

## Utilization of Photosynth Point Clouds for 3D Object Reconstruction

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### ABSTRACT:

There is a growing demand in modeling amorphous shapes like statues, figurine or monuments for computer visualization and documentation. Using photographs as the data source is a most convenient recording mode on site. The equipment is easy to handle and transportation is in no case a problem as it can occur if a laser scanning device has to be employed.

A photograph is a container of high information density. It carries radiometric information and can provide range values as well. In terms of computer vision, structure from motion is a process to find the correspondence between images. Features must be tracked from one image to the next. The 3D positions of the feature points and the camera movement is the result of the registration process. In the cultural heritage community the Epoch ARC 3D Web service is in common use. Linked with the open source tool MeshLab it provides an automated workflow including object reconstruction, mesh processing and textured rendering.

Recent developments from Microsoft introduce photo browsing. The Web community can view images from cities in Virtual Earth and participate with own objects applying Photosynth. Photosynth is designed as an image browser for objects, documented by internet imagery. The user navigates through a bundle of images representing the object. A smooth transition from one photo to the next is leading to the impression of a 3D model. Photo positions are known as well as a point cloud emerged from the registration process.

Applying a network protocol analyzer provides the location of the binary point cloud files. A Python script affords conversion into common CAD formats like PLY or DXF. Producing a low level polygon mesh for real time visualization exacts selecting the points of interest and mesh processing. The latter task will be solved applying MeshLab. It has to be mentioned, that the focus in this context points more on that low level polygon model instead of a high accurate and high density model. Furthermore Blender with its comfortable function for UV texture mapping and export script to X3D will be applicable to construct a complete 3D scene.

This contribution introduces a 3D object reconstruction method from a series of photographs processed with Web tools and open source software.

### 1. WHAT IS PHOTOSYNTH?

Photosynth is a new technology to view photos on a computer platform. It was developed in collaboration between Microsoft and the University of Washington. A large collection of photos of a site or object is taken by Photosynth to analyses them for similarities, and displays them in a reconstructed 3-dimensional space. An object needs between 20 and 300 or more photos for 3D reconstruction. Since Photosynth uses the EXIF data for further processing, pictures can be taken with different focal length lenses but must be presented in full format. After selecting the photos and uploading, no more interaction is required. The result will be automatically place at the disposal for the Web community.

A user can navigate inside the scene by selecting the angle of view and the zoom factor. Information about the photo position

in relation to one another is provided. With Photosynth fast access to gigabytes of images is realized. Photosynth needs installation of a plug-in for MSIE or Firefox and is running under Windows XP and higher. Access to Photosynth is given by <http://labs.live.com/photosynth>. Visit [photosynth.net](http://photosynth.net) for the latest release of the software.

Figure 1 reflects a screenshot from Photosynth. 50 photos are brought together for that particular reconstruction including approx. 43 300 feature points. The synth is named *LouisePlads*. The name may be typed as a search item inside Photosynth to navigate through the scene. If the Microsoft Silverlight viewer is installed, pressing the P-key switches on and off the images and displays the colored point cloud. Downloading a point cloud and further processing to a 3D object reconstruction is the major topic of this paper.



**Figure 1.** Navigation buttons of Photosynth. P-Key switches to point cloud, search for *LouisePlads*

Use of calibrated cameras and manual operating seems to be a disadvantage of photogrammetry. Computer vision methods target to the use of non calibrated cameras and totally automatic model reconstruction approximating the object geometry by triangular surface meshes, textured with image data.

Since we target to such a kind of application instead of photo browsing, an alternative to Photosynth seems to be the ARC3D web service ([www.arc3d.be](http://www.arc3d.be)). ARC3D offers the possibility to upload an image sequence, utilizing the ARC3D image uploader, to a server and analyze the 3D reconstruction downloaded from the server with the ARC3D model viewer (Vergauwen, Van Gool 2006).

After processing on the web network, the client downloads the findings as a compressed archive. The archive contains a file including the reconstruction information, for each image a thumbnail and the image texture, the camera data as a manifest file, the dense depth maps and the quality maps. The model viewer reconstructs on the client computer the 3D information. It is possible to mask the images, eliminating sky e.g., before reconstructing the surface meshes and surface texture. Final results can be stored in several formats.

Another software that has to be mentioned here is Bundler. Bundler was supported by Microsoft Research and can be faced as a corner stone or core of Photosynth. Available on the Web under [phototour.cs.washington.edu/bundler](http://phototour.cs.washington.edu/bundler). Bundler distinguishes from Photosynth as an offline tool.

## 2. DOWNLOADING PHOTOSYNTH POINT CLOUDS

A procedure to access Photosynth point clouds is given in detail on the Web at: <http://binarymillenium.com/2008/08/photosynth-export-process-tutorial.html>.

That place is as well the source for downloading a Python utility to, convert the binaries.

At the outlet it is necessary to detect the server and the URI where the binaries are located. Applying a network packet

analyzer leads to the requested information. Wireshark is an open source software running under GNU GPL (<http://www.wireshark.org>). It was initially developed 1997 by Gerald Combs under the name Ethereal. The Wireshark team is a loose group of individuals

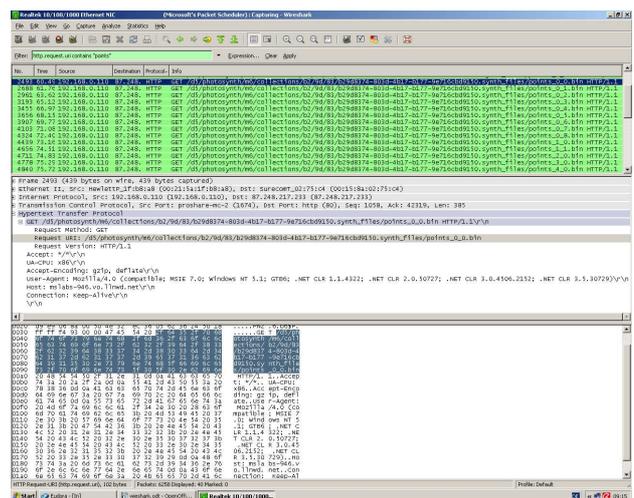
A network packet analyzer will try to capture network packets and tries to display that packet data as detailed as possible. You could think of a network packet analyzer as a measuring device used to examine what's going on inside a network cable.

The Wireshark user interface is divided into panels where one can get the filtered information, details and the packet bytes. Setting the filter to *http.request.uri contains "points\_"* reduces the incoming information to the requested URIs. The analyzing process must be running before the Photosynth will be addressed by the Web browser. The host name occurs in the details pane. Since the byte information comes into packets, it is recommended to download the files separately by typing the URL into the browser's address line. Connecting the host and the URI into one string needs to eliminate the `\r\n` characters from the substrings. The complete point cloud comes in a couple of files. Filenames are *points\_n\_n.bin*, whereas n increments.

Due to the later application of Blender we assume, that Python is installed on the machine and we call the Python utility *cldBinToASCII.py* from a simple batch procedure *script.bat*. Calling is *script points\_n\_n*. By typing F3 key the console command repeats and can altered to the next number. The batch file reads as:

```
c:\programme\python25\python.exe
ptCldBinToASCII.py %1.bin >%1.scr
```

The Python script coming from binarymillenium.com is slightly modified. The lines for writing the point coordinates will generate an AutoCAD Script for importing the points into the drawing editor.



**Figure 2.** Screenshot of Wireshark. Displaying the filter information, requested URI and the host

The two lines changed are coded as

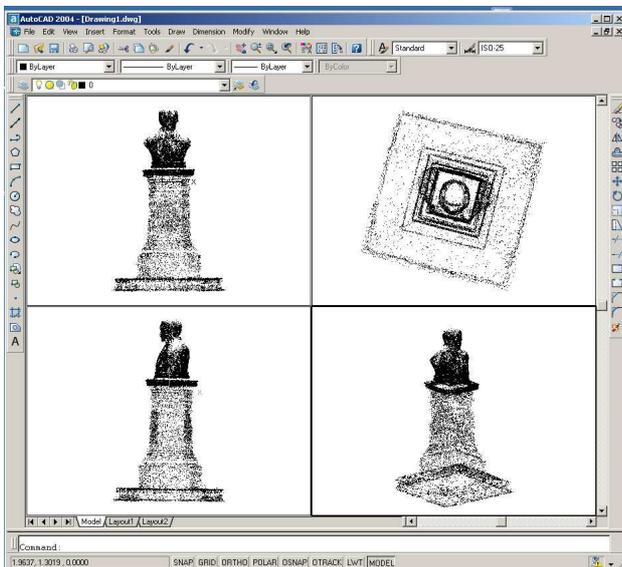
```
sys.stdout.write('_point\n')
sys.stdout.write(str(fbin[0]) + ',' +
str(fbin[1]) + ',' +str(fbin[2]) +'\n')
```

The then following color information will be skipped by a comment. It writes to a file by redirecting the standard output via the batch procedure to *%!.scr*.

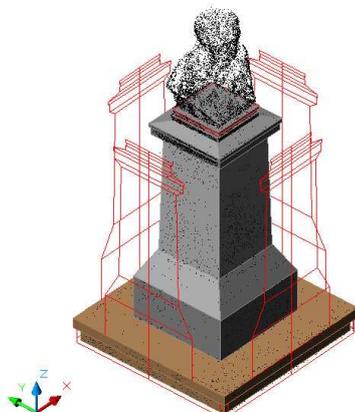
### 3. PREPROCESSING RAW POINT DATA

Subsequent that downloading and conversion mechanism the point cloud is prepared for importing into AutoCAD executed by the SCRIPT command.

The raw point cloud contains a huge amount of points outside the object of interest and is not properly aligned to a local coordinate system. Reducing the data to its object points of interest and aligning it to horizontal and vertical axis including a real scale transformation is the task for a CAD system.



**Figure 3.** Preparing the point cloud for mesh processing and construction of discrete structures



**Figure 4.** Construction of discrete structures over the point cloud

Performing the WBLOCK command writes back a DXF format of single points. In case of discrete structures, like the socket in figure 3, a construction is carried out straight. Points belonging to organic structures will be exported for mesh processing only.

### 4. MESH PROCESSING

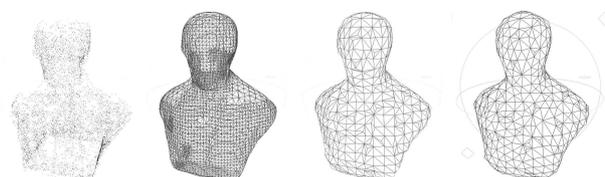
MeshLab is an open source 3D mesh processing system. The MeshLab system was developed by ISTI-CNR (Institute of information science and technology - National Research Council, Italy) in the framework of the EPOCH Network of Excellence. EPOCH is a network of about one hundred European institutions collaboratively producing applications involving digital versions of Cultural Heritage material.

MeshLab provides tools for the processing pipeline from range maps to 3D polygon models. It includes functionality for registration of different raw range maps, algorithms for surface reconstruction into a single mesh, mesh refinement and editing functions. MeshLab supports a wide range of common 3D formats.

Reading the point coordinates is taken from a PLY format, generated beforehand from the DXF. PLY is known as the Polygon File Format or the Stanford Triangle Format. PLY is principally designed to store three dimensional data from 3D scanners. It supports a simple description of a single object as a list of points or flat polygons with a variety of properties. The conversion from DXF to PLY is carried out by a Java class. All listed helpers and examples here can be downloaded from the URL [www.imagefact.de/monuments](http://www.imagefact.de/monuments).

The first step in the mesh processing workflow is the calculation of vertex normals. A Poisson Reconstruction provides a triangulation with high density. With an octree depth of 7 and a solver divide value of 5 with 1 sample per node the mesh displayed in figure 5 was calculated. As stated in the introduction, there is no need for a high resolution mesh and therefore a clustering decimation followed by a Taubin Smooth is applied. The mesh is now prepared for UV texture mapping within Blender. Output of the mesh is done in DXF and can be directly imported into Blender.

As an alternative to the Poisson Reconstruction the Ball Pivoting Surface Reconstruction is a recommended filter for mesh processing of organic structures.

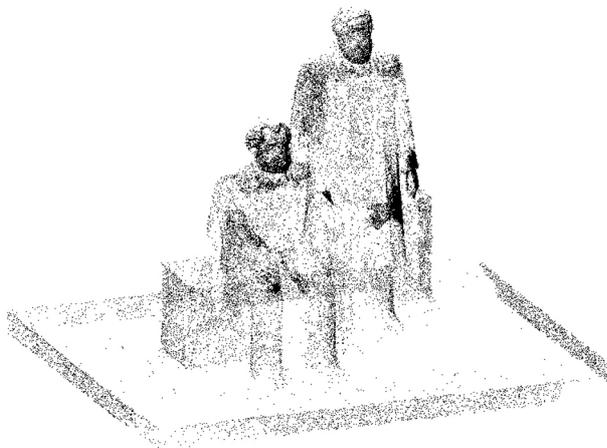


**Figure 5.** Point cloud, Poisson Reconstruction, clustering decimation and smoothing of a mesh

A more complex example is the sculpture of Friedrich Engels and Karl Marx from Engelhardt constituted 1986 in Berlin. The Photosynth can be found under the item *marxEngels*. It consists of 69 photos, 100% synth. Number of points after cleaning is approx. 40.000.

That scene is divided into two meshes. Again the mesh is constructed by Poisson Reconstruction from points and normals. To set the appropriate parameter, the help function of MeshLab gives some hints. For getting best results some alternatives should be tried subject to the shape of the sculpture. Quadric edge collapse detection is used for polygon reduction. The final number of faces or the percentage of reduction can be predefined together with a polygon quality. The 3D reconstruction as shown in figure 7 is textured with a global material bitmap. It is obvious, that the distribution of points differs very much in this test. In some areas point appearance is very poor. But there are no refinements done to the point cloud. Again it must be stated, that the quality of the range map can't contribute with a high resolution scan and that the reconstructed model is for documentation and visualization purposes. The focus lies on low level textured polygon models.

For details of the processing algorithms refer to the literature ( Kazdahn et. Al. 2006, Bernardini).



**Figure 6.** Sculpture of Karl Marx and Friedrich Engels, Photosynth point cloud from 69 images



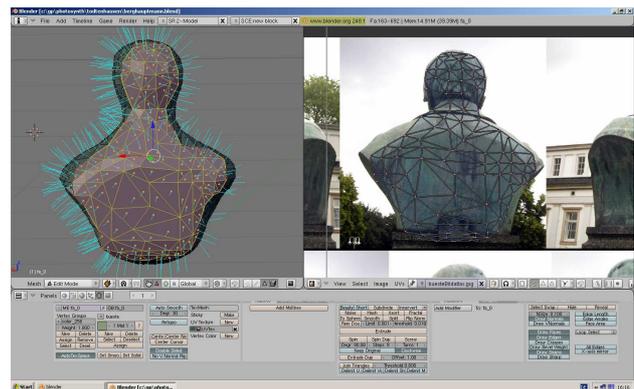
**Figure7.** Sculpture of Karl Marx and Friedrich Engels, global rendered with material texture inside SketchUp

## 5. UV TEXTURE MAPPING

UV mapping often is compared with flattening a physical paper model. Some cuts have to be performed to flat the paper on a table and to glue photos on it. Afterwards the paper must be reassembled again. The cuts are called seams and became important for quality rendering of organic shapes.

Blender is the open source tool for 3D content creation. Blender supports UV mapping with tools for unwrapping faces and stitching them onto the image atlas. Split the Blender screen into two separate windows. The left should be a 3D view and the right the UV Image Editor. It is important, that an object (mesh) does not consist of too many faces. In the mesh editing mode of Blender the mesh menu provides access to a Poly Reducer script. After polygon reduction edges can be selected and marked as a seam (CTRL E > Mark Seam). Within face select mode, faces inside a seam should be selected and projected by the unwrap function into the 2D UV image editor view.

In the editing panel under the mesh tools is a control for drawing the face normals. That tool controls the orientation of faces. If faces are not orientated to outside, flip the normals. Faces can be adjusted to the image data applying the UV image editor. Direct control in the 3D view is possible while running the 3D view in texture mode.



**Figure 8.** Blender 3D view in edit mode and UV image editor

Textures in Blender belong to the object's material. In a first step with the F6 texture button new textures and the texture type (in this case *image*) have to be defined. F5 switches to the material definition, where the texture panel provides channels for different textures and their mapping parameter. The user can select between around forty options. Most important is the UV button in the map input tab as well as the *texture* selection in the material tab.

It is obvious that the above given text requires some operation knowledge with Blender. Giving those hints should reduce the learning curve to manage the procedure of UV mapping. Figure 8 displays a screen shot with the 3D view in edit mode pointing to normals, edges in face selection mode and the unwrapped faces on the right side in the UV image editor. In the buttons window at the bottom amongst others one can find the editing panel with the mesh tools panel, where the normals display can be switched.

A final rendering of the monument of the royal minor Carl August Ludwig Freiherr von Oeynhausen, who gave the town

Bad Oeynhausen in NRW, Germany his name, is presented in figure 9. The 3D model is ready for further processing like real time animation or integration in presentation systems. It stands as a sample for reducing geometric modeling while getting detailed photo realistic information from texture mapping.



**Figure 9.** Rendering with photo textures

## 6. CONCLUSION

Microsoft Photosynth is an image browser for 3D photo models. It provides registration of internet imagery including the photo positions and a cloud of feature points. A procedure for downloading point clouds is given by the support of Wireshark, a network protocol analyzer, and a Python script to convert the binary files into text files. Cleaning and aligning the point cloud, modeling a mesh applying MeshLab and texture mapping and rendering within Blender demonstrates the power of open source tools available from the Web today.

It could be demonstrated how a true scale photorealistic 3D model can be generated from imagery based on a low level polygon mesh and UV texture mapping. The processing chain is documented with several examples of different kinds of monuments in standard formats at

[www.imagefact.de/monuments](http://www.imagefact.de/monuments). Photosynth are published at the Microsoft Photosynth network [photosynth.net](http://photosynth.net).

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[www.imagefact.de/monuments](http://www.imagefact.de/monuments) *Author's homepage regarding this contribution*