Mathematica
Balkanica

New Series Vol. 25, 2011, Fasc. 5

3D Modeling of Valuable Bulgarian Bells and Churches

Galina Bogdanova[1], *Kilian Stoffel*[2], *Todor Todorov*[1], *Nikolay Noev*[1]

A church bell is a bell which is rung in a (especially Christian) church either to signify the hour or the time for worshippers to go to church, perhaps to attend a wedding, funeral, or other service. We use photos from an archive of unique Bulgarian bells in order to create a 3D model of some of the most valuable bells and churches.

MSC2010: 97R60, 68M99

Key Words: 3D reconstrucion, image-based modeling

1. Introduction

Before mass communication they were the only way to gather a village together, so they also served secular functions. Unfortunately during the centuries many bells were melted to cast cannons and so were lost as objects of art and cultural heritage.

As an object of cultural heritage the bell has general properties such as geometric dimensions, weight, etc. But its specific property is the sound. Thus, the archive we create contains also records of the sound of each of the bells, the pitch of the tone as well as acoustical diagrams obtained using contemporary equipment.

The aim of the project BellKnow [1, 2, 18] was to develop an archive containing detailed description of church bells, as well as to develop a digital archive (using advanced technologies) for analysis, reservation and data protection. To accomplish this we have to document the main bells' characteristics: design, form, type, geometric size, decorative and artistic scheme, weight, material, state, characteristics of chime, data about the producer and owner of the bell, estimation of its historical value. We develop an ontological model of unique Bulgarian bells. So, in case that unexpected circumstances destroy a bell, the archive will keep the specific details to be investigated by different specialists.

Creating photorealistic 3D models of a scene from multiple photographs is a fundamental problem in computer vision and image-based modeling. The emphasis for most computer vision algorithms is on the automatic reconstruction of the scene with little or no user intervention. Consequently, these algorithms make a priori assumptions about the geometry or reflectance of the objects in the scene.

In this paper we use the large amount of 2D pictures stored in BellKnow's archive in order to create realistic 3D models of bells and churches. We use two types of 3D and virtual reality software in order to create our models. We also investigate algorithms and methodology that could be used in our future research in order to create our own software for 3D modeling.

2. 3D reconstruction methods

The problem of 3D model reconstruction from photographs has received a tremendous amount of attention in the computer vision literature. Here we will make a brief review of the research. More detailed information can be found in [6, 21].

2.1. Multi-View Stereo Reconstruction

Multi-view stereo algorithms reconstruct a 3D structure by automatically computing pixel correspondences across images. Stereo correspondence techniques work well when the distance between viewpoints is not too big. To deal with large changes in viewpoints, some approaches extract partial 3D shape from a subset of the photographs using multi-baseline stereo algorithms [17].

However, to produce a single 3D model requires complex reconstruction and merge algorithms [4]. Accurate point correspondences are difficult to compute in regions with homogeneous color and intensity. Obtaining dense correspondence for many image points is especially hard.

2.2. Shape From Silhouettes

Shape-from-silhouette techniques [11, 12, 14] compute the 3D model as the intersection of visual rays from the camera centers through all points on the silhouette of the object. Because of their simple and efficient computer vision processing, shape-from-silhouette methods are especially successful for real-time virtual reality applications [13, 15].

Shape-from-silhouette methods fail for scenes with multiple, occluding objects, and they only work for outside-looking-in camera arrangements.

2.3. Photometric Techniques

Additional photometric constraints can be used to recover a shape that is demonstrably better than the visual hull [10].

Voxel coloring gradually carves out voxels from a 3D volume that are not color-consistent with all images. Recent approaches extend voxel coloring to arbitrary camera placements [3, 10].

Voxel approaches do not work well for large scenes or objects with big differences in scale. Constructing a surface model for interactive viewing requires a lengthy process that may introduce inconsistencies in the mesh. Fundamentally, all photometric approaches rely on a locally computable analytic model of reflectance. They do not work for objects with homogeneous surface color.

2.4. Image-based Modeling

Image-based modeling systems split the task of 3D model construction between the user and the computer. Some methods reconstruct a model from a single image using user-defined billboards [8] or depth images [9]. Mok Oh et al. [16] use a single image and provide various tools to paint a depth image, edit the model, and change the illumination in the photograph.

It is of considerable advantage to use geometric constraints when the scene is known to have a certain structure. Some systems use user-guided placement of polyhedral primitives to reconstruct architectural scenes [5, 7].

3. 3D modelling of bells and churches

Our models are based on the fact that by photographing a surface or object from slightly different angles, there is in theory enough information to calculate a 3-dimensional model of the object, this is similar to what human brain does with the images from the two eyes. Using popular software for 3D modeling we create and publish to the Internet some beautiful and very authentic models of Bulgarian bells.

3.1. Photo-To-3D

The program produces results in 3ds, and it can be imported directly into Google sketchup [20].

In order to produce a good 3D model following instructions about the pictures should be followed:

- The photos has to contain the same surfaces;
- The object you photograph should not move. Move the camera instead;

- Movements in the object between the photo shoots will confuse the calculation algorithm and make the result look funny or not creating a result at all.
- Use a good light source. This will minimize the risk of creating fuzzy and noisy photos. Sunlight is ideal, but if you use a lamp, do not move it in between photo shots. The light source has to be still between photo shots;
- Do not use a flash;
- The two photos should ideally be taken within an angle of 5-15 degrees from each other. Note that this is a very tiny angle and the most common mistake is to use a much larger angle making the resulting 3D-model look bad;
- Make sure the object/surface you are interested in covers the majority of the photo area. This ensures that the object you are interested in is not missed. And you will get more polygons on the object of interest;
- Avoid reflective surfaces;
- Reflections in a reflective surface might confuse the 3D-generation;
- Only color photos will work (do not use black & white photos);
- Do not change the camera zoom between photo shots.

3.2. Photosynth

Photosynth [19] is a powerful set of tools for capturing and viewing the world in 3D. You can share these views with your friends on Facebook, publish them to Bing Maps, or embed them in your own Web site.

In simple terms, Photosynth allows you to take a bunch of photos of the same scene or object and automatically stitch them all together into one big interactive 3D viewing experience that you can share with anyone on the web.

Photosynth is really two remarkable technical achievements in one product: a viewer for downloading and navigating complex visual spaces and a "synther" for creating them in the first place. Together they make something that seems impossible quite possible: reconstructing the 3D world from flat photographs.

Using techniques from the field of computer vision, Photosynth examines images for similarities to each other and uses that information to estimate the shape of the subject and the vantage point each photo was taken from.

Providing that experience requires viewing a lot of data, though – much more than you generally get at any one time by surfing someone's photo album on the web. Photosynth allows you to browse through dozens of 5, 10, or 100 megapixel photos effortlessly, without fiddling with a bunch of thumbnails and waiting around for everything to load.

3.3. Mapping models of bells and churches

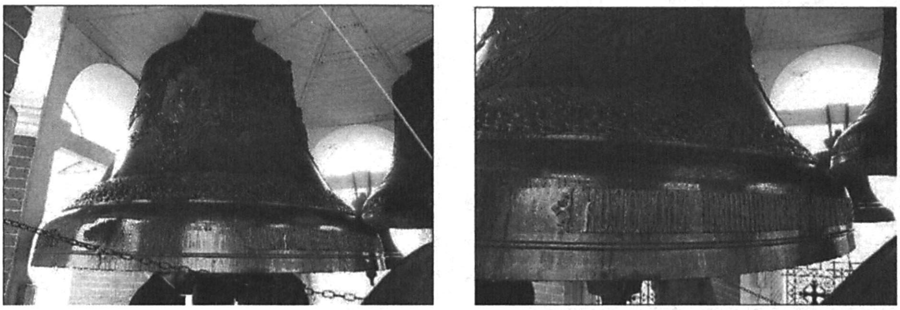

Figure 1: Sample of photo images of bell

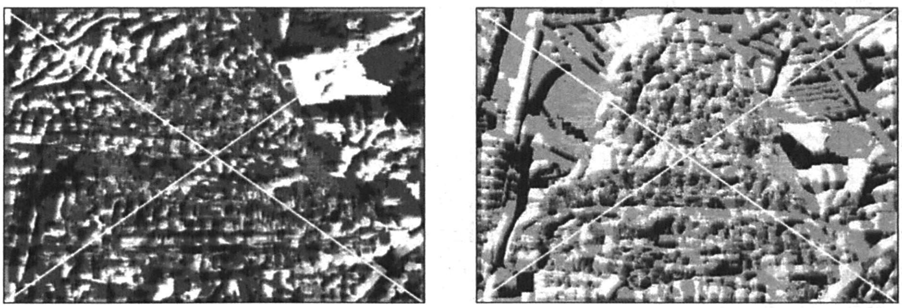

Figure 2: Map of sample of same photo images of bell

We create 3D models of bells and churches from a set of 2D images. We create 3D maps of the 2D images and then analyze them in order to create the 3D model.

Here are some example 2D images that we use and corresponding 3D maps:

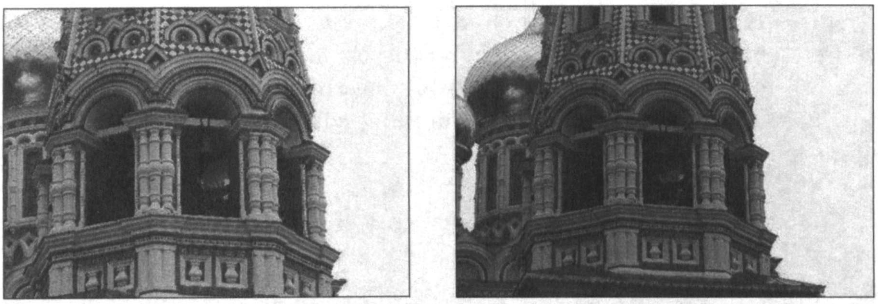

Figure 3: Sample of photo images of belfry

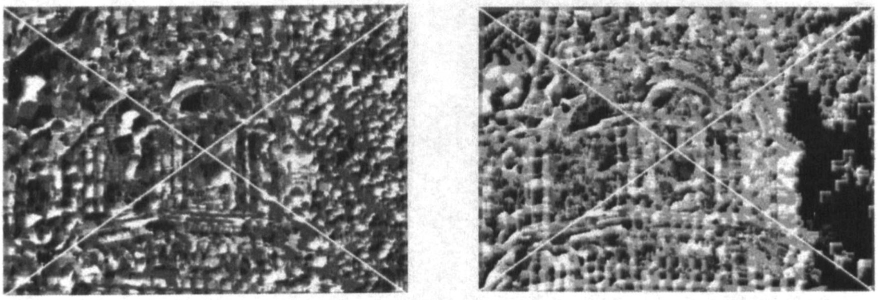

Figure 4: Map of sample of same photo images of belfry

References

[1] Bogdanova G., Dimkov G., Todorov T., Noev N., Model of Digital Repository of Information and Knowledge - Fund BellKnow, *Annual Seminar on algebraic and combinatorial coding theory* - 17-19 December 2010, Ksilifor, Bulgaria;

[2] Bogdanova G., Trifonov T., Todorov T., Georgieva T., Methods for Investigation and Security of the Audio and Video Archive for Unique Bulgarian Bells, *National Workshop on Coding Theory and Applications* - 2006, Blagoevgrad, Bulgaria;

[3] Culbertson W., Malzbender T., Slabaugh G., Generalized voxel coloring. *In Proc. of the ICCV Workshop: Vision Algo-rithms Theory and Practice, pages 100–115* - September 1999;

[4] Curless B., Levoy M., A volumetric method for building complex models from range images, *In Computer Graphics, SIGGRAPH 96 Proceedings, pages 303–312* - August 1996, New Orleans, LS;

[5] Debevec P., Taylor C., Malik J., Modeling and rendering architecture from photographs: A hybrid geometry and image-based approach. *In Computer Graphics, SIGGRAPH 96 Proceedings, pages 11–20* - August 1996;

[6] Dyer C., Foundations of Image Understanding *chapter Volumetric Scene Reconstruction from Multiple Views, pages 469–489* - 2001, Kluwer, Boston;

[7] Faugeras O., Laveau S., Robert L., Csurka G., Zeller C., Automatic Extraction of Man-Made Objects from Aerial and Space Images *chapter 3D Reconstruction of Urban Scenes from Sequences of Images* - 1995, Birkhauser;

[8] Horry Y., Anjyo K., Arai K., Tour into the picture: Using a spidery mesh interface to make animation from a single image. *In Computer Graphics, SIGGRAPH 97 Proceedings, pp. 225–232* - 1997;

[9] Kang S., Depth painting for image-based rendering applications. *Technical report, Compaq Cambridge Research Lab* - 1998;

[10] Kutulakos K., Seitz S., A theory of shape by space carving. *Intl. Journal of Computer Vision, 38(3):199–218, 2000. 2, 3, 4, 5, 12* - 2000;

[11] Laurentini A., The visual hull concept for silhouette-based image understanding. *PAMI, 16(2):150–162* - February 1994;

[12] Li M., Schirmacher H., Magnor M., Seidel H.-P., Combining stereo and visual hull information for on-line reconstruction and rendering of dynamic scenes. *In Proc. IEEE Workshop on Multimedia and Signal Processing* - 2002;

[13] Lok B., Online model reconstruction for interactive virtual environments. *In Symposium on Interactive 3D Graphics, pages 69–72* - March 2001;

[14] Martin W., Aggarwal J. K., Volumetric descriptions of objects from multiple views. *IEEE Transactions on Pattern Anal-ysis and Machine Intelligence, 5(2):150–158* - March 1983;

[15] Matusik W., Buehler C., Raskar R., Gortler S., McMillan L., Image-based visual hulls. *In Computer Graphics, SIG-GRAPH 2000 Proceedings, pages 369–374* - July 2000, Los Angeles, CA;

[16] Mok Oh B., Chen M., Dorsey J., Durand F., Image-based modeling and photo editing. *In Computer Graphics, SIG-GRAPH 2001 Proceedings, pp. 433–442* - August 2001;

[17] Narayanan P., Rander P., Kanade T., Constructing virtual worlds using dense stereo. *In Proc. Intl. Conference on Com-puter Vision, pp. 3–10* (1998);

[18] Noev N., Organization and Security of the Audio and Video Archive for Unique Bulgarian Bells, *Mathematica Balkanica, NewSeries Vol. 24, 2010, Fasc.3-4, ISSN 0205-3217, pp. 285–291* (2010);

[19] Photosynth, `http://photosynth.net/`;

[20] Photo-To-3D. `http://www.photo-to-3d.com/`;

[21] Ziegler R., Matusik W., Pfister H., McMillan L., 3D reconstruction using labeled image regions, *Proceeding SGP '03 Proceedings of the 2003 Eurographics/ACM SIGGRAPH symposium on Geometry processing, pp. 1–12* (2003).

[1] *Institute of Mathematics and Informatics*
Bulgarian Academy of Sciences
Sofia 1090, BULGARIA
E-MAIL: galina@math.bas.bg
todor@math.bas.bg
nickey.noev@gmail.com

[2] *Information Management Institute*
University of Neuchatel
Neuchatel, SWITZERLAND
E-MAIL: kilian.stoffel@unine.ch