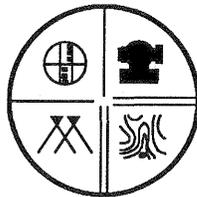


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# Integration of a GIS and a DTM

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## Abstract:

The application of Geographical Information Systems - (GIS) and Digital Terrain Models (DTM) in city planning, engineering tasks etc. is increasing. This has created a demand for an integration of the GIS- and the DTM- information within the same system. This paper describes, how a DTM and the Danish developed GIS DanGraf are merged. The concept of the integrated database is discussed and examples of new applications made possible by this facility are presented.

## 1. Introduction

The application of Geographical Information Systems (GIS) and Digital Terrain Models (DTM) is increasing in Denmark. The systems are used in town planning, road design, pipeline registration etc. Until now GIS and DTM have been used separately. Production of maps which in many cases includes contours as well as normal technical map themes, like houses and roads, have been carried out separately and finally copied together.

In 1986 the Institute of Surveying and Photogrammetry and DanGraf started a project in order to integrate a DTM with DanGraf's GIS. The main goal was to develop a system which totally integrates the DTM system with the GIS system.

As mentioned in ref. [1] the name DTM may cause a misunderstanding (is it a dataset which describes a terrain or is it a package of programs consisting of routines to manipulate a terrain dataset?). In this paper a DTM is defined as a dataset representing a given terrain with a certain quality. The programs for analysing the terrain data in the DanGraf system are called TIP (terrain information programs). TIP comprises facilities to compute contours, profiles, interpolation of single points, etc.

## 2. The DanGraf system

The DanGraf system is developed as a joint venture between Jydsk Telefon A/S, Kommune Data I/S and Kampsax A/S. DanGraf is today the most widespread GIS in Denmark with more than 70 workstations in 23 organisations. All private photogrammetric mapping firms in Denmark utilize DanGraf and each of them manage map information online up to 0.75 Gbyte.

DanGraf consists of software as well as hardware solutions to a GIS. The software offers the following facilities:

- \* Establishing, administration and revision of digital maps integrated with a DTM. The database is segment-orientated so that it can manage area of arbitrarily size without any loss of access time.

- \* Pipeline-registration as well as an information system and the establishment of complex network registration which can be used for design, consequence-calculation etc.

- \* A geolink-database for merging the digital map with other alphanumeric databases e.g. municipal databases like building and dwelling registers, cadastral information, etc.

- \* A landsurveying system, to include field data of various coding systems in the mapbase.

\* A general data exchange system. Data from the databases can be retrieved and delivered in an open format so the information can be used as input to other systems. Or data from other systems can be stored in the DanGraf database. It is also possible to use the the exchange format proposed by the Danish Society for Photogrammetry and Land Surveying, which is used as a standard in Denmark.

The software is written in Fortran IV and 77 running on Prime computers under the operating system Primos. The system is designed in such a way that it is device independent. Today DanGraf offers drivers to the commonly used workstations, plotters, etc. DanGraf has recently started cooperation with IBM Denmark to facilitate the use of the IBM 6150 as a workstation in the DanGraf environment.

### 3. Terrain information Programs (TIP)

The TIP is based on a triangular irregular network (TIN). When the DTM consists of arbitrarily distributed points, break lines and structure lines, the TIN is a convenient datastructure because interpolation is based on the original points, and break lines and structure lines constitute a logical part of the datastructure. The triangulation algorithm is based on the well know Delaunay's principle proposed by Maus [2] and MacCullagh [3]. The algorithm is modified so that it can handle break and structure lines and an excess of more than 3 points on a circle. Therefore the triangulation is unique, which means that triangulation of the same area from different windows will give the same triangulation in the area. Interpolation in the TIP is carried out linearly or the TIN can be subdivided into smaller triangles by interpolating new points from the nearest neighbouring triangles. All the calculations in the TIP are based on hashing and geographical partitioning. Due to this the computing is in anticipated linear time.

### 4. Storing the DTM in the database

In order to store a DTM in the database, the DTM must be divided into points, lines and areas. The DTM-elements can then be classified as:

#### Points:

- \* Arbitrarily distributed height points given by their X,Y and Z coordinates.
- \* Peak points given as x, y and z coordinates.
- \* Dip points given as x, y, and z coordinates.

## **Lines:**

\* Breaklines which are polygons of points describing sharp changes in the terrain such as roads, rivers, ravines etc.

\* Structurelines are very similar to breaklines, but they only describe more soft changes in the terrain, Steidler [4].

## **Areas:**

\* Dead areas are areas inside the DTM where no DTM data, have been measured. This means that no interpolation takes place inside dead areas.

\* Measured areas are the opposite of dead areas, indicating areas which have been measured.

\* Mesh areas are areas defined by points with x and y coordinates. Mesh areas are only used in the graphic display of the DTM, for example if contours are excluded from houses which are photogrammetrically measured. Thus, interpolation takes place inside the mesh area, but the information is cut out of the display.

All these DTM-elements could be stored without changes in the database. However, because of the great number of elevation points it was decided to create a new datatype, masspoints in the database to get faster and easier access to elevation points. The mapbase operates also with planimetric accuracy classes for each point. The mapbase has been extended with a height accuracy class, being essential for the integration of the DTM.

The integration offers three ways of saving the DTM in the mapbase:

### **Stored as DTM feature classes:**

This means for instance that break lines are stored in the feature class named breaklines. When DTM data are retrieved, it is through the original names.

### **Grouping feature classes into DTM types:**

The feature classes are grouped into DTM types. Roads and riverbanks belong to the DTM type breaklines, - well covers and drain gratings belong to the DTM type height points, etc.

### **DTM classifying single elements in the mapbase:**

For instance, the left side of a road can be classified as a break line and the right side as a structure line. This facility is also new in DanGraf and it is introduced because it might be necessary to point out single objects which do not fit into the general grouping of the feature classes (see also paragraph 6).

Points, polygons and areas are classified and fig. 1 illustrates how the various elements are labeled.

This leads to a new method of data acquisition proposed by Wild [5] where planimetric as well as terrain data are measured in the same process.

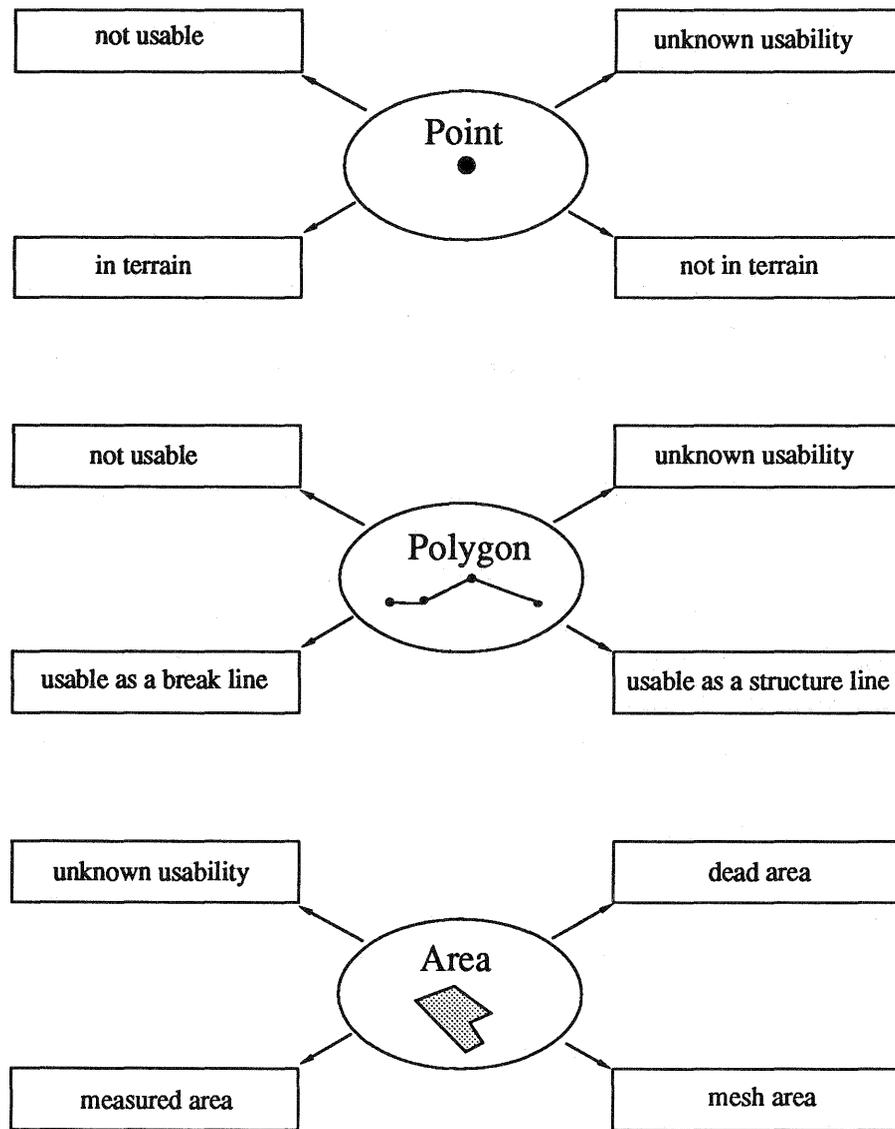


Fig. 1 Classification of points, polygons and areas. Each element can only have one label.

## 5. Integrating the DTM/TIP in DanGraf

Integrating a DTM in a GIS will influence almost every part of the GIS. In the DanGraf system, the data-interchange program MIF, the digitizing and editing program DIGIT, and the program MAP which extracts information from the database, had to be changed.

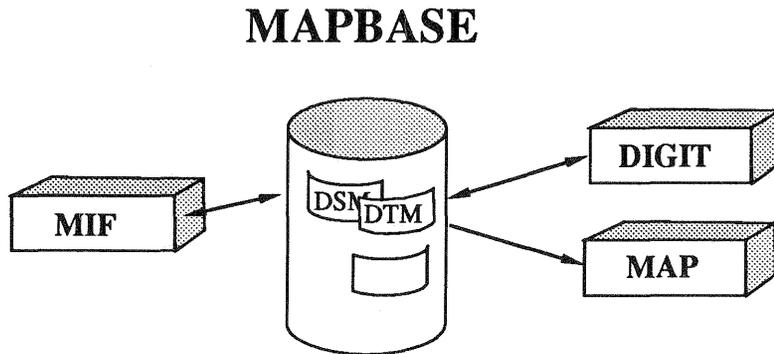


Fig. 2 The mapbase has been integrated with a DTM, causing changes in the programs around the mapbase.

The changes in MIF and DIGIT is in accordance with the new data types and classification, which are introduced to the mapbase. The extracting program MAP has been extended with the TIP. The TIP consists of 3 parts; a user interface which controls the TIP, a data retrieving module and a computing module containing triangulation and displaying facilities:

### User interface

The user interface is based on interactive communication with the user like the rest of the DanGraf system. The user interface can be divided into three different parts, one for defining the data in the database that is going to be used in the TIP, one for theme selection and one for controlling general TIP data.

In the first part an extraction list is defined. The extraction list contains the grouping of the feature classes described in section 4. When a user wants to compute contours in a area, the first action is to define the extraction list. The computing module will then use the list to retrieve the data of interest. It is also possible to use the DTM classifications, planimetric/height accuracy classes, data acquisition method, etc. as search rules.

After this the user can select the various DTM themes, and change their graphical presentation.

Finally general DTM control data such as maximum triangle edge length, interpolation method, etc can be changed.

The selections of themes, feature classes and changes of presentations parameters are stored in a macro, so that it only has to be done once.

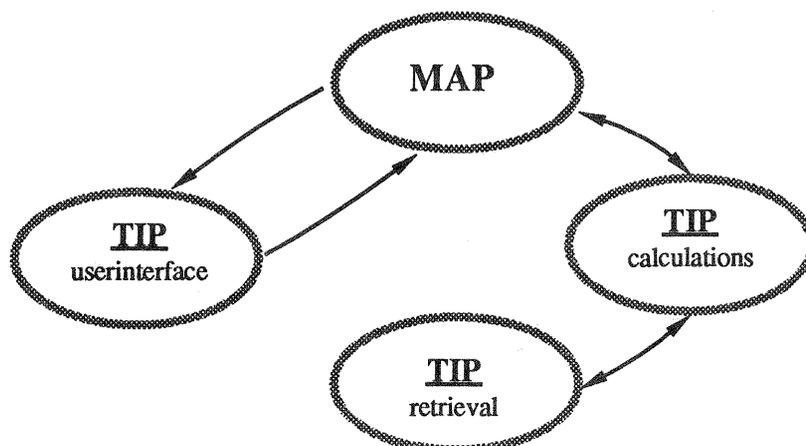


Fig. 3 The integration of TIP in MAP is very simple. The TIP or MAP programs are updated individually.

### Data retrieval

The data exchange module retrieves DTM data from the mapbase as defined in the extraction list. The extracted data are delivered in a standard exchange format. This means that changes in the database definition will not influence the TIP.

### Computing

The computing module creates the triangulated irregular network (TIN), interpolates contours and single points, and creates terrain profiles automatically. When the GIS is used for technical maps, it takes only a few minutes to compute the TIN and the contours (1000 triangles are computed per minute on a Prime 2350).

## 6. Data acquisition

The Danish mapping firm Aerokort has investigated the price for generating DTMs. The price of measuring a grid DTM, including break- and structure-lines, is twice the cost of classical contour plotting. If only the grid is measured the price is almost the same. This is in accordance with investigations carried out by Toomey [6]. However, if the DTM is established only to compute contours, it might be an unprofitable investment. So, if it is possible to use break lines, etc. in other relations the benefit of establishing DTM is improved. In urban areas DTM information is a part of the digital situation model (DSM). With the integration of a DTM and a GIS it is possible to measure both models in one step. This leads

also to new quality requirement concerning the measurements of the DSM, since it is necessary to measure and label roads, rivers etc. as break- or structure-lines. Therefore, the vectors which describe the roads, rivers, etc. must have an approximately linear variation in elevation. This might also lead to greater expenses in the establishment of the DSM; it will, however, mean a cheaper DTM.

The data capture for both models can be carried out in many ways. Some methods of interest are listed below:

1. As mentioned before, normal feature classes are grouped into DTM-types: Roads and cliffs belong to breaklines, forest areas belong to dead areas, etc.

2. Every single measured element (point, line, area) is individually DTM classified by the operator.

3. Combination of method 1 and 2, where all feature classes are divided into DTM classes, and the classification is used to point out elements which do not fit into the general DTM type.

The last method will give a useful coding system, in contrast to either method 1. or 2. because the third method takes advantage of the combination of the other two. The DTM is stored in the mapbase in accordance with method 3 (see section 4).

## 7. Applications

The TIP offers facilities for computing contours, interpolating single points and automatic profiling. In the near future, also volume calculations, perspective views, slope lines, etc are included.

A typical way to use the contouring facility is shown in fig. 4. If the DTM was constructed separately the map of fig. 4 would have been produced in this way:

1. Extraction of planimetric information from the GIS, e.g. houses and roads, etc. This information is stored in a plot file or an engraved plot can be made.

2. Generation of contours in the DTM program package. The houses are also used to cut contours. The result is stored in the same way as the planimetric information.

The final step is to copy the two maps together. This can be done digitally or analogically. It maybe difficult to do it digitally because the two plot files are not of the same format. It has been done analogically for decades, but it is of course much more time consuming.

The single point interpolation has already proved its value, which is illustrated in the following example: By one of the Danish mapping firms, Geoplan A/S, 70.000 points were recorded planimetrically for a map in a city area. These could not be used directly for superimposition in an analytical plotter. Based on a grid-measurement of elevations, height information was interpolated and added to the 70.000 planimetric points. The interpolation took place without retrieving the points from the mapbase thanks to the integration-concept.

The profiling facility also utilize the interactive communication with the user. It is possible to indicate the profile route on a graphical screen by a digitizer. For inst. one can touch points or lines in the database or use alignments in the mapbase to define the route. It is also possible to define the route by keying in coordi-



Fig. 4 Example of integration. The plot has been created in one step in program MAP. Houses, roads, etc. have been selected and plotted in the same session together with the contours.

nates, or use textfiles containing coordinates to the route. After definition of the route the terrain profile can be displayed or plotted.

## 8. Conclusion.

Integrating DTMs and GISs is only in its beginning. The new facilities of the DanGraf system is up to now just an easier and faster way of doing what always has been done. However, a great advantage of the integration is that the DTM data are stored in a mapbase, so that the database management system handles the retrieval of data from any window of the mapbase. Furthermore, the last generation of DTM programs are mostly based on sequential files, being difficult and time consuming to handle without a flexible data management system.

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