Presented for commission No. : IV, working group : 1 and 3

O. Kölbl and J.C. Pradervand

Institut de Photogrammétrie de
l'Ecole Polytechnique Fédérale de Lausanne, Suisse

Interactive Digital Stereo Plotting for the Renovation of the Cadastral Survey

Abstract :

The paper reports on the incorporation of interactive digital working methods for cadastral mapping. The practical application concentrates on the renovation of cadastral plans. The proper photogrammetric restitution is achieved by a superposition of the map to be renewed with appropriate aerial photographs. Though orthophotos could be used for this task it is more efficient as well as more precise to transform the original map and to superpose it directly with the aerial photographs. This superposition can be achieved by redrawing the deformed map on a film and using it as an overlay of the aerial photographs; another approach is the use of a graphical display unit in direct connection with a stereoplotter. First results on practical experiences are given.

Zusammenfassung :

Interaktive digitale Stereokartierung für die Katastererneuerung.

Die Arbeit befasst sich mit der Verwendung interaktiver digitaler Kartiermethoden für die Belange der Katastervermessung. Wichtigstes Anwendungsgebiet ist dabei die Katastererneuerung. Dieses Ziel wird im wesentlichen durch eine direkte Ueberlagerung zwischen Luftbild und Karte angestrebt. Dazu ist vorgesehen die Karte umzutransformieren und diese dem Projektionssystem des Luftbilds anzupassen. Prinzipiell liesse sich diese Ueberlagerung auch durch die Verwendung von Orthophotos erreichen, der umgekehrte Weg, wie vorgeschlagen, nämliche die projektive Verzerrung der Katasterkarte ist jedoch mit einem geringeren Aufwand verbunden und garantiert zudem eine höhere Genauigkeit. Diese Bildüberlagerung lässt sich einerseits photographisch durch das Zusammenkopieren einer Luftbildvergrösserung mit der projektiv deformierten Karte erzielen, eine andere Möglichkeit ist die Verwendung eines graphischen Bildschirms in direkter Verbindung mit einem Stereokartiergerät. In dem Aufsatz werden erste praktische Erfahrungen mit dem Verfahren aufgezeigt.

Sommaire :

Restitution digitale interactive pour la rénovation du cadastre.

L'article traite l'utilisation des processus digitaux interactifs pour les besoins de la mensuration cadastrale. Les applications pratiques sont concentrées sur la rénovation du cadastre. Ce but est essentiellement atteint par une superposition directe des photographies aériennes et des plans cadastraux. A cette fin, on transforme les plans cadastraux et on les adapte au système de projection des photographies aériennes. Cette adaptation pourrait aussi être faite par l'intermédiaire d'orthophotos; cependant, la méthode inverse proposée, c'est-à-dire la déformation projective des plans cadastraux, s'est avérée plus efficace et garantit une meilleure précision. Cette superposition peut s'effectuer par des moyens photographiques d'une part et, d'autre part, par un écran graphique directement lié à un stéréorestituteur. De premières expériences du procédé sont démontrées dans cette étude.

1. Introduction

Several countries, including Switzerland, are heavily preoccupied with the creation of a land information system. The cadastral survey represents one of the most important information bases for such a system. The implementation of a numerical cadastre on a computer presents no major difficulties. However, several European countries dispose of a graphical cadastre, of which parts may date back to the beginning of the last century.

The transformation of these graphical documents into a numerical form presents considerable difficulties. In their original form the precision of these plans was surprisingly high. The intermediate revisions and changes have caused serious degradation of the original precision. This is not astonishing since these plans were not really intended to be revised. This explains why most of these documents dispose of neither a co-ordinate grid nor a sufficient number of control points.

Consequently, the simple digitizing of these documents could give rise to severe degradation of the existing information. However a completely new cadastral survey would cause considerable extra cost. It is therefore of great importance to find alternatives and one possibility is the inclusion of photogrammetrical means into the process.

Photogrammetric methods for cadastral surveys are very well known. The disadvantages of photogrammetry are the great number of details which cannot be seen from the air and the need to signalize a certain number of points. These deficiencies are largely eliminated when the photographic image is only used as a reference for overall control and for the selection of appropriate check points for the transformation of the graphical map into the

national co-ordinate system. In this way the tedious completion work on the ground, typical of a photogrammetric survey, is avoided and the operation is limited to the geometrical comparison of the photographic image with the cadastral map.

However, such a comparison requires the geometric adaptation of the two information carriers. This adaptation could be achieved by stereoplotting or by the production of orthophotos, but practical experience shows that it is more efficient to transpose the contents of the previously digitized map into the projection system of the aerial photographs. This operation allows direct superposition of the line map and the photograph, which considerably facilitates the detection of geometrical discrepancies. This document may even be taken into the field and verified on the spot. This first transformation is followed by a second phase of adaptations which may be considered as the proper renovation of the cadastre. Finally, for control, the corrected cadastral map can again be transposed into the projection system of the photograph.

Practical experience has shown that a map which has been revised several times might have a very heterogeneous geometry and a simple transformation, even by spline functions or least squares interpolation, does not really meet the effective requirements. Much better results may be obtained by a zonal transformation, taking into account the particularities of map revision. Although such a procedure takes a considerable time, the costs are far lower than for a new survey and the resulting precision should be adequate for the requirements of a modern cadastre.

The practical experiences concentrated up to now on a municipality in the North of Lausanne (Municipality of Echallens) and on a country estate in the northern Jura. Before entering into the proper investigation, the historical development of the cadastral survey is shown up on the special example of the canton of Vaud. In the 3rd chapter the instrumentation used for the experiences are presented and in the following chapters the preparation of the necessary map material and the proper renovation of the cadastral survey are discussed.

2. Historical development

Digitizing graphical map documents and their renovation is of special interest in regions where a high quality survey is available which is continuously revised and which corresponds to the actual state. The problem is of special importance for the western cantons of Switzerland. Great parts of the original cadastral survey still in use date back to the beginning of the last century. The documents are permanently revised and the map contents coincide with the actual prescriptions.

The cadastral survey of the canton of Vaud, for example, was initiated by law in 1804 and ordered a survey of the whole province. The measurements were completed around 1850. The main objective of this survey was to find an equitable base for taxation. Very soon the legal aspect became predominant. Already in 1840 an index of rights and obligations was installed and at the end of the century the registration of all servitudes became compulsory. In this way the canton already disposed of a highly developed cadastre of the whole territory when in 1912 a survey of the whole of Switzerland was ordered by the central government.

The initial cadastral survey of the canton of Vaud was effected purely graphically, with the help of the plane table. The sheets are completely independent, limited by natural boundaries and without reference to the national grid system (cf. Fig. 3). In spite of the simplicity of the method relatively high inner precision was obtained.

At the beginning of this century the purely graphical method was replaced by a semi-numerical procedure, which means that the field survey is performed numerically whereas the base for the legal cadastre remained a graphical document. Around 1960 the progress in electronic data handling initiated the creation of a purely numerical cadastre and the progressive transformation of the actual survey into a numerical information system.

3. Photogrammetric equipment and computer facilities

The proposed method for cadastral renovation is mainly based on the direct comparison of a map with its corresponding aerial photograph. However, such a comparison requires an appropriate combination of the previously digitized map co-ordinates with the measurements effected in the stereomodel. In order to facilitate these data manipulations it seemed necessary to make use of a graphical work station in conjunction with a stereoplotter.

The instrumentation used for this work is a Wild A 10 stereoplotter equipped with an automatic registration device, a table computer with a graphical display unit (Hewlett-Packard 9845 T) and an automatic drawing table connected to a mini-computer (Coradi Coradomat MK3 with a General Automation SPC-16 computer). Figure 1 shows the layout of the different instruments and the possibilities for data transfer.

The stereoplotter and the computer are connected via an automatic registration device (Wild EK22) by a 16-bit parallel interface. The registration device was programmed to offer data to the computer every 0.02 sec. However the computer only reads these data when it executes the corresponding read instructions in its internal program. Besides the spatial model co-ordinates, a point identifier is also read which characterizes the data. Further, the operator disposes of a foot switch, which was programmed to initiate the plotting of line or point symbols and the storage of a co-ordinate in a data file. A preliminary transformation is necessary if the registered values are to be compared with, or superimposed on, other data registered on another device (e.g. digitized cadastral map).

The computer facilities described up to now more or less correspond to the possibilities of a conventional drawing table of a stereoplotter. Additional features of the system are a graphical editing routine and the possibility of controlling the plotting process by the computer. The latter facility is of special importance for file manipulations in cadastral renovation. In this mode a special symbol on the graphic display guides the operator through the sequence of points to be measured. The necessary precision is achieved by zooming, which allows a pointing accuracy of up to 1 micron (screen size 540 x 480 points) to be obtained.

The computer facilities around the stereoplotter are complemented by high performance automatic drawing table, used for precision drawing of the cadastral maps. This table is steered by a mini-computer equipped with a

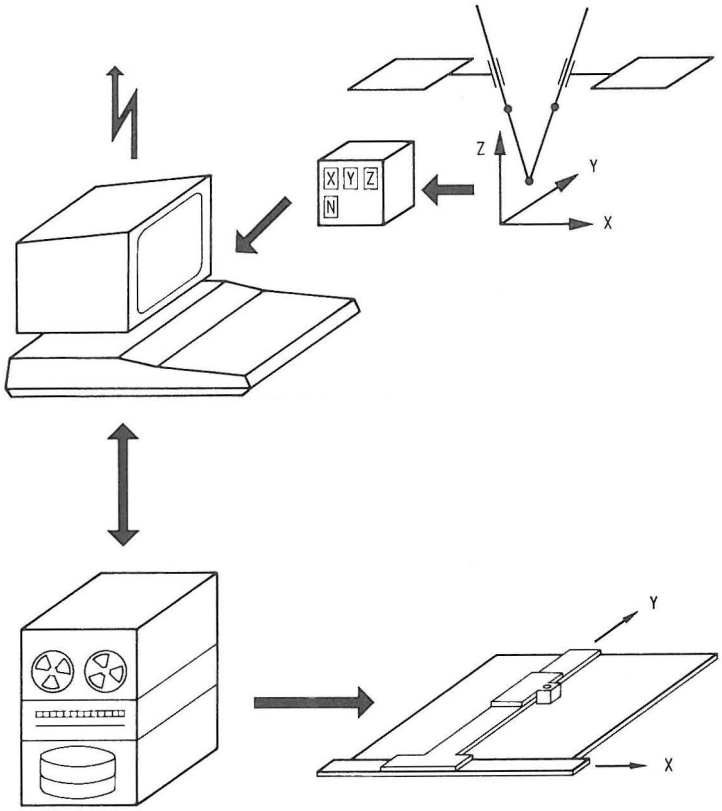

Fig. 1

View of the instruments used for cadastral renovation by photogrammetry. The essential parts are the stereoplotter in on-line connection to a computer with graphical display unit and the automatic drawing table controlled by a mini-computer. The mini-computer is in dialog with the graphical system, whereas the feed back to the stereoplotter is assured only visually by the operator.

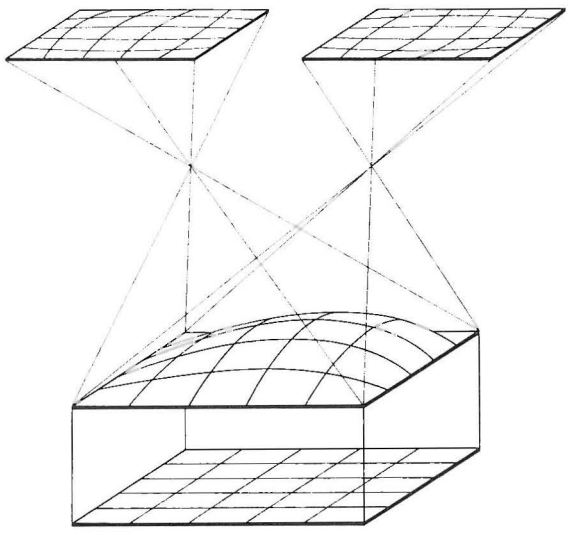

Fig. 2

Transfer of a grid (map) into the projection system of aerial photographs. For such a transfer the orientation elements of the photographs, the planimetric co-ordinates as well as the height of each point have to be taken into account.

Fig. 3

Section of a map used for renovation; scale 1:1000, area Echallens, Vaud, original survey about 1840 but still valid. Very typical is the initial great number of parcels regrouped later on. Obsolete lines are not erased but only marked by two dashes. In order to avoid confusion it was necessary to emphasis the actual situation by colour pencil (grey in the reproduction).

magnetic tape unit and two disk units of 5 Mbyte. An on-line connection of the table computer to the mini is necessary for data transfer and would allow the disk units to be incorporated into the interactive data management during the plotting process.

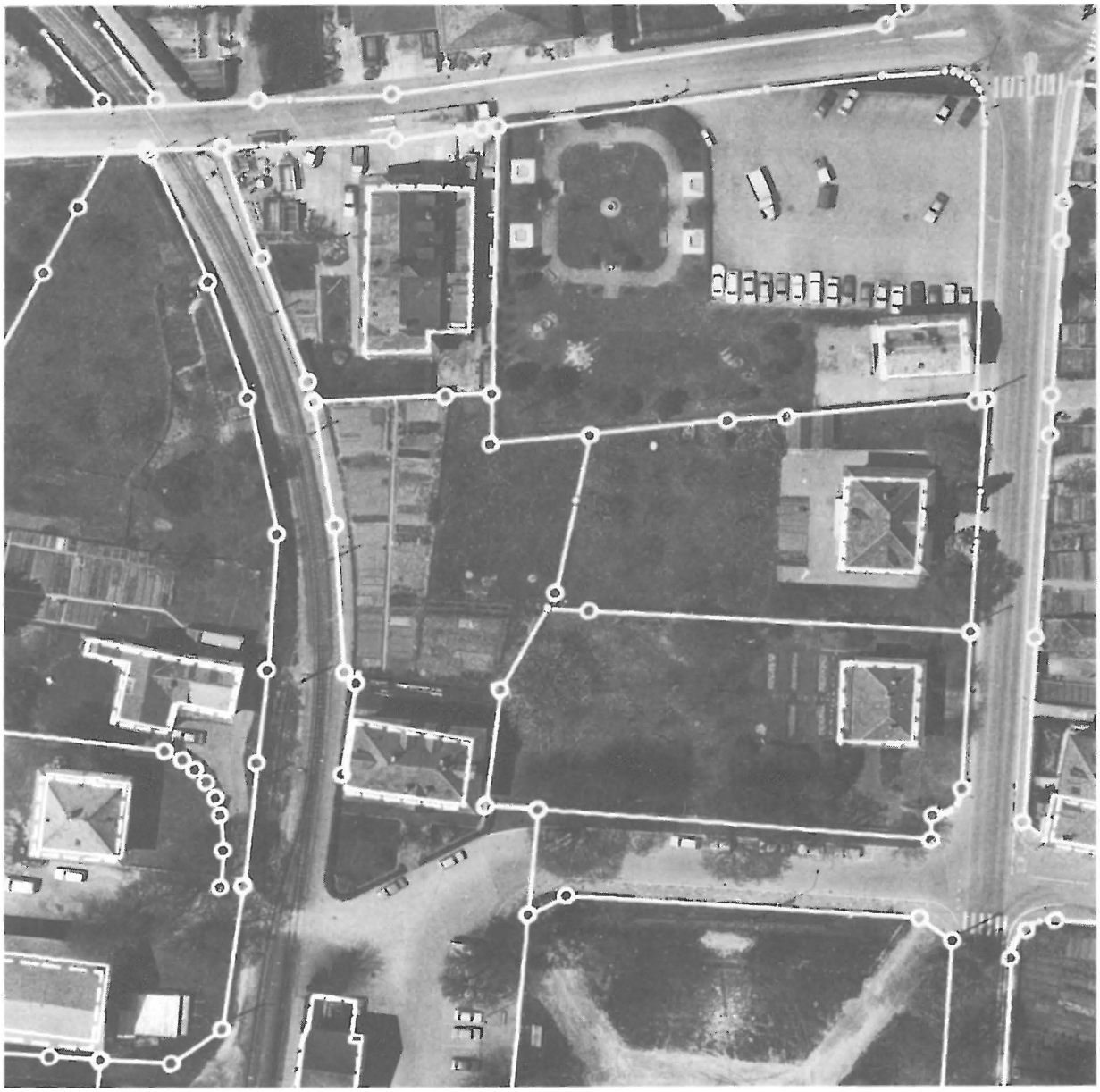

Fig. 4

Superimposition of an aerial photograph with a cadastral map (same section as Figure 3). The transfer was done analytically correct and deviations are purely due to errors of the map (e.g. the park limit should coincide with the border line). The buildings are plotted two times, the dashed line corresponds to their base at the level of the roof. The plot is very heavy in order to facilitate the reproduction (Photograph reproduced by courtesy of the Federal Directorate for Cadastral Survey, Bern).

4. Preparation of the working material

Obviously a thorough renovation of a cadastral map cannot be made without field verification. It is therefore important to design, apart from the photogrammetric restitution, the appropriate tools which may serve as the basis for this field work. It has already been pointed out, in the introduction, that enlargements of the aerial photographs with the superimposed

cadastral map are most useful for these activities.

This phase also includes the preparation and the taking of the aerial photographs. It proved most useful to foresee the signalization of the control points intended for the orientation of the photographs in the stereoplotter, as well as of a certain number of boundary marks in open rural areas. The photographs for the practical experiments were taken in May 1978, before the appearance of the young leaves; this flight was performed without any signalization. A second flight is planned for this spring, for which considerable efforts for signalization have been made. A scale of 1:4500 was chosen for the aerial photographs.

The preparation phase also included the digitizing of the original map documents on a special digitizer. The data file, with the digitized coordinates, was transferred to the table computer linked to the stereo plotter and served as the reference for the determination of the heights of all cadastral points by photogrammetric measurements. At the same time the orientation elements of the photographs were determined with the help of grid measurements. This information is needed for the subsequent transformation of the cadastral points into the projection system of the photographs (cf. Fig. 2). Finally the projective deformed map was plotted on the automatic drawing table and superimposed on an enlarged photograph in a rectifier (cf. Fig. 4).

The precision required for the height measurements is in the order of 10 cm, because of the planimetric precision required of a cadastral map. This explains why the inverse procedure, namely the preparation of an orthophoto and its superimposition on the original cadastral map would never yield similarly high precision. In general a map sheet of 50 x 70 cm (scale 1:1000) included 1000 to 1500 points. Consequently it was sufficient to measure the heights of this number of points, whereas an orthophoto would have required a much larger number of height points because it would have been necessary to measure the heights, with the required precision, all over the image. Furthermore it proved extremely useful to calculate two height levels for the buildings, namely the ground and the roof levels. In this way it was possible to draw the projective deformed perimeter of the buildings given by the map at both levels (cf. Fig. 4). The equivalent procedure for orthophotos would be the rectification of the individual buildings, a procedure which would give rise to considerable problems.

5. Proper renovation

Up to now the activities dealt with preliminary operations, without touching the numerical problem of the cadastral renovation itself. Obviously there is no general solution to this problem. In the literature, various continuous functions such as least square interpolation or spline functions have been used. An alternative would be to define homogeneous sectors with similar deformation within a map sheet and treat these parts independently. The choice of the procedure must depend on the effective geometric conditions of the map sheet.

As already mentioned, it turned out that the deformations of the map sheet might be relatively heterogeneous (cf. Fig. 5), especially due to map revisions and that a zonal transformation seems more appropriate

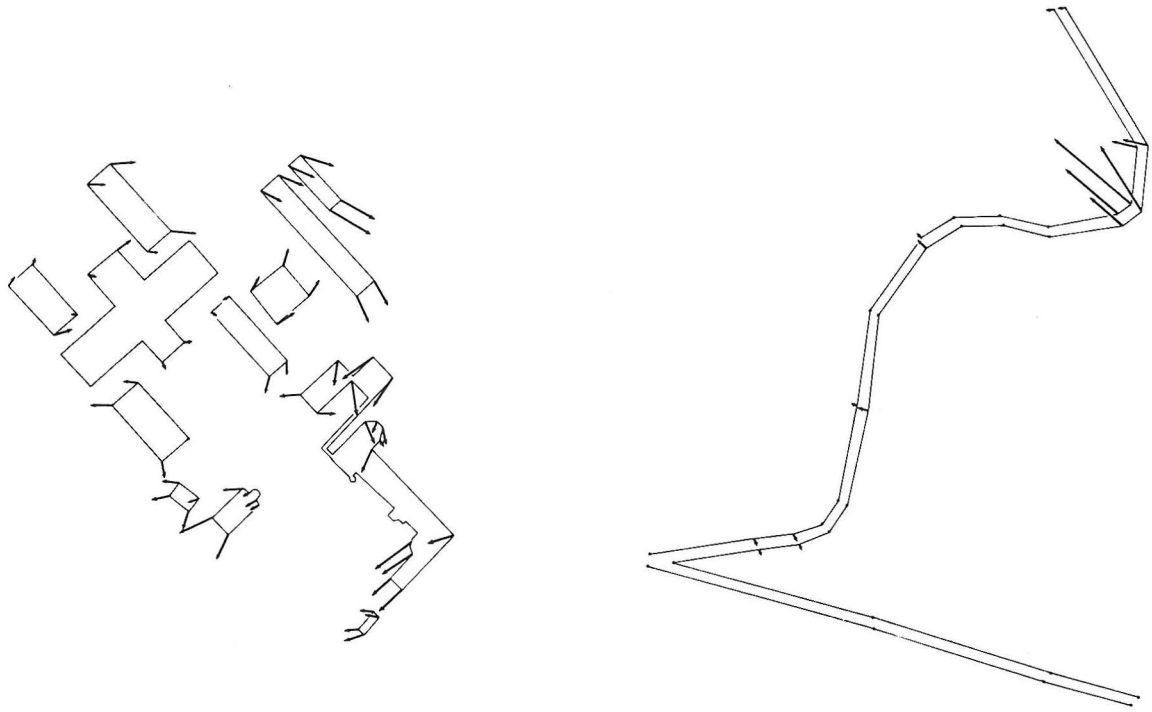

Fig. 5

Vector diagram showing the deviation of a cadastral map in comparison to stereo plotting; vector scale 5 x larger than map scale (section of the map Loewenbourg, canton Jura).

than a continuous transformation. The definition of the transformation zones and the selection of the control points (2 - 4 per zone) was principally made in the field. In all, around 20 zones were chosen per map sheet. Although the transformation points were chosen in the field, their co-ordinates were determined with the help of photogrammetry, which required a second orientation of the model. As the boundary marks were not signalized prior to the flight, on only a few occasions was it possible to immediately determine these co-ordinates. In all other cases it was necessary to define auxiliary points nearby, clearly visible in the photographs. The boundary marks were then determined relative to these auxiliary points by their distance and azimuth measured with a compass. In general these distances were within 1 - 2 m and the precision required for a cadastral survey should not be effected by the use of a compass. With this information it was possible to transform the whole map sheet into the national co-ordinate system and at the same time perform the necessary corrections. These operations were done on the table computer and were supported by the graphical display unit. For final control another photograph, with the corrected map superimposed was prepared.

6. Conclusions

The tests have shown that photogrammetry allows a thorough renovation of the cadastre. The results of the method should be comparable to a resurvey, but with considerable lower cost. However the procedure is more costly than a simple digitizing and transformation of the original document. Consequently the photogrammetric methods are only justified when a real renovation of the cadastral survey is necessary.

The most important tool for this procedure is the direct comparison of aerial photograph and map over larger zones. The method requires a superposition of the two information carriers. As shown this superposition is relatively easy to be obtained by the methods of electronic data handling, an equipment which demands considerable investments. But this equipment corresponds to the installation needed anyhow for a modern land information system and apart from the stereoplotter no real extra investments are necessary. In this way the procedure is completely conform to the present efforts in cadastral mapping.

The presented investigations must not be considered as concluded and a number of further experiences are necessary until a broader application will be possible. This especially concerns cost estimations and it would be unrealistic to deduce from the present experiments any figures on the effective costs under operational conditions. Nevertheless it can be stated that the proposed method is a very efficient approach to the problem of cadastral renovation.