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## The possible use of free on-line tools for digitizing old relief models

*Keywords:* Relief models; digitizing; 3D modelling.

*Summary:* Relief models are a peculiar type of cartographic products. These models are usually hand-made or produced in small number of copies, so their digital archiving is very important. There are special tools for this task, but these equipments are rather expensive, and libraries or other institutes that usually own these models cannot spend too much. The authors developed a method which uses the Hypr3D free on-line tool to create digital 3D representation of relief models using a set of photographs as source. This tool creates point cloud and textured triangle mesh based on matching patterns on the photos. This paper introduces the method, discusses the details of successful photographing and the possible post-processing of the results.

### Introduction

The increase in computing and graphical power of computers in the recent years and the emerging new technologies and image processing algorithms brought a wide variety of three dimensional digitizing methods. These methods can be divided into three groups:

- The shape of the object is known, we only have to create the texture of the surface. A good example is the Virtual Globes Museum project (Márton 2008), where the shapes are almost exclusively spheres, and the textures are created from photosets or scanned globe map segments.
- The shape of the object is unknown, but it is scanned by a special instrument (usually based on laser technology) which creates a point cloud and a surface mesh of the object. The textures are generated from photos
- Both the shape of the object and the texture is created from a set of photographs using a set of photogrammetric methods.

The last option is very promising: nowadays many websites offer 3D object creation from photos as a free service. With these services museums or libraries can create digital models of their objects and develop “virtual 3d exhibitions” relatively cheap.

This technique is also used for other purposes: a recent project reconstructs rock walls using the same technology (Mészáros 2011).

### The Hypr3D website

The authors use the *Hypr3D* web service for creating surface meshes. This service was introduced in 2010. The use of the site requires registration which is free of charge.

After registration users can upload sets of photographs or videos, set the appropriate data (title, description of the models and a few keywords for the search engine) and start the processing. The processing time depends on the number of images and the actual server load but usually is under

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half an hour. If the technical data of the camera used is not in the database yet, there can be a longer waiting time initially, as the maintainers of the site have to find the required camera information and feed it to the camera database.

The process starts with the analysis of the photos: the software look for matching patterns and tries to calculate the camera positions for each photo first. The further steps are the creation of point clouds, then the triangle mesh, finally the textures.

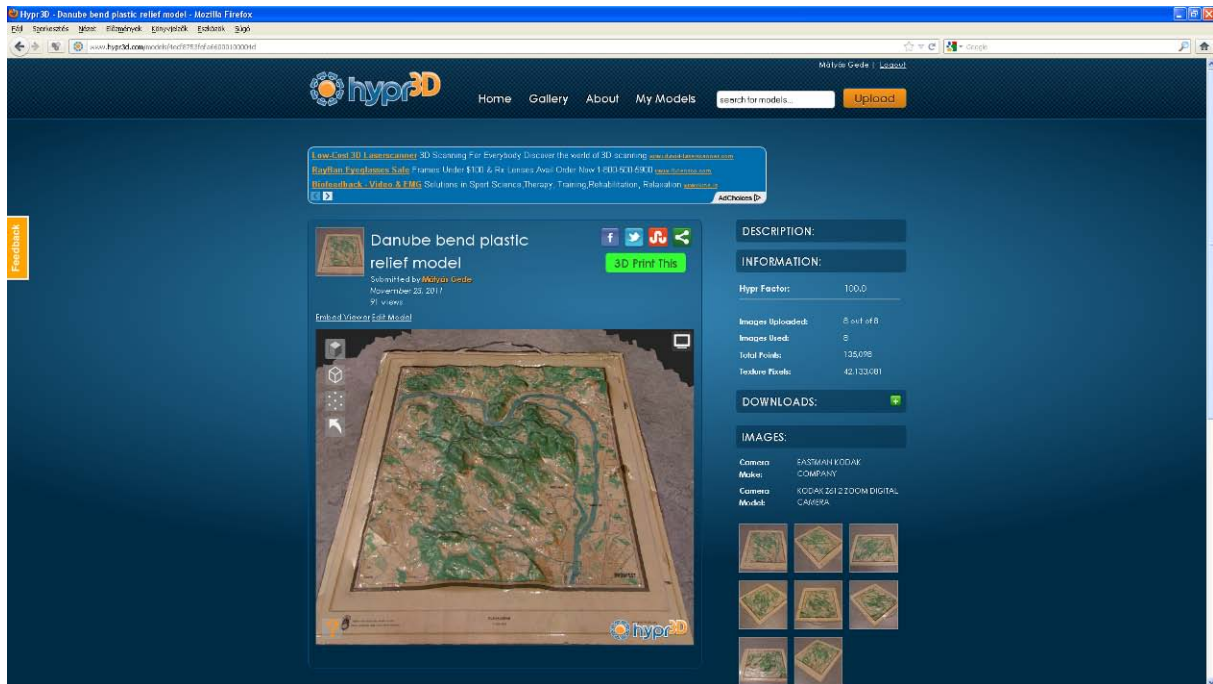


Figure 1: The Hypr3D web page with a 3D relief model in the embedded viewer.

If the processing finishes successfully, a Flash-based viewer appears with the low-resolution version of the 3D model just created (Fig. 1). Users can download the results in high as well as in low resolution as COLLADA model (.DAE file with JPEG texture), point cloud (.PLY file) or surface mesh (.STL file).

The service gives results a “hypr factor” number to describe how successful the process was. This measure depends on the number of points that are reconstructed given the amount of image data uploaded. A maximum (100) hypr factor however, doesn’t automatically mean that the result is perfect: it simply shows that a relatively large number of points was generated.

The most often occurring defects of the 3D models are holes in the surface mesh (which usually means that specific parts of the object are not visible on enough photos), and unwanted “bumps” on the surface (caused probably by “too homogenous” surfaces, where the pattern matching algorithms get confused).

These problems can be usually cured with a few additional photographs, so it is advisable not to move the object from the photographing place until the model-building results are acceptable.

The 3D model created by Hypr3D often contains parts of the background (e.g. the floor or desk under the model, parts of furnitures or walls). This is not a problem as we can crop the unwanted parts during the post-processing.

### Secrets of successful photographing

The main rule of thumb is that every single point of the surface of the relief model has to be visible on minimum three different photographs, but the total number of photos should be minimized as far as possible.

If the slopes are not too steep (e.g. no vertical walls) and the model is not too big, 8 photos can be enough (Fig. 2): the camera positions are at every 45° around the object, above its plane. This constellation is only adequate if the back side of the model is not relevant (the sample model was formed from plastic plate i. e. its back side is simply the negative of its front). Larger and/or more complex models need much more pictures.

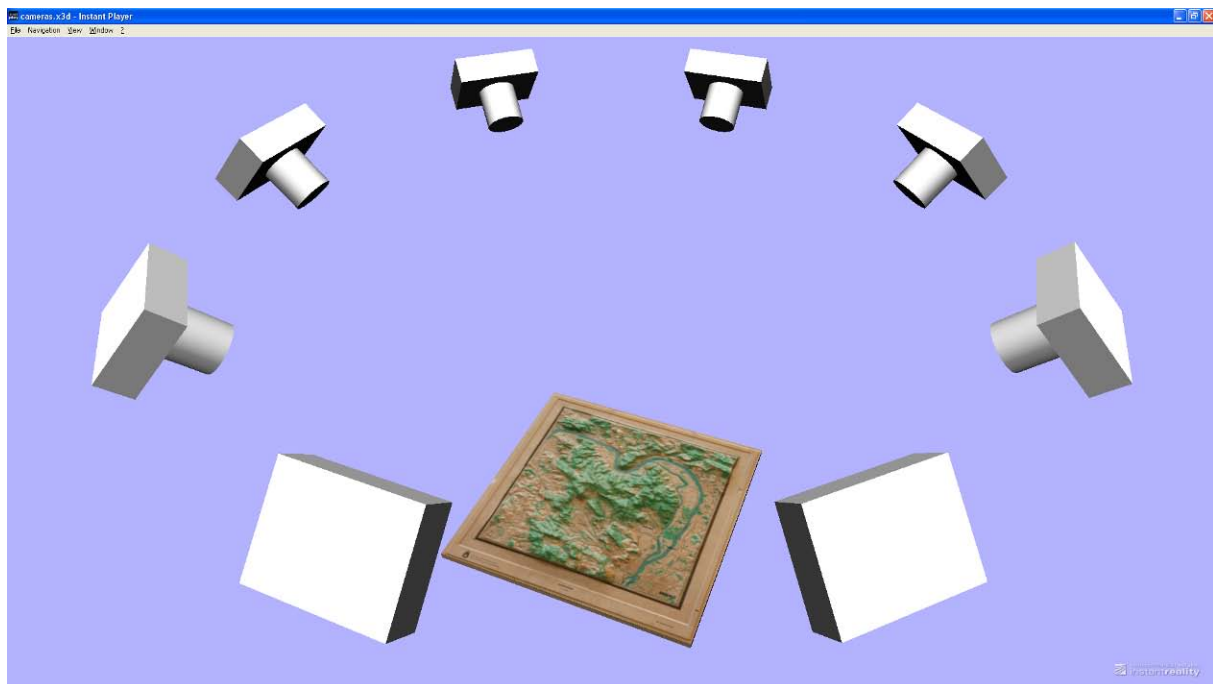


Figure 2: Camera positions for a simple relief model.

We should always turn the flash off; set the aperture as narrow as the camera enables and use a tripod. If we can use spot lights, it can improve the contrasts of the model and therefore the chance of successful evaluation.

The camera type is not a crucial option: the authors had the best results with a simple bridge camera with 6 megapixels resolution.

### Post-processing

The COLLADA model created by Hypr3D can be opened in all major 3D modeling software. To keep it on the field of open source programs, authors use *MeshLab* for most of the further work. (MeshLab 2012)

The first task is cropping the unnecessary parts of the model (ground, walls, etc). It is relatively easy while those unwanted parts are separated shapes, and a little bit harder when they are connected to the edge of the model, but with a bit of mouse-handling skills it can be managed.

The next step is rotating the object into one of the planes defined by the axes of the coordinate system (the created models are usually in an arbitrary rotated position), and eventually scaling it to its original size.

At this point we get the first “product”: we can save the model in several different formats. The authors prefer the X3D as it can be easily published on the web and/or examined in a simple viewer application.

### *Replacing the texture*

Relief models can usually be represented as “two and a half dimensional” objects, as there aren’t vertical or overhanging slopes. In this case the quality of the model can be easily improved, by replacing the original texture.

There are two problems with the texture created by Hypr3D:

- adjacent triangles of the mesh are often given textures coming from different photos which can cause “mosaic-like” appear of surfaces.
- the texture image is divided into small rectangles, each used by a triangle of the mesh. This means that the half of the texture image is unused (rectangles versus triangles) and that triangles with different size use the same texture-size.

Taking advantage of the 2.5D nature of the model, we can re-texture it with a high resolution “orthophoto” of the surface. This photo can easily be created e.g. by hanging the original model on a wall and taking a photograph of it from a distance using appropriate (zoom or telephoto) lens.

If the digital model is rotated into the X-Y plane and its edges are parallel with the axes, the texturing can be done by assigning each point of the mesh to a point on the orthophoto, coordinates calculated by the following formulas:

$$x_{texture} = [ x_{model} - \min(x_{model}) ] * width_{texture} / [ \max(x_{model}) - \min(x_{model}) ]$$

$$y_{texture} = [ y_{model} - \min(y_{model}) ] * height_{texture} / [ \max(y_{model}) - \min(y_{model}) ]$$

These formulas simply mean that the mesh points are vertically projected to the X-Y plane and scaled to the size of the texture.

The authors created a small program for this task which reads the X3D file of the model, drops the original *texCoordIndex* property, and replaces the *TextureCoordinate* node with a new one with data generated according to the formulas above (Web3D 2012).

Figure 3 represents the difference between the original and the re-textured model. It is also noticeable that the size of the X3D file and the texture image file was also reduced; altogether by more than 50%, which is a great advantage if we want to publish our models on the web.

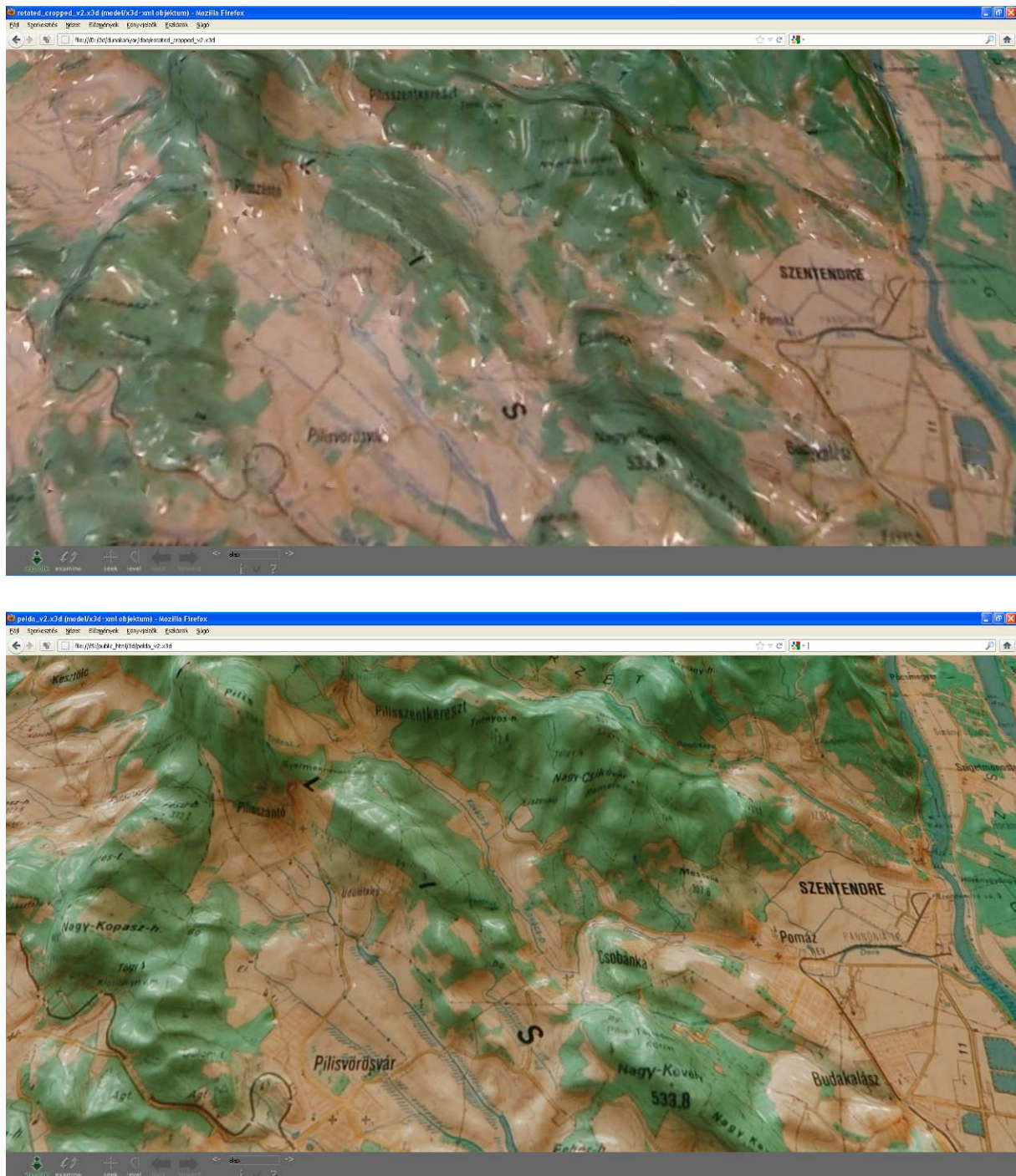


Figure 3: The re-textured 3D model (below) compared to the original one (above).

### *Converting to DEM*

An interesting possibility is to treat the model created by Hypr3D as a surface model of the depicted part of the Earth. If we georeference the mesh, it can be converted to DEM (digital elevation model) which can be compared to real DEMs to analyze its accuracy.

The mathematical base of the georeferencing process is a three dimensional Helmert-transformation. To perform this transformation two additional open-source programs were used: *ScanView* (ScanView 2011) to label and measure control points in the point cloud created by

Hypr3D and JAG3D (JAG3D 2012) to calculate transformation parameters and coordinates of the points in the geodetic coordinate system.

During the process we have to search and sign easily noticeable control points (peaks, hilltops or specific parts of the riverbed) in the point cloud with ScanView and save the relative coordinates of control points. If the created model was downloaded in PLY format which stores the coordinates and RGB colours based on the pixel values of original photographs of the point cloud, it is mandatory to delete these colour values and store only the coordinates in a simple text file which has to include the coordinates of control points, too. The real world geodetic coordinates of control points have to be saved in another text file in the same sequence than their relative coordinates in the previous file. These two file are the input data in the JAG3D tool which performs the calculation of the Helmert-transformation parameters and the geodetic coordinates of all points. Based on these new values a georeferenced DEM can be generated in several GIS software, like Global Mapper or ArcGIS. Figure 4 shows the DEM of the Danube Bend, based on Hypr3D point cloud and SRTM data.

Further developments and research are required to improve the relative and absolute accuracy of the generated DEM.

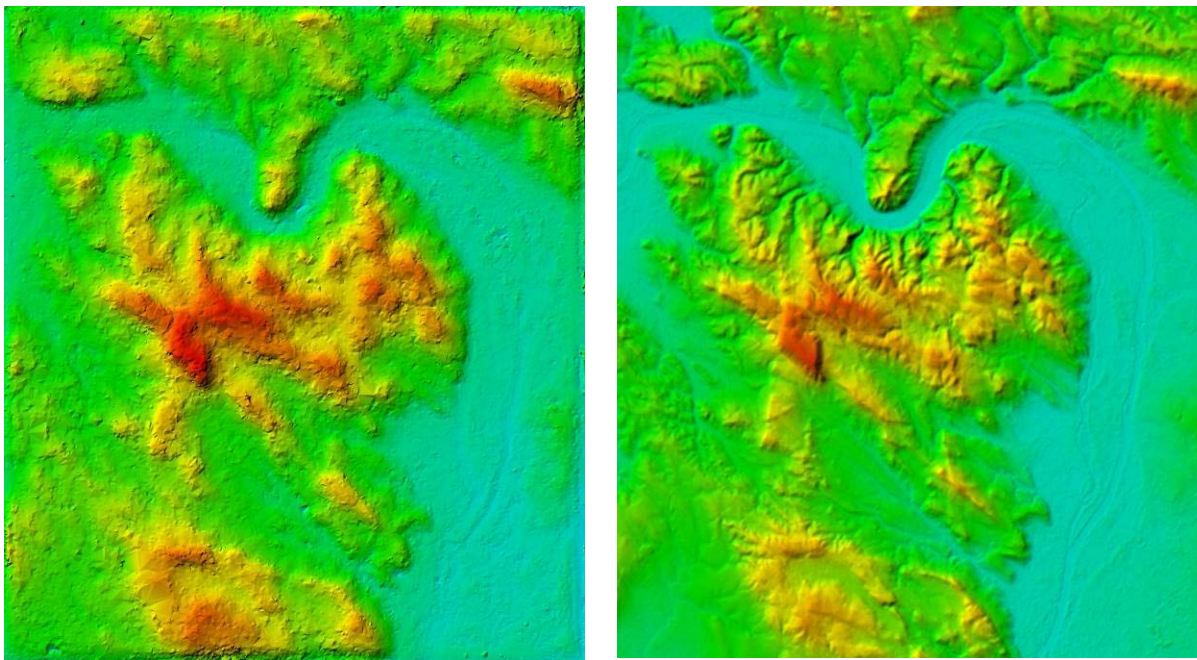


Figure 4: DEM of the same area generated from the Hypr3D model (left) and on SRTM data (right). The elevation legend values and colours are uniform in both models.

### Conclusions

Although the method described above is far from perfect, it can be an option if the digital representation of relief models is desired but there is no financial support for this task. This solution is cheap (since all the software packages used are free, and nowadays almost everyone has some kind of digital camera) and easy-to-use.

The main defect of the method is its limited accuracy. A typical problem is that the straight edges and flat surfaces are represented with minor faults (probably the same errors exist at other parts of the model also but are not so eye-catching).

Another problem is scalability: the solution that worked well for a 50cm\*50cm object was initially unsuccessful when authors tried it on a large (3m\*2m) wall relief map, and when finally an

appropriate photoset was created, the resulting model had severe errors: very limited resolution and unwanted “terrain bumps” almost larger than the original mounts of the model.

### Further plans

This research is only at the first stage yet. The authors plan to try and examine other web services and/or desktop applications performing 3D model creation based on photographs. The post-processing possibilities could also be improved.

If the method becomes successful on a wide variety of relief models, we wish to extend it to relief globes. Trials with such globes were already taken but with poor results: it worked well while modeling only a smaller part of the globe, but failed to build the whole surface. Further investigations may find the causes and a usable solution.

Finally, using this method a “Virtual relief model museum” could be established on the model of the Virtual Globes Museum.

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