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Georeferenced Orthophotos and DTMs from Multiple Oblique Images

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Recent interest in the application of computer vision methods to archaeological aerial images has concentrated on several commercial programmes which are designed for terrestrial 3D photo modelling. For making geo-referenced orthophotos from multiple oblique aerial images and combining them with maps or satellite imagery which is the main problem in aerial archaeology, this can now be accomplished with version 2 of AirPhotoSE (AirSE) which may be downloaded from the Internet and installed at no cost.

There is only one working window (figure below). First, a collection of images is selected by the user. These are then displayed as "thumbnail" pictures. Processing steps are shown in the left window. Calculations are faster than in the commercial programmes, and there is no need for special hardware or a 64 bit OS.

Thanks to Rog Palmer for providing this set of test images from southern England.

Clicking the Run button starts a series of programmes which are freely available from the Internet and whose code is not proprietary. The following steps are applied without user intervention:

> Image selection and automatic pre-treatment as set in an Options dialogue before starting: white-point correction, automatic global contrast and brightness correction, Retinex local contrast and brightness correction, luminance scaling, or local contrast and sharpness enhancement,

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Keypoint detection for matching images. A list of salient image points is made for each image,

Keypoint matching for correspondences between images,

Bundle adjustment for minimizing the reprojection error between corresponding points in all images,

A "Point Cloud" can be generated for inspection and further use by clicking on the Preview button. This starts:

Radial lens distortion correction with constants calculated during bundle adjustment is applied to each image,

Conversion of the bundle adjustment results to input acceptable for a patch-based multi-view stereo programme (PMVS2 or CMVS) is computed,

The computation of PMVS2 or CMVS follows automatically.

The resulting point cloud is displayed in the second author's programme CCViewer (see below).
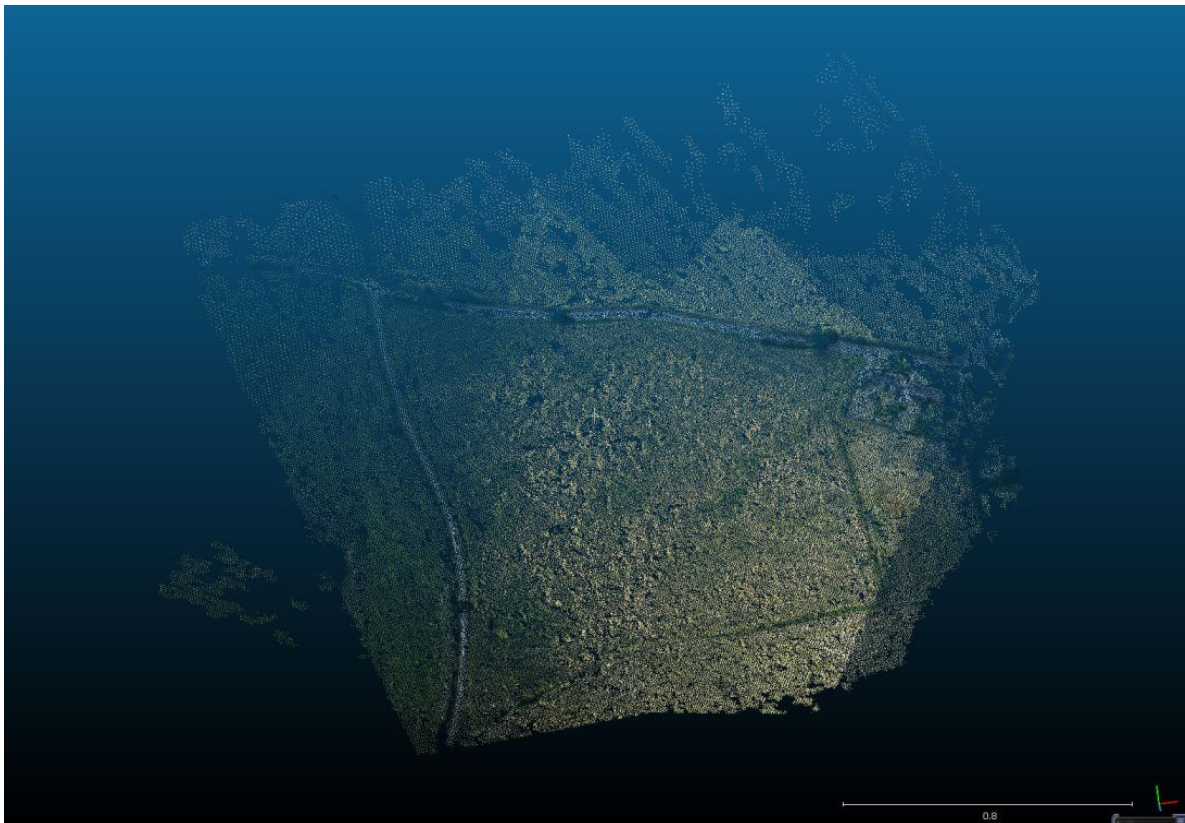
Alternatively, the Apply button may be clicked immediately after bundle adjustment terminates. This displays results in the second author's programme CloudCompare where the set of rectified images is displayed on top of a digital terrain model computed from the point cloud or from the bundle adjustment (see the following two illustrations).

The DTM (below) receives the colours from the images and can be manipulated interactively to display relief.

The result of this sequence of operations is not oriented with north at the top, nor is it horizontal relative to the Earth's surface, and it is not geo-referenced. By entering several control points in the result and at corresponding places in either a map, a satellite picture, a GeoPortal orthophoto saved in AirSE, or a Google Earth or Bing 3D image geo-referenced in AirSE, an accurate plan can be made quickly by transforming the result of the calculations above to a Google Earth geo-referenced target using the normal transformation tools in AirSE (see figure below). There are projection errors in the distant parts of the obliques, so it is necessary to use the selection tool in AirSE prior to transformation to limit the area to that of the DTM. Where image overlap is poor or non-existent it is not possible to produce an orthophoto and consequently those parts of the image will not be correctly located.

Here is an example with more relief in pictures made near Ram-Branicevski in Serbia by Rog Palmer.
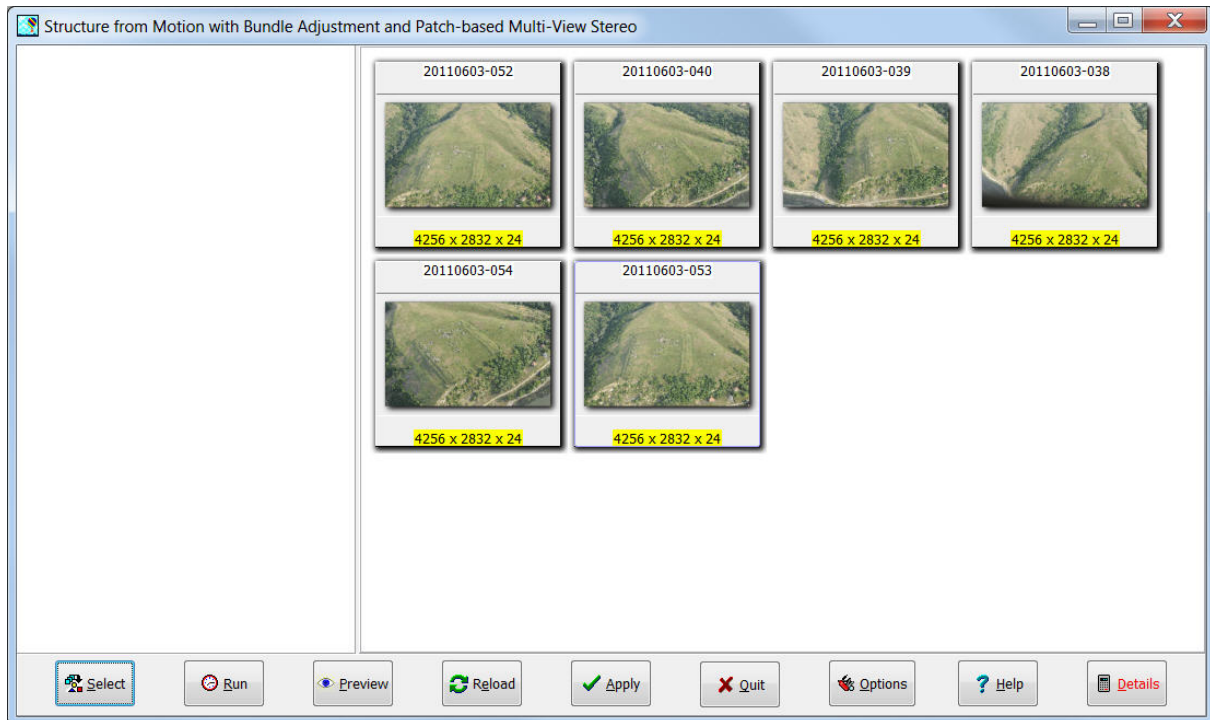
The relief is shown clearly in the combined view of the six chosen images and can be manipulated interactively to look at the site from various angles as if flying around it.
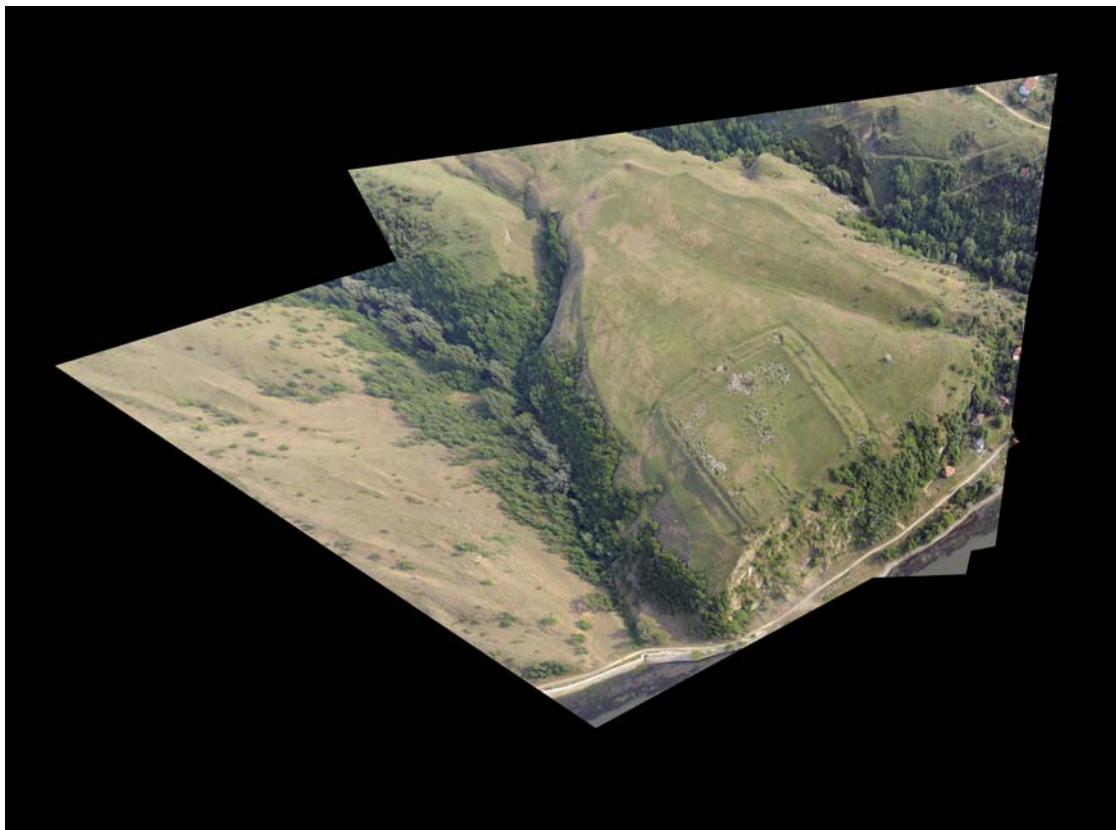
The orthophoto (below) from the Serbian GeoPortal web site's geo-referencing and orientation was transferred in AirPhotoSE to the result using a transformation with a few corresponding points. Only the geo-referencing of the GeoPortal site need be used for the transformation. The GeoPortal orthophoto itself need not be used.

Internet Links to the programmes spawned from AirPhotoSE and other details in alphabetical order:

Approximate nearest neighbor search: http://www.cs.umd.edu/~mount/ANN/

Bundle adjustment: http://phototour.cs.washington.edu/bundler/

CloudCompare and Viewer: CloudCompare (version 2.3) [GPL software]. EDF R&D, Telecom ParisTech (2012). Retrieve from http://www.danielgm.net/cc/.

Keypoint detection: http://www.vlfeat.org/

Multi-view Stereo: http://grail.cs.washington.edu/software/pmvs/
http://grail.cs.washington.edu/software/cmvs/

More general:

There is free software for creating 3D surfaces (but not geo-referenced orthophotos) by Gianluca Cantoro at: http://www.archaeolandscapes.eu/index.php/capture/aerial-photography/218.html

A general explanation with links can be found at:
http://through-the-interface.typepad.com/through_the_interface/2010/11/au-2010-handout-point-clouds-on-a-shoestring.html

AirPhotoSE may be downloaded without charge from:
http://www.uni-koeln.de/~al001/airphotose.html