CAD Modeling of Historic Pianofortes by Means of Photogrammetric Data

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Abstract

A procedure for recording historically valuable pianofortes of the 18th century is described. A research project was carried out in co-operation of photogrammetrists and musicologists and aimed at generating precise 3-d object models of a series of pianofortes. The instruments exhibited in museum rooms were photographed using medium format analogue cameras. The images were measured with analytical plotters. Bundle triangulation resulted in the orientation of the photographs, and a multitude of details was determined by intersection. Finally, all the photogrammetric 3-d data were transferred into AutoCAD for further processing, i.e. modeling, visualization etc.

1. Introduction

Photogrammetry has been applied successfully to provide spatial data for generating object models in a CAD system. An interdisciplinary research project referring to the precise survey, 3-d modeling and visualization of a series of outstanding pianofortes of the 18th century was realized in close co-operation of photogrammetrists and musicologists. The photogrammetric as-built documentation allows for detailed investigations of the recorded pianos, for the comparison of several instruments and the construction of replicas. Generally speaking, the secret behind the production of historic pianofortes may be revealed, i.e. the correlation between the geometrical arrangement and the resulting sound pattern.

Old and precious instruments being very sensitive to variations in the environmental conditions are usually displayed in museum rooms equipped with devices for controlling temperature, humidity, light etc.. To date, surveys have been carried out only by hand measurement in cases when an instrument was partially dismantled for restoration. These measurements are not sufficiently accurate and they do not relate to
a common co-ordinate system. Precise investigations require a measuring accuracy of a few tenth of a millimeter. However, valuable pianos have to be surveyed on-site and as fast and carefully as possible. Photogrammetry is thus the appropriate measuring technique for all the visible parts of such an instrument.

In the following, the photogrammetric recording and CAD modeling of the pianoforte exhibited in the Haydnmuseum in Eisenstadt/Austria is described. The data acquisition was performed by the Institute for Photogrammetry and Cartography, University of Federal Armed Forces Munich, the data processing by the Institute of Photogrammetry and Remote Sensing at the Vienna University of Technology, the CAD compilation by the musicologist K. Restle (Kotowski and Peipe, 1994; Kerschner and Schöner, 1998; Restle, 1997).

2. Data acquisition

The pianoforte of the Haydnmuseum in Eisenstadt is a famous instrument built by Anton Walter in the late eighties of the 18th century, all in all an outstanding example of piano making in Vienna. The photogrammetric survey of the instrument included the determination of three-dimensional co-ordinates of discrete object points to generate, for instance, the ground plan of the piano and also the measurement of the positions of hundreds of pins driven into the bridge, nut, wrestplank and hitchpin-rail, which define the exact attitude of the piano strings. The instrument was photographed by an analogue medium format Rolleiflex réseau camera. First, an image strip was taken from above the instrument (vertical photography, see Fig. 1). In order to "fly" over the piano, a simple camera mounting device was built up. Secondly, about 20 convergent photographs forming a closed image block around the object were added (Fig. 1). These images substantially improve the network geometry as well as the precision and reliability of the 3-d object point determination. Besides, the inclination of hitchpins and pins on the bridges can be seen clearly from these photographs. Finally, some pictures of the action - i.e. the mechanism of the instrument - which was removed from the piano case at that time, and of two key levers were taken.

Fig. 1 Schematic ground plan of the pianoforte with exposure stations (circles indicate vertical photographs, arrows convergent photographs)

For the purpose of bundle triangulation, some 70 self-adhesive removable targets were attached to the pianoforte and served as tie points. Scaling information was provided by six ultra-light carbon fiber scale bars with calibrated target spacing of approx. 0.5 m or 1.0 m ± 0.05 mm, respectively.
3. Data processing

The photographs were measured using an analytical plotter WILD BC3. This type of analytical plotter does not provide on-line réseau correction, which would have been advantageous especially for measuring the stereo pairs, i.e. the images taken from above the piano. In our case, the observed image co-ordinates had to be transformed off-line to the known positions of the réseau grid.

Surveying the pianofortes photogrammetrically was quite a time consuming task as the instruments were measured on a high level of detail, including the exact shape of the soundboard, the mechanical parts striking the piano strings (keys with levers and mallets) and all parts responsible for stretching and fastening the strings. The position of each of some hundred pins was required with sub-millimeter accuracy. Therefore the pins were measured in at least four photos, some of them in up to 14 photos taken from different viewing directions. All in all, nearly 10,000 points were registered to describe one pianoforte, which took about 100 hours of measurement per instrument.

The calculation of the three-dimensional co-ordinates of the points was done in the hybrid photogrammetric adjustment system ORIENT (Kager, 1989). First, local deformations originated from distortions of the photos and from the non-planarity of the film surface in the camera were corrected performing a transformation of measured image co-ordinates to the known values of the réseau crosses. For that purpose a least-squares interpolation with smoothing was applied (Kraus, 1972). In this algorithm the local deformation is estimated using many crosses in the surrounding, not only the directly neighboring ones. This was necessary, because many of the black réseau crosses could not be identified clearly due to the poor contrast, especially in front of dark background.

The spatial resection of the photos was calculated as a free adjustment using all targets attached to the piano and the scale bars. After orientating the bundles of photos, the three-dimensional positions of the huge amount of details were derived by intersection. Finally, those points that were measured at the dismounted mechanism had to be transformed back to the mounted position in the piano using some control points. As result after calculation, a three-dimensional point cloud of all points of the instrument in a common co-ordinate system was available.

Musicologists analyzing the sound of the instrument require the positions of the pins with an accuracy of a few tenths of a millimeter, because these pins define the length and strength of the swinging part of the string. The selected photo arrangement allowed to measure these details in different views. Thus a mean point error between ± 0.1 mm and ± 0.2 mm could be achieved for the pins. The accuracy of the other measured details was worse by a factor of 10. Further raise of accuracy is hardly possible because of uncertainty in the definition of these points.

4. CAD Modeling and Visualization

On the basis of the photogrammetric 3-d data a CAD model of the piano was generated by the musicologist. In AutoCAD, different layers were used to represent the main parts of the instrument. The following images show more or less detailed views of the pianoforte of the Haydnmuseum in Eisenstadt derived from the CAD model.
5. Concluding Remarks

The photogrammetric survey of pianos enables high precision three-dimensional point determination of all significant visible parts of an instrument without touching the object. The photographs are documents of the present state of the piano and can be used for further measurement at any time. Due to his expert knowledge, the musicologist is able to reconstruct the instrument in the CAD system and, for instance, to measure distances in the 3-d model or to compare the models of different pianofortes.

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References


