University of West-Hungary

PhD thesis

PHOTOGRAMMETRIC APPLICATION OF NONLIENAR MODELS IN GEOENVIRONMENTAL SCIENCES

Tamás Jancsó

Sopron
2006

PhD School: „Environmental Sciences” PhD School
(supervisor: Dr. Csaba Mátyás)

Program: Geoenvironmental Sciences
(supervisor: Dr. László Szarka)

Science: Photogrammetry

Advisor: Dr. József Závoti

Objectives of the research and its precedents

The dissertation is based partly on the research project No. OTKA F004382 completed in 1995, which examined the possibilities and details of photogrammetric application of the Jacobian Mean Value Theorem as a core procedure for gross error detection. Also in that period a demand is occurred for further development to have a new adjustment and gross error detection method and its application in some areas of geoenvironmental sciences and the present dissertation gave an opportunity for it.
In addition the doctoral work describes the automated DTM checking with cross-correlation image matching using stereo-photos carried out in the frame of an experimental research work conducted by the EuroSDR organization.

The methods of the investigations and its practical importance

- To build the theoretical basis for the gross error detection the first step is to solve the nonlinear model of the outer orientation without iterations using minimally necessary data and points. After this the next step is to determine the adjusted parameters based on redundant measurement data. For this we have to carry out the non-iterative solution in every possible combination and we should build the weigh matrices to each combination based on the implicit Jacobian error propagation law. Based on the solutions and weight matrices of all possible combinations the adjusted parameter can be derived by the Jacobian Mean Value Theorem as a weighted mean value. Using the χ^2 statistical test the gross error detection is based on a null hypothesis which means the RMS values can be estimated before the adjustment and they can be compared with the RMS values gained after the adjustment and investigating the full combinatorial sequence during the adjustment procedure we will able to pick out the

points having gross errors. The practical importance is large in all areas of geoenvironemental sciences where ortho-photos are used since to produce ortho-photos we need to have error-free outer orientation elements.

- Comparing the model and ground points and calculating the residuals of the scale factors in every combination we are able to find unanimously the gross errors exceeding a pre-set value. The practical importance of this method is large at those geoenvironmental sciences where the data acquisition is made by stereo-photogrammetry and the coordinates of the control points used in the orientation should be checked against the gross errors.

- At the non-iterative spatial similarity transformation we can avoid the Groebner-basis, if the parameters are separated into three groups and they are determined on procedures based on one another. To gain the adjusted parameters here we also need to know the weight matrices for each combination, and they are determined by the implicit error propagation law as it was applied at the calculation of the outer orientation elements. The adjusted parameters are calculated by the Jacobian Mean Value Theorem. The practical importance of this method is appearing in those areas among the geoenvironmental sciences where a transformation between the spatial coordinate systems should be carried out but the approximate values of parameters are not known.

- At the automated checking of the DTM points the image matching was carried out by the cross-correlation equations in 7 different modifications and by experimenting these modifications the most efficient method was selected. The practical importance of this method is appearing in those areas among the geoenvironmental sciences where the DTM and its derived products are used directly. In addition to produce an ortho-photo there is also a condition to have an error-free DTM.

Summary of the new scientific results

1) **Determination of the outer orientation elements with a non-iterative analytical method.**
   - The author gave a mathematical procedure to solve the photogrammetric space resection without iterations based on three points.
   - The candidate described in detail the determination of the weight matrix based on the implicit Jacobian error propagation law concerning the space resection made by three points.
   - Using the Jacobian Mean Value Theorem a solution to the adjusted outer orientation elements is gained for the case when the number of control points is more than three.
2) **Gross error detection based on the comparison of scale factors calculated from the model and ground coordinates.**
   - The candidate gave a complete method for the gross error detection based on the comparison of scale factors calculated from the model and ground coordinates.
   - The elaborated method was demonstrated by a numerical example.
3) **The non-iterative solution of the spatial similarity transformation without the usage of the Groebner-basis.**
   - The candidate gave a general solution to the non-iterative spatial similarity transformation not applying the Groebner-basis.
   - As a numerical example the author compared the usual iterative method with the spatial similarity transformation carried out with and without the Groebner-basis. By the results the spatial similarity transformation carried out without the Groebner-basis gave similar results in comparison to the other methods. The RMS value calculated from the residuals was the smallest at the candidate's method (to prove this statement further theoretical investigations and practical tests should be carried out). (to prove this statement further theoretical investigations and practical tests should be carried out).

4) **Gross error detection at the determination of the outer orientation elements.**
   - The author gave a universal algorithm for the gross error detection at the space resection made by adjustment.
   - The elaborated method was demonstrated on some application examples.
   - The candidate gave a summarized description about the conditions, which should be fulfilled to apply the elaborated method for those transformation tasks which differ from the photogrammetric space resection.

5) **The automated checking of DDM points based on stereo-photos and made by 2D image matching extending the cross-correlation equations.**
   - The author gave a complete algorithm for the DTM checking with the help of the image matching based on the cross-correlation of stereo-photos in automated operation.
   - Modifying the cross-correlation procedure seven different methods were elaborated for the automated DTM checking. To gain this goal, new altering coefficients (weight, texture coefficient) were introduced as well.
   - The elaborated methods were tested by the author on a DTM at all possible setting values. By the gained experiences concerning the seven different methods, the candidate proposed to introduce two methods in practice.

Application of the results of the dissertation

In the dissertation to utilize the results of the thesis the author demonstrated the elaborated methods on different application examples. To gain this the candidate developed some applications in Visual basic 6.0 development environment.
The described methods in the thesis **1)** and **4)** were tested by a practical application based on the stereo-photo No. SC3958-3957 originated from the aerial survey carried out by the FÖMI (Institute of Geodesy, Cartography and Remote Sensing) in 2000.

The thesis **2)** was demonstrated by the candidate on model and ground coordinates gained from a photogrammetric evaluation.

To test and practically demonstrate the thesis **3)** the author used some data from a local and global WGS84 coordinate system.

The method described in the thesis **5)** was tested in practice in the frame of an EuroSDR (European Spatial Data research) project under the name of „Automated Quality Control of Digital Terrain Models". The results of the gross error detection were fitted well into the results gained by other participating European universities.

As a summary, we can state that the methods described in the dissertation contribute to the production and usage of different DTMs and ortho-photos. The usage of these end-products is justified on those areas where the usual maps don't contain sufficient or important information for the professionals. The other important area (where the usefulness is evident) is the area of the thematic mapping, on this area there is a large support in the GIS systems, in other words the DTMs and the ortho-photos can be integrated well into the GIS systems.

The next list is a short summary showing that among the environmental sciences which areas and which products, procedures are supported by the DTMs, the ortho-photos or the ortho-photo maps. The methods described in the present dissertation aiding the production of these end-products.:

Forestry

- Thematic maps derived from ortho-photos by classification: for example survey of species of trees, infrastructure development in wooded areas, land cover maps
- Combination with vector data: for example visualization of forest-plot boundaries, planning of forest roads, compilation and update of forestry maps
- 3D visualization (rendering the ortho-photo on the DTM) for planning tasks

Environmental protection

- Mapping base: for example mapping of national parks, seasonal change detection
- Thematic maps derived from ortho-photos by classification: wild-habitat analysis, land-cover maps, environmental load, water quality, soil quality, re-cultivation, eutrophication, sewage disposal, waste disposal, air pollution

Soil science, agriculture,

- Land use planning and monitoring: for example the MEPAR program, precision agriculture
- Thematic maps derived from ortho-photos by classification: for example soil type, land evaluation, erosion (+DTM), soil humidity, monitoring and modeling of soil creep procedures

Hydrology

- Flood-control – ortho-photo, DTM for interpretation planning
- Thematic maps derived from ortho-photos by classification: water management, ground water, hydrology network, flooding maps and models (+DTM)

Geology

- Thematic maps derived from ortho-photos by classification: pl. mapping of ground or near-ground rocks, geothermic phenomenon, surface damages, resource search, movement detection of loose, sedimentary rocks, correction of tectonic lines and blocks (+DTM), engineering-geology mapping

Land planning and ecology

- Ortho-photo + DTM: landscape planning
- Thematic maps derived from ortho-photos by classification: settlement-environmental impact assessment

List of papers connected to the dissertation

Publications

Abroad, in foreign language

1. Jancsó T.: Gross Error Detection of Control Points with Direct Analytical Method, ISPRS Volume XXXV Part B3/W3, pp. 678 ff., Istanbul, 2004a.

In Hungarian journals, in English language

2. Závoti J., Jancsó T.: The solution of the 7 paramter datum transformation problem with and without the Groebner basis, Acta Geodetica Geophisica Hungarica, 41. kötet (I. kötet), 2006., 11-14. pp., 2006.

In Hungarian journals, in Hungarian language

3. Jancsó T.: A külső tájékozási elemek meghatározása közvetlen analitikus módszerrel (Determination of outer orientation elements with direct analytical method), Geodézia és Kartográfia, 46. évf. 1. Szám 33-38. old.,1994.

4. Jancsó T.: Durvahiba-szűrés a fotogrammetriai hátrametszés kiegyenlítése előtt kezdő értékek megadása nélkül (Gross error detection before the adjustment of photogrammetric space resection and without giving approximate values), Geomatikai Közlemények, VII. szám, Sopron, 181-195 old., 2004b.

Presentations

Presentations held at International Conferences

5. Jancsó T. (1994): Durva hibaszűrés a légi háromszögelésben (Gross error detection in aerotriangulation) -Jubilee Scientific Conference dedicated to the 215th Anniversary, International Scientific Conference May 25-27, 1994, MIIGAiK, Moscow
6. Jancsó T.: Gross Error Detection of Control Points with Direct Analytical Method, ISPRS XX. Congress., Istanbul, poster presentation, 2004a.
7. Jancsó T.: Quality control of digital terrain models using different autocorrelation technics, EuroSDR Seminar on „Automated Quality Control of Digital Terrain Models", Aalborg, August 18-19., 2005.

Presentations in Hungarian held in Hungary

8. Jancsó T. (2004): Durva hibaszűrés a fotogrammetriai hátrametszés kiegyenlítésekor (Gross error detection at the photogrammetric space resection) – GIS OPEN 2004 Konferencia, Székesfehérvár, NYME GEO, 2004 márc. 17-19.
9. Jancsó T., Engler P.: Digitális domborzatmodellek ellenőrzési módszerei (DTM checking methods) – GIS OPEN 2005 Konferencia, Székesfehérvár, NYME GEO, 2005 márc. 17-19.

Reports

10. Jancsó T.: F 4382 sz. OTKA témapályázat zárójelentése (A durvahiba-szűrés újszerű megoldásai és alkalmazása a fotogrammetriai on-line légi háromszögelésben) zárójelentése, (Novel methods in gross error detection in on-line aerial triangulation), EFE Földmérési és Földrendezői Főiskolai Kar, Székesfehérvár, 1995.