TOPOSCOPY, A CLOSE RANGE PHOTOGRAMMETRIC SYSTEM FOR ARCHITECTS AND LANDSCAPE DESIGNERS

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ABSTRACT:

Toposcopy is a new design, visualization and photogrammetric method that is primarily intended for use in urban and rural planning and architecture. The method links a 2D map to photos taken in a horizontal or upward direction through a perspective calculation of 2 or 3 points that can be identified both in the photo and the map. After the data has been processed the map and images form an interactive 3D system that can be used to create 2D photo-realistic visualizations of spatial designs in the existing environment and 3D virtual models of urban and rural areas. This is done by alternately clicking on points in the map and a photo. The map becomes 3-dimensional with the photo data and a perspective fits exactly on a photo once it is properly linked with the map. After defining a line in the map one can make accurate drawings of façades by simply tracing the elements in the photo. Modelling of existing houses is done using parametric mathematical models. Toposcopy exports data in DXF and VRML and can be used in combination with standard 3D CAD and visualization programs and software aimed to build virtual worlds for the internet. Toposcopy basically adds the photogrammetric functionality and automatic texture mapping and has advanced means to visualise realistic trees in either a still or a 3D world. Being a close range photogrammetric method, Toposcopy can also add detail to large-scale virtual worlds made with GIS related imaging programs.

1. INTRODUCTION

A visualization of spatial designs without the existing environment looks sterile and artificial. Usually it is difficult to recognize the presented site and the viewer has problems with the orientation.

For architects that work with 3D CAD and visualization programs there are possibilities to use photo-matching techniques to integrate perspectives of new buildings properly in photos of the present surroundings. However such programs do not offer the possibility to extract 3D data by clicking on points in images. Therefore they are not accurate as far as the 3D modelling of existing objects is concerned. Buildings are either constructed face by face and mapped with textures manually, which is very time-consuming, or they are shaped roughly by simply extruding the 2D shape of the city map.

Landscape architects usually have to make their designs in large scale 2D maps. When they want to show how a design fits in the urban or rural landscape they often make an artist view using digital photos and a Paint program like Photoshop or they make hand-drawn sketches using dia projections. It is obvious that both methods cannot ensure any kind of accuracy.

There are a number of photogrammetric programs like PhotoModeler that allow to make an accurate model of an existing building by measuring in images. However such programs are not practical in build-up areas, because they need photographs taken from all sides. Obviously, it is usually impossible to photograph existing buildings in such a way in an urban area.

There is also the option to create a virtual maquette from GIS data and aerial photos. This gives a nice view from above and there is a good connection with CAD and GIS data, because it works in the same or a related coordinate system. However aerial photos are not very suitable for visualizing and modelling upright elements like buildings and trees that render the surroundings pictorially from a standpoint on the ground.

There are also programs that are designed to make 3D models for the internet. However they do not offer a practical solution for large scale designs because they can handle only limited dimensions (< 1000 meter).

So for 3D visualizations of spatial designs in the existing environment there still is a need for a method that

- Can handle large-scale maps in the coordinate system normally used in GIS,
- Has an accuracy comparable to that of 2D maps, used as a basis for a design
- Can extract 3D information by clicking in 1 photo, considering the restricted sight in build-up areas
- Can build models from existing houses in an efficient way to reduce costs
- Can map a 3D maquette automatically with photo images.

In this article we will show how Toposcopy can meet these needs. We will explain the working principles of Toposcopy and the way we visualize and measure existing buildings, trees and other plantings. After that we will show some of the results and how we have tried to make modelling less elaborate.

2. THE TOPOSCOPIC METHOD

2.1 Principles

Toposcopy is a new (Groneman-van der Hoeven, 1998) close-range photogrammetric method, that links a map to one or more photos through a perspective calculation of some calibration points. In Toposcopy map and photos form one interactive 3D system (Groneman-van der Hoeven, 2003) . The map becomes 3D with the photo data and a perspective fits exactly on a photo when properly linked with the map.

2.2 System

The method is easy to carry out. A 2D map is usually available. For visualizations photos may be taken from a tripod or off-hand when in each photo there are at least 3 points that can be identified both in the photo and in the map.

Figure 1. The toposcope

However when accuracy is important, or in cases that it is difficult to orient or in sloping areas without available elevation data we prefer to combine photography with some land survey measure-ments. For that we developed the toposcope (see Figure 1) with accompanying software.

The base of the toposcope is an automatic level. For the toposcopic method photos usually are taken in a horizontal direction. However when for example the top of a building, that has to be modelled, is not visible in the horizontal photo, the same direction in the x/y plane, but with a positive vertical rotation angle. Photos can be taken in either portrait or landscape position.

To facilitate taking a combination of a horizontal and an upward photo and switching between a landscape and a portrait view we developed a special adapter, that connects the level with a camera. It is constructed in such a way that on the one side you can take it off from the level and on the other side remove the camera.

We use the level plus a rod to measure directions and distances in order to calculate positions, the direction of the line of sight and the angle of the viewing cone. In the landscape we sometimes work without a rod. Then it is easier to determine a position by measuring the direction to 3 known points that are far away, like church steeples. Because the level has an angiometer and can be rotated a certain number of degrees the toposcope also allows to make excellent 360 degrees panoramas.

Most retail cameras with a quality lens can be used. Straight lines in reality should show up pretty straight in the photo. Nowadays it is advised to use a digital camera, because then you can skip the time consuming process of scanning photos or negatives. However we still use a single-lens reflex camera with an interchangeable lens in cases we need a very wide-angle view.

The toposcopic software consists of 2 programs, named Topo and Scope. They are tested with the Windows operating systems 95/97/NT/2000. The programs run on a Pentium PC with at least 64 MB RAM.

2.3 The fieldwork program Topo.

Topo is the fieldwork program of Toposcopy. It has some CAD functionality build-in (see figure 2). Topo processes the measuring data, collected with the toposcope. All measurements and calculated 3D data are stored in a Microsoft Access database and can also be added to the 2D CAD drawing. During the fieldwork the position of the camera in the map and the location and height of additional points are determined with standard land survey techniques. In our office for landscape architecture we sometimes even use the toposcope to make a new map in case we don't have one. To accurately link a photo to the map and to calculate the exact vertical rotation angle the camera point and at least one point that is visible in the photo must be known in 3 dimensions.

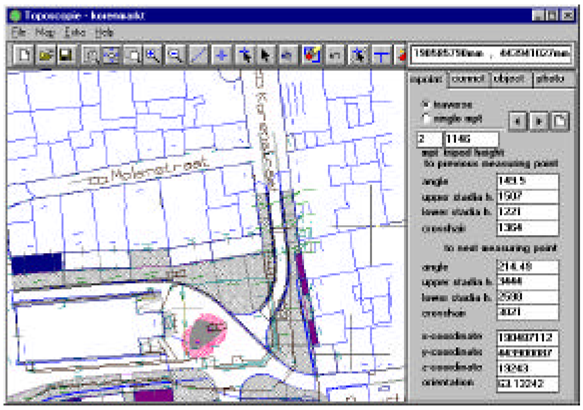

Figure 2. The fieldwork program Topo

2.4 The visualization and photogrammetry program Scope.

In Scope you can load 2 photos and a map at the same time. You can switch between them easily. Then also the user interface changes. Figure 3 shows the interface with a CAD drawing loaded. Besides the general CAD toolbar at the top of the screen, there is also a bar with specialised tool buttons, that automate the procedures to make ground planes, extrusions and parametric models. These will be explained later.

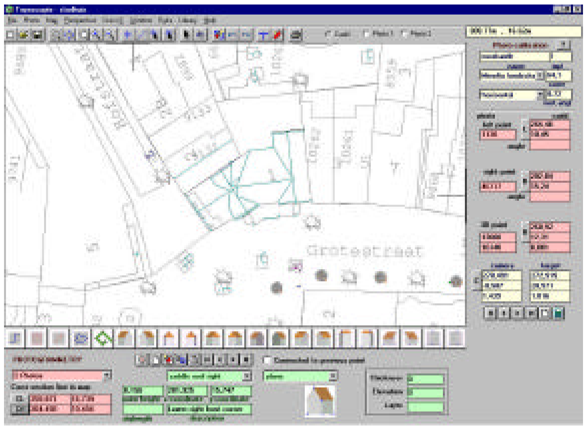

Figure 3. The visualization and photogrammetry program Scope.

2.4.1 Linking the photo to the map

At the right-hand side of figure 3 is the calibration window, where the photo is being linked to the map. Most data are entered by clicking on points in the photo or the map. The calibration varies according to the available hardware and data. When the camera point is not known, it can be calculated in Scope after clicking on 3 points in the map and in the photo. In such a case the angle of the viewing cone has to be estimated. When the camera point is located in the program Topo with one of the standard land-survey methods or measured in the field with a tape, then the viewing cone can be calculated instead. The orientation is determined with a 3D point. When there are no elevation data available and the photo is taken in a true horizontal direction then the relative height of the 3D point can be calculated accurately and the vertical rotation angle is supposed to be 0. If both the heights of the 3D point and the camera point are known, then the vertical rotation angle can be calculated instead.

2.4.2 The photogrammetric tools

When photos and map are linked together it is very easy to measure locations and heights by alternately clicking on points in the map and a photo. The principles are simple and most routines work as well in horizontal and upward photos:

- If the location of a point is known in the map, we can determine its height with a single click in the photo.
- Vice versa if the height of a point is known, we can determine the location by clicking in 1 photo.
- If it is known that a point lies in the vertical plane running through a line known in the map, then we can determine both its location and height with a single click in the photo.
- We can also measure like that in vertical planes that are at a certain distance from the known line.
- Only when an object is not shown in the map and its height is also not known, then we need 2 photos to determine both its location and height.

2.4.3 Façade drawings

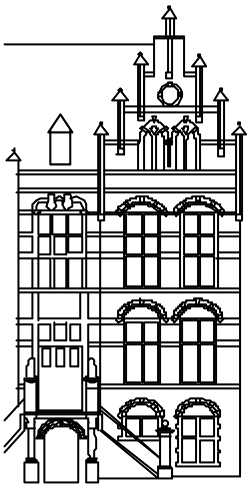

Figure 4. Façade drawing

Toposcopy can be applied in architecture to make accurate drawings of façades. You first need to define the front line in the map. After that you can just trace the circumference of the different elements, occasionally changing the distance to the known line (elevation). Windows, that are a bit farther away to the viewer get a negative elevation and extruding decorative elements get a positive elevation.

Each point is stored in 3 dimensions in the database. They may be drawn on top of a photo or in CAD as a cross-section or façade drawing (see figure 4), as an inventory in the 2D map or as a perspective view. If you want to find a particular point in the database you can click on it in either the map or the perspective drawing.

2.4.4. Perspectives

A perspective view of objects that are measured in a photo will always fit exactly on that photo, because the photogrammetric calculations use the same parameters as the perspective calculations. 3D points, lines and other objects that are created by clicking on points in a toposcopic photo, can always be drawn back accurately on top of that photo (see figure 5). Therefore in case of façade drawings the perspective lines can be used as a tracing tool.

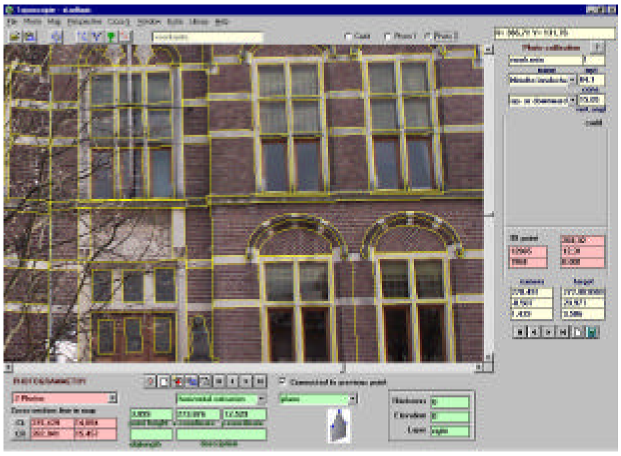

Figure 5. Perspectives used as tracing tool

When the 3D lines of a spatial design are drawn on top of a toposcopic photo then the perspective view is used for visualization. Although the result looks like an artist view, made in Photoshop, it actually has the accuracy of land survey. This visualization method is very useful for landscape architecture. Figure 6 shows a visualization of a planned change in the water regime, which will from time to time inundate the area. The perspective lines determining the border of the new lake were drawn on the photo. The trees are taken from a ‘tree library’ and are automatically scaled and drawn on top of the photo. The visualization is finished in a paint program.

Figure 6. Visualization of planned changes in the landscape

Whether 3D points and lines measured in one photo will also fit well on another toposcopic photo depends on the accuracy of the 3D system. This can easily be checked by drawing the whole object database in perspective on top of a number of photos. Then you can visually control the accuracy. This makes the toposcopic way of modelling the existing environment very dependable. Figure 7 shows an urban area of which a 3D maquette was made with the toposcopic photogrammetry and the mathematical parametric models, to be discussed in the next paragraph.

Figure 7. Perspectives used to control the accuracy

2.4.5 Parametric models

The Scope program has a number of specialised tools to increase the efficiency of modelling. Most house types can be distinguished by the shape of the roof and can be constructed from 5 or 6 3D points. After pressing a special house button (see figure 3) the records spatially describing the house are set up automatically. In a help form you can tell how the model has to be finished. The walls can be coloured, automatically mapped with a portion of the photo used for modelling or semi-automatically mapped with another image. The roofs are coloured or mapped with a repeating pattern. The x/y/z coordinates are measured photogrammetrically as far as possible. However the x/y coordinates of parametric points that are invisible in the photo (usually the back of a house) are acquired by clicking in the map instead. You can combine different models and shapes to form a complicated building as is shown in figure 8.

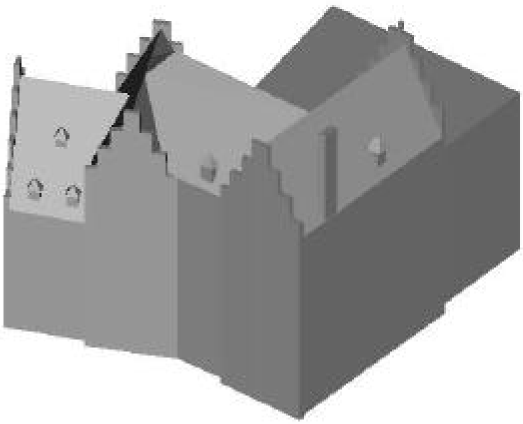

Figure 8. Uncoloured isometric drawing of an old city hall, modelled with Toposcopy and imported in DXF in AutoCAD.

2.4.6 Modelling extrusions and ground planes

The user interface of Toposcopy lends itself well for modelling extrusions and a 3D ground plane with varying heights.
With the 2D polygon tool of the CAD interface one can trace any irregular area in the 2D map. The 2D points are automatically added to the toposcopic database. There they can get a certain ground elevation and height. During the export in DXF or VRML the connected points become an extruded object, that can be coloured or mapped with a photo image or a repeating pattern.

A façade can be made with the photogrammetric tool "front polygon", that produces an irregular vertical surface in a plane that goes through or is parallel to a known line in the map. This surface can be extruded over a certain distance in a horizontal direction perpendicular to the known line. When exported the resulting 3D object can be coloured or mapped with a photo image.

Figure 9. 3D model with automatic texture mapping exported in VRML

Ground planes or 3D meshes are set up in a help window as a grid with a certain direction, spacing and dimension. The height of the points is added manually in the database. The grid points can be drawn in the 2D CAD map. However when exported they become part of a 3D elevation grid or mesh., that can be colored or mapped.

2.4.7 Special tools for landscape architects

Toposcopy has a number of special tools for landscape architects. It allows realistic trees, taken from a :tree library" and showing either their summer or winter form, to be placed in a virtual environment (see figure 9). These automatically turn perpendicular to the direction of view. This is called the billboard function. The same trees can also be drawn on top of a photo (see figure 6). You can switch between summer and winter form through a menu setting.
Because of the fact that the billboard function is not supported in the VRML import of programs like Autodesk Viz and the Internet Space Builder (Parallel Graphics) you can choose to export all objects in the database, only the trees or the 3D world without the trees. This way you can add trees on billboards to, for example, a VRML created in Autodesk Viz. On the other hand an architect may, for example, like to finish the inside of house models created in Toposcopy with the drag-and-drop features of the Internet Space Builder and then add the toposcopic trees later on.

3 CONCLUSIONS

Toposcopy speeds-up the modelling of urban and landscape areas considerably. After linking a photo to the map you can directly acquire 3D information by clicking in one photo at the time. Therefore the method is easy to use in build-up areas. Toposcopy gives visualizations that look like artist views the accuracy of land survey. With its build-in CAD functionality and export in DXF and VRML it can successfully be used together with GIS, 3D CAD and visualization programs. Toposcopy adds the photogrammetric functionality, the special modelling routines for buildings, the automatic texture mapping and the library with easy to use realistic trees. On the other hand you need a program like Autodesk Viz to combine a textured toposcopic maquette of the existing environment with new 3D designs drawn in a CAD program. Toposcopic 3D models are written in a native VRML code that is suitable for use on the internet.

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