A NEW TOOL FOR OBTAINING CARTOGRAPHIC GEOREFERENCED DATA FROM SINGLE OBLIQUE PHOTOS

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Abstract:

Since its invention in the first half of the nineteenth century, photography has assumed a leading role as a means for documenting the real world. With the improvement of technology, photography developed into photogrammetry, enabling the mapping and georeferencing of landscape elements beginning with stereo photographs. With the introduction of aerial photography, terrestrial oblique photography became obsolete for cartographic purposes and was nearly forgotten by most specialists in photogrammetry. This evolution is understandable from a technical point of view, but regrettable from the historical and landscape dynamic perspectives. In fact, although they do not systematically cover all territory, terrestrial photographs date back significantly earlier than aerial photography and are generally rich in landscape-relevant details that are easily interpretable because they coincide with normal human view-points. In recent times, the improvement of computing power and the production of high resolution Digital Elevation Models has made the spatial georeferincing of single oblique pictures (monoplotting) more approachable. To our knowledge, however, no specific user-friendly monoplotting tool has been developed so far. We have therefore developed a new tool specially conceived to georeference ordinary individual photographs and then produce map layers (e.g. georeferenced vector data) by drawing them directly on these pictures. The basic requirements that have to be fed into the system are the digital version of the historical picture, the DEM of the depicted landscape, and the real-world coordinates of a suitable number of control points unambiguously recognizable on the picture. Although not absolutely necessary, the tool naturally performs best if the real-world coordinates of the precise shooting point and of the center of the picture are known as well. In this contribution we will illustrate the present version of the tool and the results of the first study cases we have developed thus far. We will also discuss future developments as well as potential fields of application.

1. INTRODUCTION

Soon after its early development in the first half of the nineteenth century, photography became very popular as an effective method of documenting landscape features and dynamics. In Switzerland, as in the rest of Europe, there are many large collections of old photographs in public or private archives [1,2,3]. The quality of these historical pictures is often impressive owing to the very high resolution that was possible using photographic glass plates and other classic types of support and film. All this heritage of old photographs represents an enormous resource for the study of landscape evolution and land use change [4,5,6]. Unfortunately, on account of the difficulties in obtaining quantitative geographical data from single oblique pictures, this resource remains for the most part unexploited by researchers in historical geography. In fact, reconstructions of landscape history are often based on the analysis of old maps or old aerial photographs. Nevertheless, it is unquestioned that terrestrial historical photographs present numerous advantages. These include similarity with our everyday perception and experience of the environment, the better view of the landscape in mountain regions, a higher level of detail and resolution, and the existence of an extensive quantity of photographic material dating back in the late 1800s and early 1900s, that is, before the advent of aerial photography [7].

In recent times, the general increase in computing power [8], the improvements in digital elevation models (DEM) [9,10], as well as the implementation of user-friendly and versatile releases of the Geographic Information Systems (GIS) have opened new perspectives for a broad use of single terrestrial oblique pictures for photogrammetric purposes (monoplotting). After the pioneer works of Makarovič [11,12] several attempts have been made to develope software and tools for monoplotting oblique pictures [13,14,15,16,17]. None of these products, however, really meet the needs of potential end-users in terms of operational flexibility and user-friendliness of the interface, which discourage their broad use.

Recent further improvements in digitalizing techniques of historical pictures and the availability of high performance digital cameras make the development of a specific and user-friendly monoplotting tool more interesting and necessary. We therefore started developing, in 2010, a new monoplotting interface with the aim of offering, to a broad public of non-experts, an intuitive platform for georeferencing individual oblique photographs. The tool has been conceived to accept all kinds of individual photographs without distiction between non-metric and metric cameras, high-oblique and vertical views, terrestrial and aerial pictures or historical and recent photos. This platform enables monophotogrammetric and geographic measurements, as well as editing of map data directly onto the picture perspective. This data may be exchanged with the most common GIS packages.

In this paper we briefly present the concept and the state of development of the interface, providing selected examples from the broad field of potential applications.

2. TOOL ARCHITECTURE AND MAIN FEATURES

2.1 The mono-plotting principle

To georeference a single oblique photograph it is necessary to assess, simulate and reproduce, as accurately as possible, the optical system at the time when the picture was taken. Basically this means determining the position and orientation of the camera (extrinsic parameters), as well as the focal distance, the center of the image, and if possible, also the image distortion due to imperfections of the lenses (intrinsic parameters). With all this data, one can place the picture in the real world so that a ray originating from the camera center and passing through a selected point in the picture plane, will intersect the land surface (Digital Elevation Model) in the corresponding real point (see Figure 1).

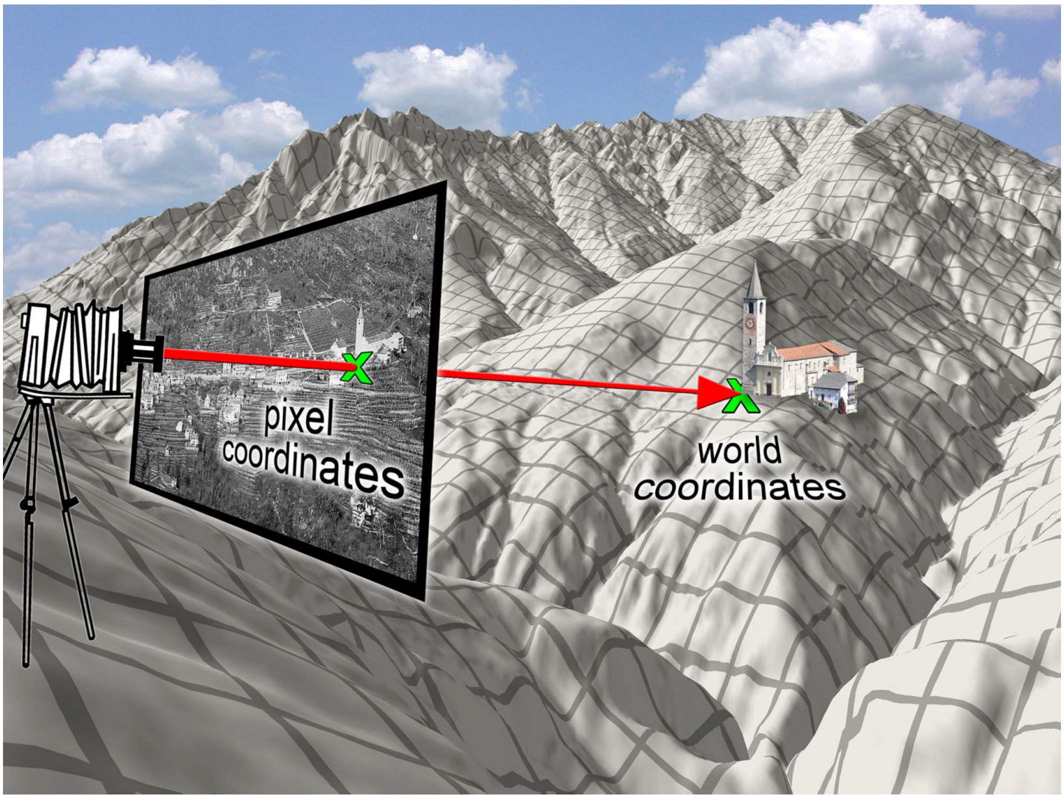

Figure 1: the monoplotting principle.

2.2 The system components

The main components that make up the system are:

1. the picture (photo, postcard)
2. the control points (the position of features in the image and their corresponding positions in the real world)
3. the Digital Elevation Model (DEM)
4. the camera (i.e. a mathematical model of the camera used to take the picture)

The reliability of the system and the precision of the results are clearly affected by the quality of the photograph (e.g. low resolution, lens distortion, film unflatness), the precision and the distribution of control points, the accuracy of the DEM, the accuracy of the camera calibration and the angle of incidence of the optical ray on the DEM surface (in general, the higher this angle of incidence, the higher the obtained precision).

2.3 The camera calibration

The camera calibration is an essential step in the process of georeferencing images to real-world coordinates. In our tool this step has been addressed using a mathematical model based on the collinearity equations commonly used in photogrammetry [18]:

$$x - x_0 = -c \cdot \frac{a_{11} \cdot (X - X0) + a_{21}(Y - Y0) + a_{31} \cdot (Z - Z0)}{a_{13}(X - X0) + a_{23} \cdot (Y - Y0) + a_{33}(Z - Z0)}$$

$$y - y_0 = -c \cdot \frac{a_{12} \cdot (X - X0) + a_{22}(Y - Y0) + a_{32} \cdot (Z - Z0)}{a_{13}(X - X0) + a_{23} \cdot (Y - Y0) + a_{33}(Z - Z0)}$$

where:

- x_0, y_0 are the coordinates of the principal point
- f is the camera focal length
- $X0, Y0, Z0$ are the coordinates of the camera position
- a_{ij} are the coefficients of the rotation matrix $R = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{13} & a_{23} & a_{33} \end{pmatrix}$ defining the camera orientation.

Unknown camera parameters are obtained using the least square method after a linearization of the collinearity equations [19]. According to the quality of the results, sometimes an interactive fine-tuning of some camera parameters can be required. This additional manual tuning may improve the accuracy of the system.

2.4 Data exchange with GIS applications

The georeferenced system guarantees the correspondence between picture and real world. By using common editing instruments, it is therefore possible to map any object visible on the image and to convert it directly into georeferenced vector data (i.e. points, polylines or polygons) including the three-dimensional coordinates (x, y, z) of the object in real space. Then, one can easily transform the format and the coordinate system of these vector layers in order to export them from our software to a GIS environment (e.g. ArcGIS, Quantum-GIS). Data exchange is possible in both directions, so that one can also import vector data, like shapefiles from ArcGIS, and quickly plot them into the picture projection system by calculating the pixel coordinates for every point (see Figure 2 for an example).

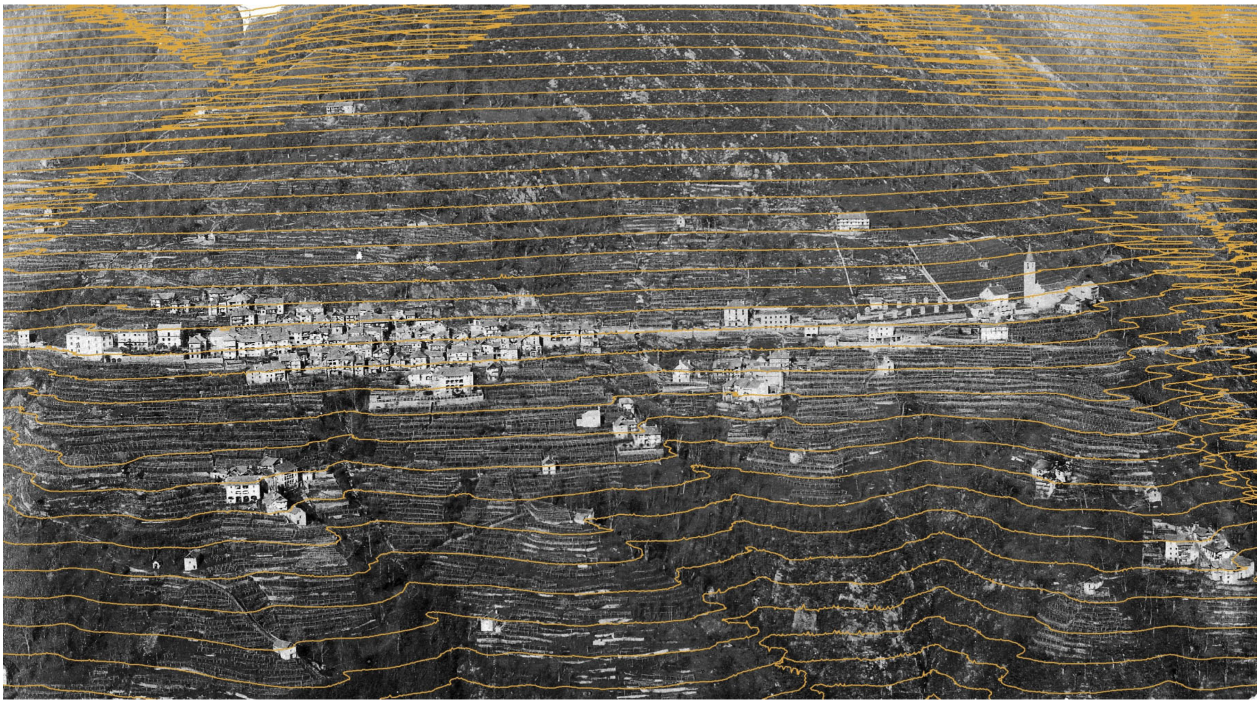

Figure 2: 10m-contours created in ArcGIS, imported into the tool and visualized on an old picture taken in 1885 (Loco, Onsernone Valley, southern Switzerland).

3. APPLICATIONS

3.1 Potential fields of application

The developed tool has the advantage of flexibility so that there are many possible fields of application. These include:

1. Mapping and recovering disappeared or no longer recognizable elements of the landscape, such as old buildings, agricultural terraces, former footpath networks and ancient fruit tree orchards.
2. Geographic reconstruction of the landscape history, as regards, for example, forest and tree line changes, the evolution of forest composition and structure, glacier regression and urbanization processes.
3. Geographic reconstruction of past natural events, such as forest fires, landslides, floods and avalanches.
4. Low-cost monitoring of current environmental processes like the melting of snow, the movements of the front of a glaciers and the effects of wind erosion.

The recent flourishing of the applications of repeat photography in natural sciences [20] furnishes additional arguments for the usefulness of the developed tool. Some examples of possible uses are detailed in the following sections.

3.2 Example 1: cartography of old channels for wood hauling

In the past, before the invention of cable installations (e.g. cableways) and other modern means of transport, in many mountainous areas of the Alps fuelwood and timber were transported downhill to the valley floor or to the lake, by dragging them along semi-natural stream channels [21]. This method of wood hauling or wood skidding was as simple as it was effective and thus rather widespread. It is at present, however, extremely difficult to reconstruct accurately the historical geography of this traditional practice because of a lack of information. On an old postcard (14 x 9 cm) from the early twentieth century showing the mountain slope above the village of Bissone in southern Switzerland, these skid channels have been identified and colored according to the degree of reliability in the photo interpretation: green represents those that almost certainly were often used for this purpose, and red those with lower reliability (Figure 3).

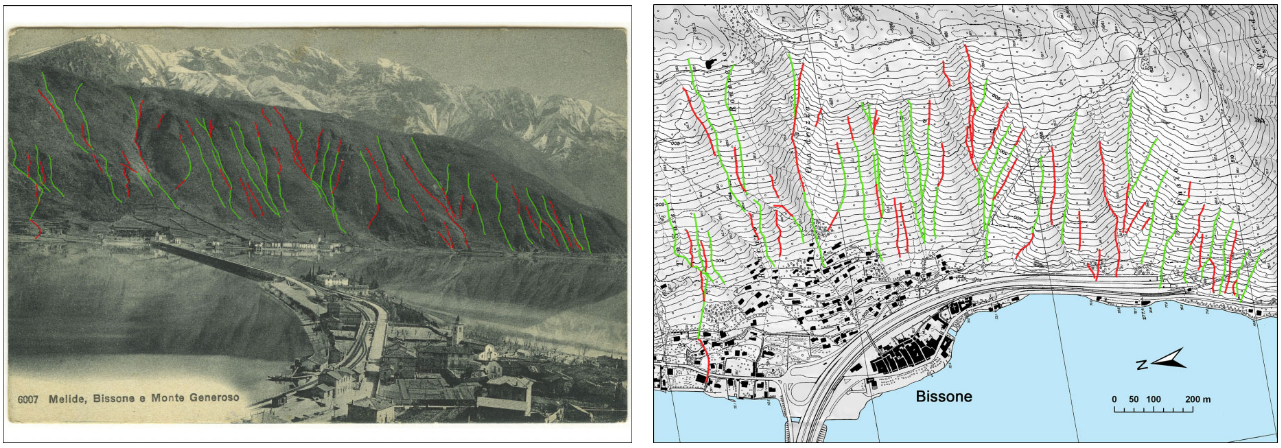

Figure 3: Photo and map of stream valleys and channels used in the past as semi-natural ways for wood skidding (in the area of Bissone, near Lugano, Southern Switzerland):
in green - channels with high reliability, red - low reliability.

3.3 Example 2: reconstruction of the surface damaged by a past flood event

The study of the chronology and amplitude of past flood events is fundamental for flood risk assessment and management. Unfortunately, it is difficult to obtain precise data for these events, for instance in terms of surfaces damaged by floods. Many of them are, however, well documented in historic photo archives. Starting with some old pictures of an extensive flood that severely hit the valley floor near Olivone (Blenio valley, southern Switzerland) on the 25th of September 1927 [22], it was possible to map quite precisely the surface damaged by this event and to reconstruct the limits of the alluvium (Figure 4).

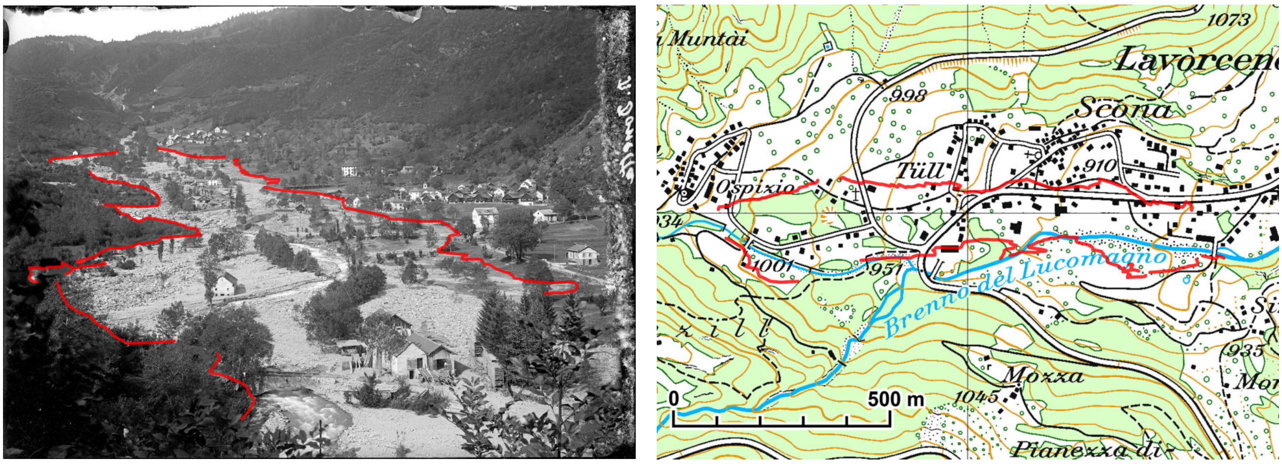

Figure 4: Photo and map of the flood that hit the valley floor near Olivone in southern Switzerland in 1927.

4. CONCLUSION

Although still a prototype, the presented tool proved to be useful and effective for many monoplotting applications. Provisional estimates of the precision of the system are quite promising, especially if we take into account the fact that for many applications there is no alternative solution for obtaining the desired geo-historical data. The first tests implemented to date show that when meeting the basic requirements (image of high quality, good distribution of control points, DEM with high definition, and good calibration of the camera) it is possible, in most cases, to limit error below 10 or even 5 meters. A scientific evaluation of the accuracy of the system is currently underway and will be based on precise data collected by land surveying with total stations and other topographic equipment. This should enable the assessment of the influence of each component on the final result, such as, in particular, the accuracy of the DEM, the characteristics of the image support (e.g. photographic glass plate, postcard, film negative, digital photo) and so on.
For the immediate future, some improvements are already planned. Automatic camera calibration is now based on control points, and the result sometimes requires interactive adjustment to optimize the camera

parameters. This additional manual process, with a view to obtaining a better overlap of the defined control points with those calculated, could be improved by considering, in addition to points, linear elements of the landscape such as roads, railways, and the horizon.
The reliability of the calculation of the coordinates of a point depends on several factors: the accuracy of the DEM, the camera calibration and the angle of incidence of the ray with the surface of the DEM (see 2.2). A significant improvement could be to calculate a sort of precision index that combines all these reliability factors in a single value, giving the expected accuracy for every single point. This index could be included in the attribute table of the vector data.

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