

A PC-BASED EDITOR FOR DIGITAL ELEVATION MODELS

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ABSTRACT

A graphical editor for Digital Elevation Models has been developed. It is written in C for 16-bits personal computers and it is intended to be used as an editing station during data acquisition.

The editor continuously updates a DEM and displays contours on a graphic screen. Randomly located data points as well as breaklines are handled. In this paper software considerations and basic editing functions are described.

INTRODUCTION

Along with the increasing use of computers to handle terrain information, elevation data is used for an increasing number of applications. The processing of elevation data includes several steps, such as data acquisition, pre-processing (editing, filtering, co-ordinate transformation etc), main processing (interpolation), storage and output of result (contour maps, profile plots, volume calculation etc).

The acquisition of elevation data may be performed using many different methods, for instance photogrammetric methods, geodetic field measurements, digitalisation of existing maps or elevation profiles, recordings from airborne lasers or radars, GPS etc. In the past, the data acquisition phase was separated from the preprocessing and main processing stages. But during latter years, these stages have been more and more intergrated, resulting in improved performance and cost reduction.

During the latter years, there has been a trend to improve the photogrammetric data acquisition by using computer graphics (Simonsson, 1982 and Kölbl, 1984). When specific features, such as buildings, roads and rivers etc, are digitized, the use of interactive graphics has shown to be of great value. Erroneous codes are detected and the completeness of the acquired data is checked.

The use of interactive graphics for photogrammetric data acquisition of DEM's, has been proposed by Östman (1982).

Fundamental algorithms and data structures for such a PC-based graphical DEM editor was later described by Östman (1984 and 1986a). When using this editor, the operator may measure irregularly distributed points, while a DEM is continuously updated and contours are displayed on a graphic screen. The editor handles single point measurements as well as breakline measurements.

This editor is not to be regarded as a complete system. It should instead be considered as an editing station within a larger system. Although this approach intergrates the data acquisition, the preprocessing and the main processing, its capability for a flexible presentation of the elevations is limited. For such purposes, interactive work stations as provided by the major CAD/CAM manufacturers may be used.

One reason for developing this on-line graphical DEM editor was that optimum sampling patterns for DEM's were to be studied. It was here originally assumed that an increased geometric quality of the DEM would be achieved if the points to be measured were selected with respect to the topography. However, this assumption was later found to be incorrect (Östman 1986b). In this work it was found that regular grid measurements complemented with breaklines gave about equal standard error in interpolated elevations as compared with operator selected points. There are however two important limitations in this study, that should be observed. Firstly, the average point spacing for photogrammetric data acquisition is rather small. In applications where a larger point spacing is used, the importance of operator selected points may increase. Secondly, the standard error of interpolated elevations is a very limited descriptor of the quality of the data. It is a very general descriptor but it is not well suited to the description of local characteristics.

Regardless of the conclusions drawn by Östman (1986b), a graphical DEM editor has been constructed. The purpose of this paper is to give a brief overall view of the hardware requirements, some programming considerations and to describe the main editing functions of the DEM editor developed. The main benefits of the editor are that the completeness of the data is checked and that large errors within the measurements may be detected. On basis of this presentation, it is hoped that this technique will be evaluated and used also for other applications.

HARDWARE REQUIREMENTS

The hardware of the editor consists of two major components (Figure 1). The first component is a co-ordinate input device, for instance a photogrammetric stereo instrument. The second component is a micro computer. So far, an IBM

PC/XT has been used, but other IBM compatible micros can be used. The program requires at least 256 Kbytes of primary memory. A Winchester disc for the storage of programs and data is recommended.

The contours are displayed on a graphic screen. For data acquisition purposes, the standard IBM monochrome display is usually sufficient.

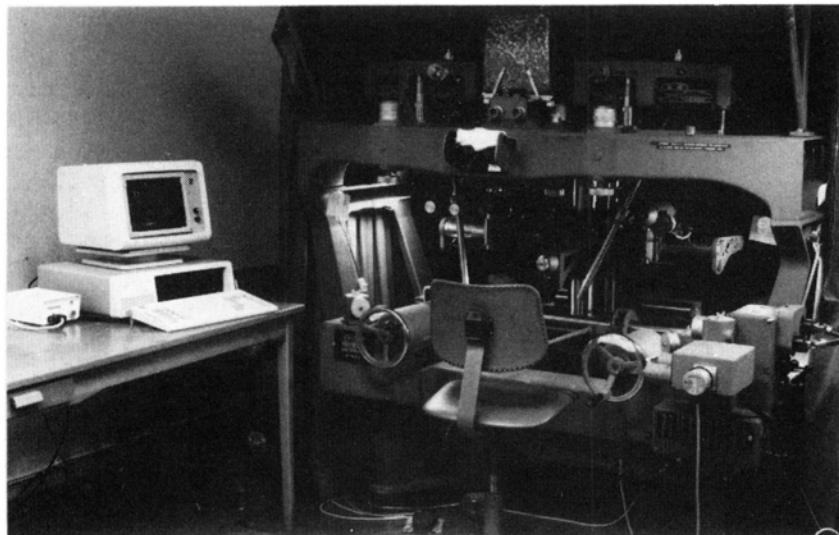


Figure 1. Stereo Plotter and Personal Computer for the Acquisition and Editing of DEM Data.

PROGRAMMING CONSIDERATIONS

The software of this editor is mainly written in C, except for some standard basic routines for graphics and file management. The choice of C as the programming language increases the portability of the source code, as compared with for instance FORTRAN.

The internal file structure consists of four regular grids and one linked list (Figure 2). The grids contain the necessary information for the updating of the DEM when measurements are entered or deleted, while the linked list contains the co-ordinates of the measurements. The links in the co-ordinate file are used to chain polygons (breaklines) and as an overflow link in case measurements are too dense. The data structure is described in more detail by Östman (1986a). Access to the internal files are made using

When measuring single points, randomly located points may be entered. As the data are acquired, the DEM is continuously updated and contours are displayed on the graphic screen. In Figure 3, a sequence of single point measurements is illustrated.

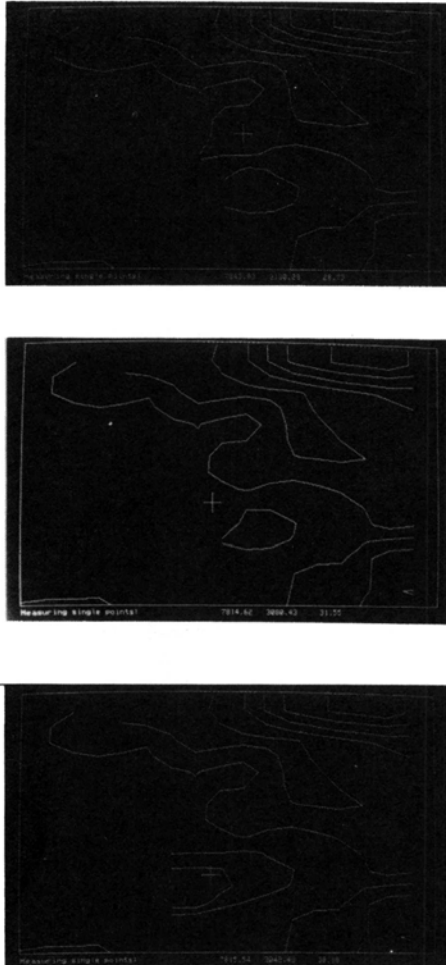


Figure 3. Displayed Contour Lines from a Sequence of Single Point Measurements. The cursor indicates the last registration made.

As seen in Figure 3, the updating of the DEM and the contours is only performed within a small window, surrounding the measurement. For interpolation, the weighted mean interpolation is used and the width of the weight functions specifies the size of the window to be updated. Currently, a parametric cubic convolution function, as described by Park and Schowengerdt (1983), is used as a weight function. The interpolation parameters can be chosen by the operator. In order to provide nonisotropic interpolation, the parameters are separated into x and y.

When measuring breaklines, subsequent registrations are connected to polygons and stored in the measurement file. Along with the registrations, the DEM is updated and the contours are displayed. When breaklines are measured, the weight functions of the surrounding single point observations are truncated. This means that measured elevations of one side of a breakline do not affect the grid nodes on the other side.

The main purpose of the program is to provide editing facilities during the sampling of DEM's. When entering the editing command in the main menu, the points and breaklines measured so far are displayed on the screen, together with the contours. By moving the cursor with the keyboard, individual registrations can be manipulated. The editing function for single point measurements consists only of a delete function, but it has to be confirmed by the operator.

When editing the breaklines, six commands are available for the operator, namely delete (a node in the breakline), insert (new nodes), move (a node), join (two nodes), cut (the breakline between two nodes) and append (new nodes). From a programmer's point of view, these commands are arranged in two levels.

The bottom level consists of the join, cut and append commands. To be able to join two nodes, both nodes have to be either starting or ending nodes. To be able to cut a breakline between two nodes, these nodes have to be linked together. The append command, at last, works only on starting and ending nodes.

The commands on the top level (delete, insert and move), use the three basic commands (join, cut and append). A delete command means for instance that a node of a breakline is to be deleted. This commands consists of two cuts and one join operation (Figure 4).

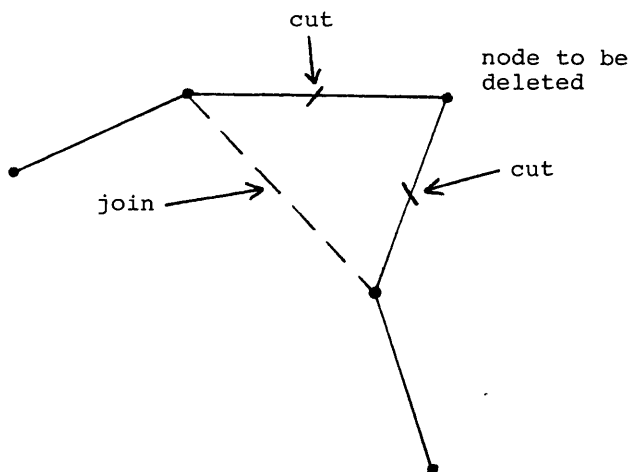


Figure 4. Fundamental Operations for Deleting a Node.

In the same manner, the insert command consists of a cut, an append and a join operation, while the move command consists of two cuts, one append and one join operation. During these commands, the double linked list of the measurement file is updated, together with DEM and the contours.

The other commands that can be entered into the editor are commands for supporting grid measurements, setting of the viewing parameters (contour interval and the graphic window), generation of a hard copy of the displayed image on a graphic printer or loading external measurements stored on file. These commands are regarded as self-explanatory and will not be further described here.

The last command to be described in this paper is the command for checking the consistency of the data. For interpolation, the weighted mean interpolation method is used. For each grid cell, the elevation and its accumulated weight is stored in two grids of the internal data structure (Figure 2). A low accumulated weight indicates that measurements are missing in that specific area. A local densification may then be needed.

Another consistency check is performed by comparing the actual measurements and the corresponding elevations as interpolated from the DEM. A large mismatch may be due to erroneous registrations, too large grid spacing of the DEM with respect to the undulations of the terrain, or due to missing breaklines. Except for the case of too large grid spacing, such mismatches can be removed by proper editing operations.

THE FUTURE

The software for a graphical DEM editor that has been developed was used to study the optimum sampling patterns for DEM's. On basis of these results, the editor seems to be of less interest for photogrammetric data acquisition. It might, however, be of value for other applications. Situations where an on-line graphical DEM editor may be of interest are for instance

a) when operator selected points are needed. Apart from checking the completeness of the data and detecting gross errors, this interactive approach also implies that the operator learns successively how the measurements are treated by the algorithms. Due to this feedback, the experience of the operator can gradually be built up.

b) for checking the sampling parameters. In many cases, pre-defined patterns, such as regular grids, are used for the data acquisition of DEM's. Sometimes, for instance in difficult terrain or for non-standard applications, the uncertainties of choosing the sampling distance may be great. This uncertainty can be reduced by using an on-line DEM editor, where the operator has the freedom to add points in areas where the basic grid is too sparse.

c) for checking data reduction processes. Along with the increasing use of raster scanning techniques and matching of digital images, the need for data reduction has become apparent. While studying different algorithms for data reduction, an on-line DEM editor may be of value.

d) for other types of measurements than elevation data, for instance geophysical measurements.

If the editor is to be used in the future, this first prototype has to be revised. When performing such a revision, some general questions should be considered.

The current version runs on an IBM PC/XT micro computer. The response time is so far satisfying. This indicates that the computing power of micro computers seems to be sufficient for this kind of work. At the present time, more powerful micros, based on for instance UNIX and 32-bits processors,

are available. Since the main part of the software is written in C, which is considered as a very portable language, an upgrading on the computer side should not cause any major changes in the software.

Another important further development is the use of the GKS standard for the graphical presentation. In the current version, the GSX-VDI has been used to write device independent GKS-similar function calls. To ease the maintenance work on the software, the use of the GKS standard is encouraged.

The software was originally intended for photogrammetric data acquisition for DEM's. But the editor can of course also be used for other purposes in the Geo-science field. Along with the development of portable micro computers with graphical screens, the possibility of using graphical editors in the field has increased. A computer-supported on-line analysis of field measurements, for instance geodetic or geophysical data, may be realized in the near future. Further investigations are of course needed, to show the advantages of such an approach.

A general conclusion concerning the use of such a graphical editor is that it seems to be of minor interest for photogrammetric data acquisition. But the technique might be useful for other purposes, for instance as a field editor for geodetic or geophysical purposes.

ACKNOWLEDGEMENT

This work has been financially supported by The Swedish Council for Building Research (BFR), contract number 840432-2.

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