MATHEMATICAL ASPECTS OF DIGITAL TERRAIN INFORMATION; REPORT FROM ISPRS WORKING GROUP III:3 FOR THE PERIOD 1980-84

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ABSTRACT

The objective of the working group is based on a resolution made by the ISPRS Congress in Hamburg 1980. As stated in this resolution an international comparative test was organised, in order to study the relations between methods for sampling the terrain in a photogrammetric stereomodel, approximation (interpolation and filtering) of the terrain surface, accuracy of derived (resampled) elevations from a digital elevation model (DEM), and the type of terrain. Some ten participants have measured DEMs and resampled elevations in check points for the six test areas that were selected for the study. The errors have been analysed by the Department of Photogrammetry at the Royal Institute of Technology in Stockholm. The results are reported separately.

The same test areas have been studied with respect to various ways to classify the type of terrain with respect to its elevations. The working group organised an international colloquium in Stockholm in April 1983. The presented papers and the deliberations are reviewed.

1 RESOLUTION

The 14th Congress of the International Society for Photogrammetry held in Hamburg 1980 accepted a resolution saying: "The Congress noting that Digital Terrain Models have been studied for a long time and a resolution for continuing those studies was made at the 13th Congress, recognising the importance of the results of such studies to practice, recommends that further studies, including comparative tests, be peformed in such relevant areas as resampling and accuracy aspects". This resolution was the basis for establishing the working group No 3 of Commission III with the name Mathematical Aspects of Digital Terrain Information. The author was elected chairman of the group and Mr Anders Östman, M Sc, has been appointed secretary, both persons at the Department of Photogrammetry at the Royal Institute of Technology in Stockholm.

2 COMPARATIVE DEM TEST

As stated in the resolution a comparative test has been organised. The main objective of the test can be summarized as to study the relations between methods of sampling (measuring) the terrain, approximation (interpolation) function for the elevations, and the accuracy of derived (resampled) elevations from a digital elevation model (DEM). The test is restricted to photogrammetrically measured digital elevation models available for practical applications. It is recognised that the type of terrain has an important influence on the relations to be studied. For that reason six different areas have been selected for the test.

2.1 Test Material

For each of the six test areas there are two sets of aerial photographs at different scales. The smaller scale photographs are used by the participants to measure the terrain elevation and the larger scale is used for determination of the "ground truth" for the succeeding accuracy analysis. Each participant is asked to derive two DEMs for each area, one DEM more accurate than the other. The accuracy requirement is vaguley stated; in most cases stated as DEMs applied to contouring in given map scale and given contour interval; in a few cases as DEMs applied to volume calculation of earth masses with tolerances in m^3/ha. The test specifications are summarized in Table 1. Each participant was also asked to predict measures of accuracy that he can specify himself. The intention was to check his prediction against the "ground truth". His type of specification of accuracy could be chosen freely, e.g. standard error, maximum error, systematic error, error distribution parameters etc. Data were collected on instrument type, sampling mode, approximation function, computer used, time and cost estimates for the production of the DEMs etc.

2.2 Test Measurements

The testing procedure was as follows. The participants were given the aerial photographs, camera calibration data, ground control for orientation, and border lines for the DEM test areas. When they had used the photographs and generated their DEMs they sent the photographs back to the project leaders, returned data for orientation and size of a test grid. Each test grid comprises some 2500 check points. The participants were now asked to derive from their DEMs a new set of resampled elevations in the test grid nodes. Depending on the practical routines of the participant this was a primary or a secondary generation of DEM values. The "ground truth" of the DEM was determined in the larger scale photography by static measuring in the test grid nodes. This was done independently by two operators in two analytical stereoplotters.

2.3 Participation

The photographs and control point co-ordinates for the comparative test were put at our disposal on very favourable conditions, often free of charge. The great generosity shown to us by the photogrammetric departments at

the Technical University, Suttgart, FRG
the Technical University, Hannover, FRG
the Technical University, Trondheim, Norway
the National Road Administration, Borlänge, Sweden and
the National Land Survey, Gävle, Sweden

is very much appreciated.

Without the contribution of the participants that made all the measurements and calculations, no comparative test would ever be possible. We thank them all for providing us with their data.

They were

Liu Xianlin	Research Institute of Surveying and Mapping, Beijing, People's Republic of China
Marie Knutsson	National Land Survey of Sweden (LMV), Gävle, Sweden
Ingo Kruse	Niedersächsische Landes Verwaltnings Amt, Hannover, Federal Republic of Germany
Ingo Kruse	Institut für Kartographie, Universität Hannover, Federal Republic of Germany
Henry Kvarnström	Helsinki University of Technology, Helsinki, Finland
Heinrich Ebner	Technische Universität, München, Federal Republic of Germany
Klaus Tempfli	ITC, Delft, The Netherlands
William Young	Riverside County Flood Control and Water Conservation District, California, USA
Manfred Sigle	Technische Universität, Stuttgart, Federal Republic of Germany
Ingolf Hådem	Norwegian University of Technology (NTH), Trondheim, Norway
Unni Antonsen	Geographical Survey Office (NGO), Lillehammer, Norway
G Mélykúti	Technical University of Budapest, Budapest, Hungary
B Magyarosi	Surveying and Mapping Company, Budapest, Hungary
P Divényi	Institute of Geodesy and Cartography, Budapest, Hungary
József Závóti	Geodetical and Geophysical Institute of the Hungarian Academy of Sciences, Sopron, Hungary.

2.4 Analyses of Results

The results of the DEM measurements were analysed at the Department of Photogrammetry at the Royal Institute of Technology, Stockholm. Most of the data processing was done by Ralf Lindgren M Sc. Anders Östman M Sc made very valuable contributions in organising the experiment and suggesting ways for analyses. The results of the experiments are reported separately.

2.5 Terrain Spectra

Poul Frederiksen at the Surveying Department of the Technical University of Denmark has studied the terrain spectra of some of the models in the experiment.

3 INTERNATIONAL COLLOQUIUM

The working group III:3 arranged an international Colloquium in Stockholm in April 1983 on the topic Mathematical Aspects of Digital Elevation Models. There were 32 guests and some 10 participants from the organiser, the Department of Photogrammetry at the Royal Institute of Technology. The following 12 papers were presented and discussed.

Ammannati F, Benciolini B, Mussio L, Sansò F. An Experiment of Collocation Applied to Digital Height Model Analysis

Bjerhammar A. On the Foundation of Collocation in Physical Geodesy

Borgefors G, Jungert E, Olsson L. A Method for Transformation of Terrain Elevation Contours into a Sparse Grid Structure

Faintich M B. Interactive Analysis of Digital Terrain Elevation and Surface Feature Data Bases

Frederiksen P, Jacobi O, Kubik K. Measuring Terrain Roughness by Topological Dimension

Förstner W. On the Morphological Quality of Digital Elevation Models

Lindgren R. The Establishment of Ground Truth for the ISPRS Working Group III:3

Nagy I, Závoti J. Determination of Elevations for Covered Areas by Means of Two-Dimensional Covariance Functions

Shapiro H S. Some Aspects of Interpolation and Approximation

Torlegård K. Photogrammetry and Digital Elevation Model, present status of development and application

Yaşayan A, Güler A. Experimental Results of Least Squares and Multiquadric Interpolations in Digital Elevation Models

Östman A. An Outline of an Analysis of the ISP DEM-Test.

The proceedings can be obtained from the Department of Photogrammetry, Royal Institute of Technology, S-100 44 Stockholm, Sweden at a cost of 200 SEK (some 30 USD).

TABLE 1 International comparative test on photogrammetrically measured digital elevation models.
Data on the test material

Area name	Type of Terrain	DEM Photo Scale	Check Photo Scale	Accuracy requirement Scale-Equidistance/Volume tolerance Low	High
Uppland Sweden	Farmland and forest	1:30 000	1:6 000	1:10 000 - 5 m	1:2 000 - 2 m
Bohuslän Sweden	Rugged granite bedrock without soil cover	1:30 000	1:5 300	1:10 000 - 5 m	1:2 000 - 2 m
Stockholm Sweden	Urban communication areas	1:20 000	1:4 000 1:5 000	1:10 000 - 5 m	1:2 000 - 2 m
Drivdalen Norway	Steep and rugged mountains	1:17 000	1:10 000	1:10 000 - 5 m	1:2 000 - 2 m
Soehnstaetten Germany	Hills of moderate height	1:10 000	1:3 000	1:5 000 - 5 m	1:1 000 - 1 m
Hannover Germany	Smooth terrain	1:4 000	1:1 500	$P(\varepsilon > 1\,000 \frac{m^3}{ha}) < 5\%$	$P(\varepsilon > 400 \frac{m^3}{ha}) < 5\%$