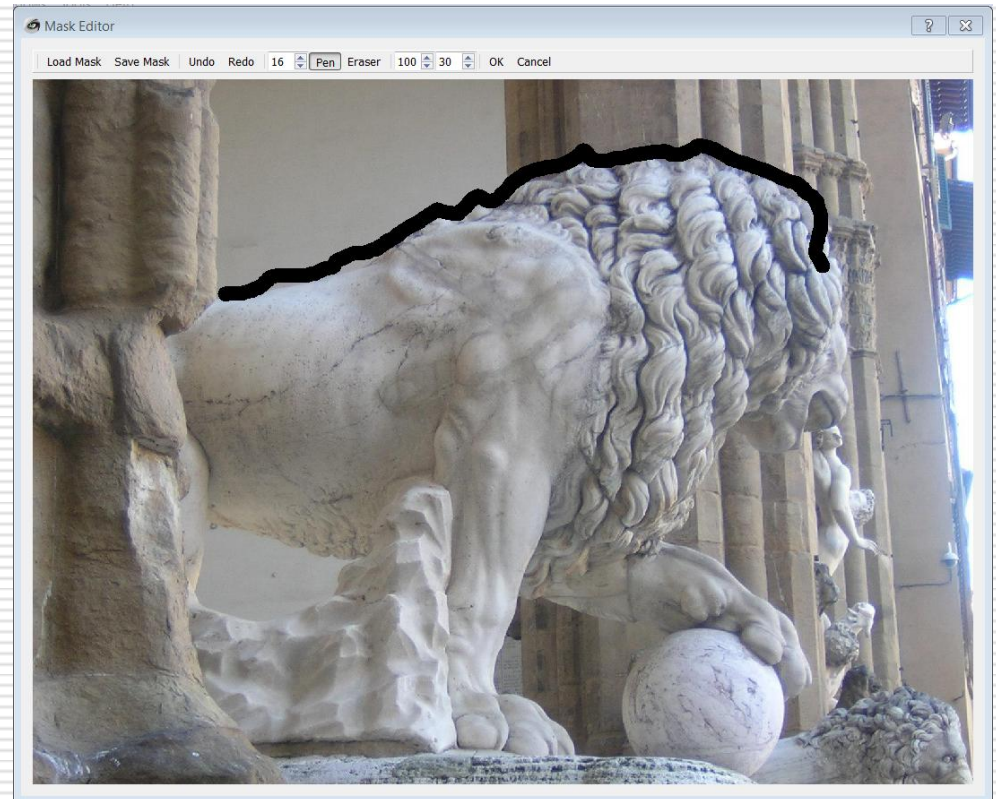
Fast merge Resolution: Min Max

one image every 3

Select OK Export as PLY Cancel

Processing Parameters

- **Mask:** it's possible to create manually a mask by indicating the parts of the image we don't want to be taken into account for reconstruction.
Very useful for silhouettes.



Model creation with MeshLab

After the 3D model is exported in MeshLab, there's a procedure to enhance it a bit and have a final result:

- Cleaning
 - Sampling
 - Poisson reconstruction
 - Poisson Model cleaning
 - Vertex Color Transfer
 - Cleaning
 - Scaling
 - Saving!
-

Model creation with MeshLab

If you want to scale the model to its real size, you need to have a measurement of a known element, and the corresponding measurement in MeshLab.

The scaling factor to be applied (using the Transform:Scale filter) is:

$$\text{ScaleFactor} = \text{RealMeasure} / \text{MeshLabMeasure}$$

Arc3D and MeshLab: final comments

- The creation of the final result is an iterative process. You probably need several tries to find the number of needed images, the resolution for the model creation, the quality threshold etc etc.
 - The quality of the final results can be greatly improved with the use of mask and an accurate cleaning and editing in MeshLab.
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Next in line...

Next lesson:

- Dense stereo matching: Photosynth toolkit

Contacts:

Matteo Dellepiane

c/o ISTI-CNR Via G. Moruzzi 1

56124 Pisa (PI)

Tel. 0503152925

E-Mail: dellepiane@isti.cnr.it

Personal website: <http://vcg.isti.cnr.it/~dellepiane/>

VCG website: <http://vcg.isti.cnr.it>
