Visualisation and analysis of Mars data using ArcOBJECTS

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ABTSRACT

Geographic Information Systems (GIS) are powerful tools for integration of different planetary datasets, e.g. images, spectral data and digital terrain models which are typically given in different formats like ASCII, vector and raster. We are currently involved in a project to import large volumes of data from the recent Mars missions into a planetary GIS database for joint analysis and interpretations.

1. INTRODUCTION

Before working in GIS with planetary datasets, it is necessary to prepare them for import. Using ArcOBJECTS, a collection of ArcGIS programming objects, and Visual Basic, we create ESRI (ESRI, 1998) shape files according to a suitable specification. Regular shape files are not sufficient, because often large numbers of attributes are available to individual data points in the original ASCII dataset. Here, the MOLA (Smith et al., 2001) dataset is a typical example with over 33 attribute columns. These have to be imported using a .dbf database file. Once this is accomplished, it is possible to combine all these different datasets with raster information, such as High Resolution Stereo Camera HRSC (Neukum et al., 2004), or Mars Orbiter Camera MOC (Mallin et al. 1992) images, or MDIM 2.1 (Archinal et al., 2003) maps for joint analysis.

Subsequently, we have developed an improved method for analysis of volumes of large areal extent. ArcGIS Desktop provides a measurement with the "Area and Volume Statistics" module. It is possible to "calculate statistics above plane" or "calculate statistics below plane" for volume. This is not accurate enough for measuring, e.g. craters or valleys covering large areas, because the local surface may deviate from a planar surface. Furthermore it is not possible to specify a carefully selected area, but only the entire dataset. In our solution to the problem, we consider the resolution of the underlying digital terrain model, the slope of very large areas and the choice of a defined sub-area for accurate surface feature analysis of differential levels. We also implemented ArcOBJECTS to define our appropriate solution.

We have applied our GIS tools for various geologic mapping and interpretation tasks, and for 2d and 3d visualisations and analysis. We will demonstrate the possibilities to import, measure and project large datasets in different formats with ESRI's object model for ArcGIS 9.X., presenting different examples.

2 CARTOGRAPHIC REFERENCE AND DATA BASIS

2.1 Cartographic References

To implement a geodetic accurate and consistent database, which is essential for comparative analysis, all datasets have to be transferred into the same geodetic reference frame (i.e. the same coordinate system / projection and reference surface) (Deuchler et al., 2004). Using our experience in referencing planetary data within GRASS (Deuchler et al., 2004) we decided to use a similar reference format in ArcGIS (Saiger, 2004) see figure 1.
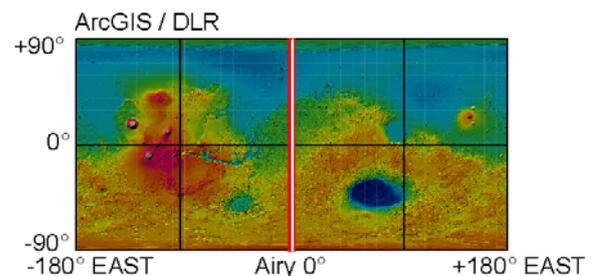

Figure 1: Reference System for Mars within ArcGIS

Combining data in different formats within ArcGIS, the input data have to be prepared in a different way.

2.2 Raster data sets

The 8-bit raster image data of HRSC, MOC or MDIM2.1 should be available in Vicar format (VICAR = Video Image Communication and Retrieval) and have to be converted to a ESRI BSQ, Erdas RAW or ER Mapper format which can be imported straight forwardly to the ArcGIS software.
The 16-bit Digital Terrain Models derived by MOLA and HRSC were converted to Erdas RAW or ER Mapper format. (Saiger et al., 2006)

2.3. Vector formats

A vector graphic is two or three dimensional, composed of basic graphic elements like points, lines and polygons. They can be saved in a lot of different formats but in this case we use the special format to work in ArcGIS called an ESRI Shapefile. (ESRI, 1998)

2.4 ASCII tables

During the import of ASCII tables like MOLA (Smith et al., 2001), HRSC footprints or Thermal Emission Spectrometer TES (Christensen, et al., 1992) data into ArcGIS it is necessary to observe some rules:

- The first row is reserved for the header
- The second row defines the kind of values ("s" for character or "d" for real numbers)
- The first column contains the longitude
- The second column contains the latitude
- The separator is a semicolon, comma or tabulator

3. METHOD

We are working on the basis of commercial GIS software ArcGIS 9, ArcGIS 9.1, ArcGIS 9.2 BETA including the ArcGIS extension 3D-Analyst running on a Microsoft Windows XP platform provided by ESRI.

The core of the software package is based on ESRIs ArcOBJECTS® (ESRI, 2004, Höck, et al., 2003) which ones are as Microsoft's Component Object model (COM) summarized. This brings the advantage of the language-independence within all programming languages which support the COM Technology. This technology is based on a client / server principle.

The COM server provides the classes (ArcOBJECTS) and their interfaces for the client. With the aid of these interfaces ArcGIS can be adjusted, manipulate and enlarged. Detailed information on the object model used, and its classes and interfaces are found on ESRI's developer website http://edndoc.esri.com/arcobjects/9.0/

3.1 Developing Environment

We develop the ArcGIS tools using Visual Basic For Applications (VBA) and Visual Studio .NET from Microsoft.

3.1.1 VBA

The VBA Software is available free for ArcGIS Users and similar to Microsoft's Visual Basic 6. It allows the development of VBA Macros running without compiling and linking. The user may test directly the macro after starting it in the ArcGIS environment at runtime but it works only on a local machine.

3.1.2 Visual Studio .NET

Visual Studio .NET is a programming package provided by Microsoft, too, including the object oriented languages Visual Basic .NET and C#.
.NET is a technology by Microsoft that will detach the previous COM Technology in the long run, but reuse it, however, with the aid of the so called interop-technology. In this case the COM objects will be transferred to packaged .NET classes. For further information please look at the Microsoft developer website. http://msdn.microsoft.com/netframework
With this costlier form of development the distribution and facility of the generated components is simple. After compiling it can be used as an executable (exe) or a dynamic link library (dll).

For the distribution it is necessary to use a setup routine to register all components in the registry of the operating system and ArcGIS.

4. RESULTS

4.1 DLR ASCII2SHAPE

We developed a program with .NET and ArcOBJECTS which generates ESRI shape files (ESRI, 1998) from text files with coordinates. Shape files do not include only pure geometry data but they can have an almost unlimited number of attributes (linked by their FID - Feature Identification Number). The correct formatting and processing of the text files was described in chapter 2.4. To start the process the path points to a given source
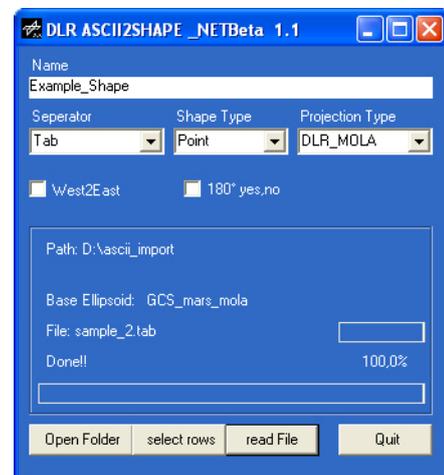

Figure 2: Program surface ASCII2SHAPE

folder, in which there are as many files as desired. Furthermore the separator, the target projection and the name of the shapefile to generate are indicated.

4.1.1 Line Feature

All files from the source folder are processed in turn. As an attribute each file is given its source name and minimum and maximum values of the expansion in geographical coordinates. Supplementary information behind the coordinates in the ASCII file is ignored but a separate file can be linked in by its FID (see figure 4.1), however, with the readily generated Shapefile.

4.1.2 Polygon Feature

The basic procedure under 4.1.1 to which attention is paid here is that the order of the coordinates is kept and that the last entry corresponds to the first so that the polygon can be closed. It has not always been possible to guarantee this, so the first and the last entry in the coordinate list are adjusted where appropriate so that the polygon is closed. In Figure 3.1 you see an example for a created polygon shape. It inherits all footprints from the HRSC experiment of the ESA Mars Express mission until June 20, 2006 between latitude ± 30° in an equidistant cylindrical map projection.
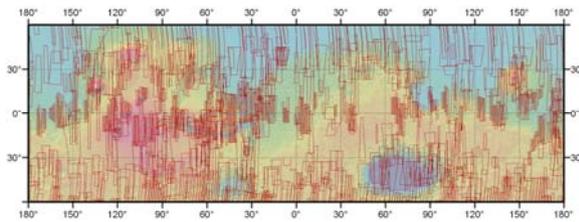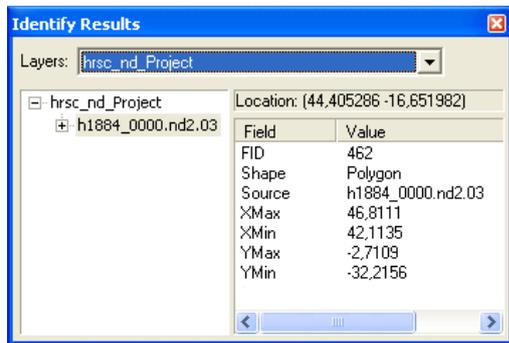

Figure 3.1 coverage by HRSC Footprints

Figure 3.2 Identify results of a polygon feature

4.1.3 Point Feature

During the generation of a stigmatic geometry the coordinate can be handed over with our program more than only once. This means before the program is started a separator must be indicated (see chapter 2.4). This separator in the source files defines which fields are written in which column of the DBF table. However the attributes in the DBF table join with the Shapefile during the explicit FID. So as many attributes as desired may be linked with a coordinate to select features by attributes to identify them or obtain new cognitions.

The figures 4A to 4D shows thermal emission spectrometer (TES) information of the Mars Global Surveyor mission. It shows a filtering by the imported Attributes to improve the information of the surface temperature. Figure 4A is a HRSC image to identify the region. It shows the caldera of Olympus Mons (overlay is a MOC image). Figure 4B shows the raw unfiltered point information of the TES measurement of surface temperature. Figure 4C shows the same data but filtered by the "quality" attribute. This means all data with quality = 0 have been removed. Figure 4D shows the improved data with quality attributes better than zero and recorded between 1 am and 5 am. This is possible by the

record "local time" attribute. The color ramp are sorted from 0 [k*100] (dark red) to 290 [k*100] (dark blue).
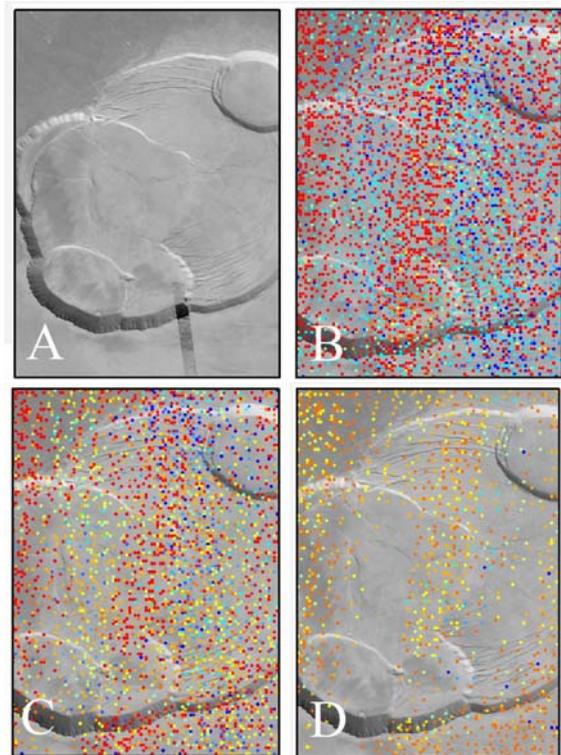

Figure 4.1 Improve data by attributes

Figure 4.2 displays the identified result for an unfiltered point feature within ArcGIS.
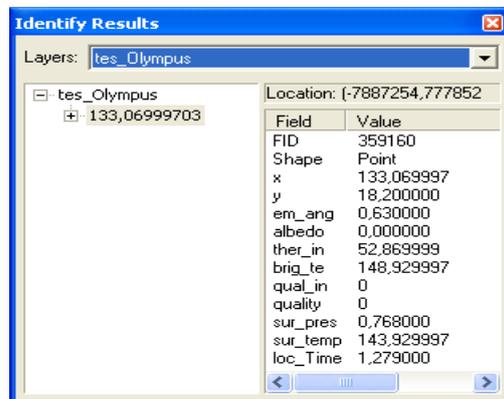

Figure 4.2 Identify Results from a point feature

4.2 DLR Toolbar

The DLR Toolbar is a collection of useful functions that facilitate the handling of a large volume of heterogeneous data in ArcGIS. An example is the "Black" module, which toggles the black background information from raster information which contain their "no data" value.

Figure 5 DLR Toolbar

Another function lets you mark any position on your map by a graphic element. On this marked position the function reads the latitude, the longitude, and if available the pixel value of a digital elevation model and offers you the facility to comment this coordinate. This data will be written into a text file which is accessible under Unix or Windows for further use.

Furthermore it is possible to measure the area in equal-area map projected polygon features, or to complete the available information from raster information, such as height or slope to a shape file attribute table. A very useful function to measure volume will be explained in section 4.3.

4.3. Volume calculation of Mars' impact craters based on raster data

The availability of digital terrain models often suggests to the possibility to use these as a basis for volume calculations. It was found that this presumption contains some danger in handing the calculation to software in the belief that this software determines the volume without a lot of communication. It was recognized that the used software packages did not pay attention to the projections used for the representation. This lead to the calculation of volumes on basis of distorted areas. Another important item is that programs can calculate a volume only from a given height level. The height could be entered optionally by the user and/or it could be determined using the middle, minimum or maximum height of the individual points of the crater.

Furthermore it should be considered that the ejecta of a striking impactor deposit themselves around the crater. The volume of a crater is, however, only the volume up to the pre-existing surface (Melosh, 1996). A mapping of the crater edge is absolutely not the crater edge, but often a mapping on the ridge of the ejected material, since the transition from the crater to the ejecta is not distinct.

Within the framework of a master's thesis a concept was created in order to model the former relief through inclined planes and to use these for the volume calculation as a limit. This approach also facilitates the calculation of volumes of long objects, as for example flowing-structures in the same way as the calculation of sublimating ground forms.

Points around the craters which are supposed not to be influenced by the ejecta or other craters must be mapped out by an operator for this purpose. The practical realization occurred through mapping of a polygon. Within the polygon the points are sorted, which eases a simple distribution in planes. For every vertex the three dimensional coordinates can be determined. The grouping of three points forms the basis of an inclined plane. Each plane will be saved as a polygon (triangle), defined by its three base points. The combination of many points leads to a comprehensive covering of the crater with differential planes, according a special algorithm, compare figure 6. So the number of created planes depends on the number of mapped points, see figure 3 and 4.

If these points are lying beyond the ejecta, the masses above and below the planes can be considered separately (see figure 6 and 7).
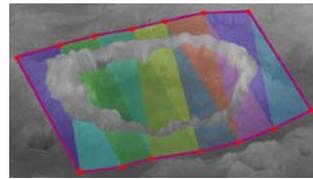

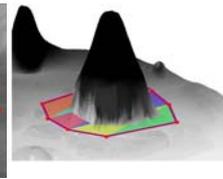Figure 6: covering of a crater with differential planes (triangles)

Figure 7: volume calculation of a sublime form

Due to the fact, that these points can be lying greater distances from the actual crater, the probability is very high, that there can be also other impact craters and/or the ejecta masses within the polygon. Since it is not supposed to calculate the volume of several craters at once, it is indispensable to map the field in which the volume is supposed to be calculated. This is also realized through a polygon (see figure 8 and 9).
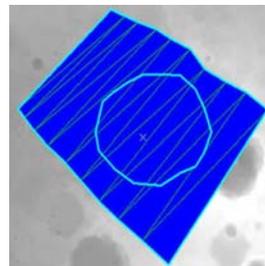

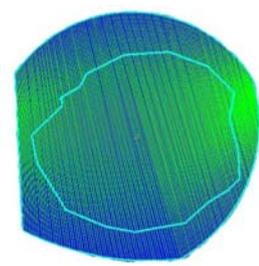
Figure 8: coverage with only a few inclined planes

Figure 9: coverage with many inclined planes

Following the idea to use different inclined planes, which adapts to the terrain, for each pixel the required volume difference has to be computed separately (Behend, 2005). The lower height has to be obtained from the digital terrain model but the upper height has to be computed in the inclined plane, in which triangle/polygon-borders the centre of the pixel is lying. The calculation occurs by vector analysis (Lindner, 1994), by using the three plane-building points (base points), see figures 10 and 11.
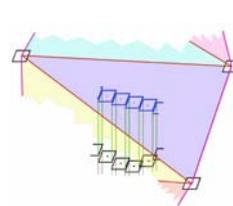

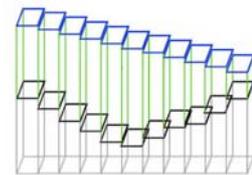Figure 10: computation of heights at location x,y

Figure 11: volumes of a pixel row

Regarding the latitude (based on a Plate-Caree-Projection) a correction for the surface of each pixel is determined accordingly to the influence of the latitude. Additional other interacting effects were investigated, such as radial effects of heights over zero height, based on the MOLA-globe (Seidelmann et al, 2003).

Tests produced volume differences of up to 6 percent compared to calculations with one horizontal plane with an average height.

Due to the fact that the volume depends on the mapped points, several tests were made. So the volume deviates for one crater up to 25 percent (percentage between the

lowest and the maximum height within 10 successive measurements), depending on the position and extent of the enclosed polygons. Deviations not only refer to calculations with inclined planes but also to calculations with horizontal planes. So it should be pointed out, that both models range within the same scope. More research is essential to gain more accurate results and to interpret them.

5. CONCLUSION

The available modules are being continuously improved. Also new modules for map layout or functions for geological and geomorphologic interpretation will be simultaneously developed in order to facilitate the handling of planetary data records, specifically for Mars.

It can be definitively said that the adaptation of our own approaches, in particular for planetary cartography, is optimally achieved by means of ESRI`s ArcGIS and ArcOBJECTS.

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