

ANALYSIS OF MARS DATA USING ARCOBJECTS AND MODELBUILDER

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ABSTRACT

Geographic Information Systems (GIS) are basic tools for integration and analysis of different planetary datasets, e.g. spectral data, digital terrain models, images or vector data. We are currently involved in a project to import large volumes of data from recent Mars missions into a planetary GIS database for joint analysis and interpretations by available modules and own methods.

1. INTRODUCTION

For the analysis of planetary datasets, GIS applications have become popular. Before working in GIS with vector datasets, it is necessary to prepare them for import. Using ArcOBJECTS, a collection of ArcGIS programming objects, and Visual Basic modules and, we create ESRI (ESRI, 1998) shape files with 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. Typical examples are the MOLA (Smith et al., 2001) dataset with over 33 attribute columns or TES data with 15 attribute columns (Christensen et al. 1992). We stored these large datasets in an open source MySQL database for better handling.

Once this is accomplished, it is possible to combine the vector 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 been involved in several planetary science applications. First, we have developed an improved method to find and analyze drainage networks on Earth and Mars and their potential watersheds. 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 visualizations 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 transformed 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). Combining data in different formats within ArcGIS, the input data has to be prepared in a different way, based on the MOLA sphere with all axes by 3396 km.

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 has to be converted to a ESRI BSQ, Erdas RAW or ER Mapper format which can be imported in a straightforward way 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 Follow 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 or tabulator

3. METHOD

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

The core of the software package is based on ESRI's ArcOBJECTS (ESRI, 2004, Höck, et al., 2003) which are summarized as Microsoft's Component Object model (COM). 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 more functionality can be added. Detailed information on the object model used, and its classes and interfaces are found on ESRI's developer website <http://edndoc.esri.com/arcobjects/9.1/>

3.1 Developing Environment

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

The VBA Software is freely available for ArcGIS users and similar to Microsoft's Visual Basic 6. It allows the development of VBA Macros which run without compiling and linking. The user may test directly the macro after starting it in the ArcGIS environment during runtime on one local machine.

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 replace 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 check the Microsoft developer website (see <http://msdn.microsoft.com/netframework>). With this costlier form development the distribution and setup 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 DB2SHAPE

We developed a windows front end with Visual Basic .NET to create specific shapefiles as point-shapes, polyline-shapes or polygon-shapes from a planetary Mars database. Thus, it is possible to search very large datasets for attributes or label points from MOLA, TES, HRSC, or the USGS crater catalog ue using ArcOBJECTS and MySQL Connector Net 1.0.8. This results in smaller datasets which facilitate the handling in ArcGIS for further analysis. Figure 1 shows an example of overlapping HRSC footprints, classified by their ground – start resolution, in combination with craters (light blue). The background is a shaded MOLA relief map, based on a 463 m/pixel grid in a Robinson projection.

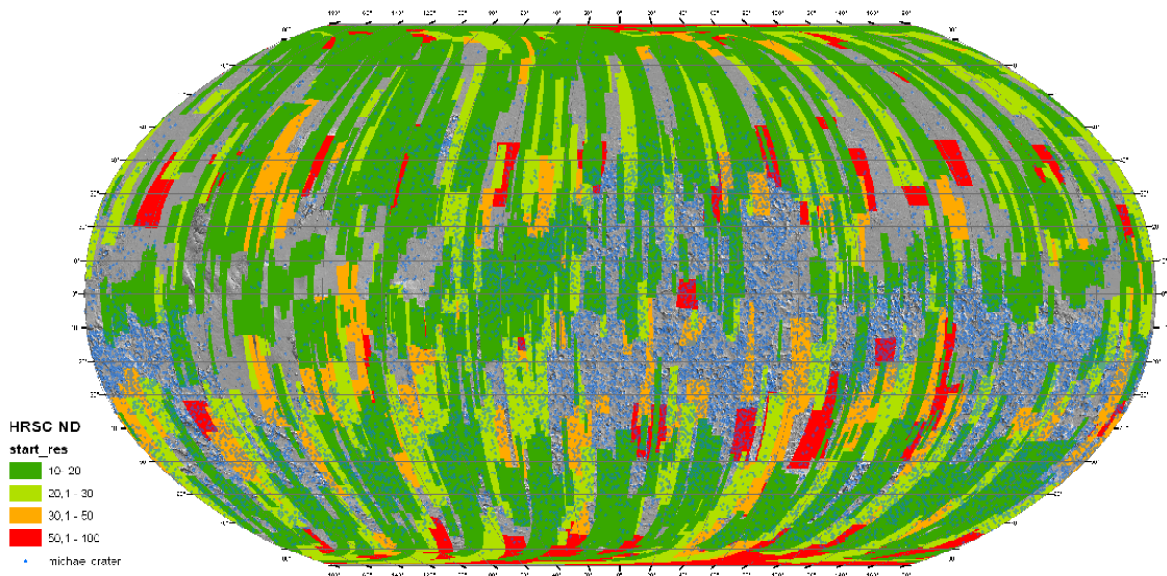


Fig. 1 HRSC footprints combined with craters

4.2 DLR ASCII2SHAPE

In addition we developed a program with .NET and ArcOBJECTS which generates ESRI shape files (ESRI, 1998) from text files consisting of 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 section 2.4. The process is started with the

path to a source folder, containing as many files as desired. Furthermore the data separator, the target projection, and the name of the output shape file are required.

4.2.1 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 to it by its FID (feature identify number), in the final generated shape file.

4.2.2 Polygon Feature

In contrast to the generation of line features the order of the coordinates is kept and the last entry corresponds to the first one so that the polygon is closed. Since it is not always possible to guarantee consistency of the first and last coordinate pair, both entries in the coordinate list are adjusted where appropriate so that the polygon is forced to close.

4.2.3 Point Feature

During the generation of a point 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). The separator in the source files defines the relation between the fields and the columns in the DBF table source files. However the attributes in the DBF table join with the shape file 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 draw new conclusions. Figures 2A to 2D show thermal emission spectrometer (TES) data of the Mars Global Surveyor mission. It demonstrates a filtering of the imported attributes to improve the information of the surface temperature. Figure 2A is a HRSC image of the region without any superimposed data, showing the caldera of Olympus Mons (overlaid is a MOC image). In figure 2B the raw unfiltered point information of the TES measurement of surface temperature are to be seen. Figure 2C shows the same data but filtered by the “quality” attribute. This means all data with quality = 0 have been removed. Figure 2D shows the improved data with quality attributes better than zero and recorded between 1 am and 5 am. This is possible by interpreting the “local time” attribute. The color ramps are sorted from 0 [k*100] (dark red) to 290 [k*100] (dark blue).

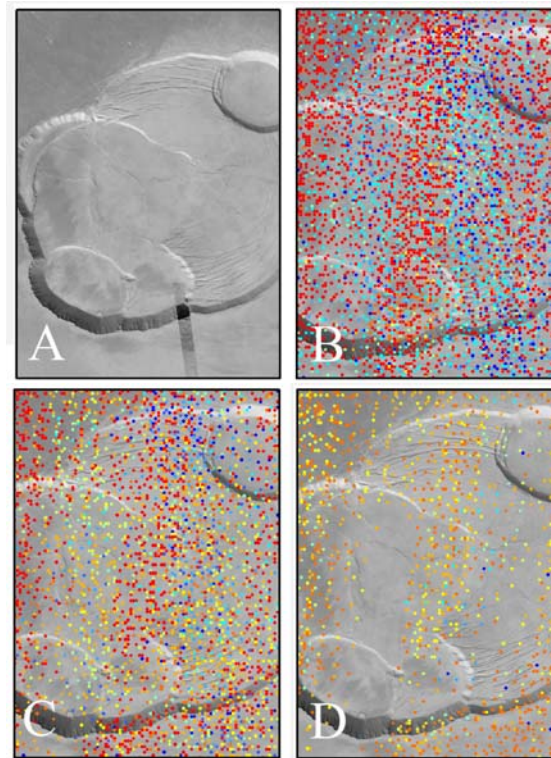


Fig. 2 TES thermal emission data improved by attributes

4.3 DLR Toolbar

The DLR Toolbar is a collection of useful functions that facilitate the handling of a large volume of heterogeneous dataset in ArcGIS. An example is the “Black” module, which toggles the black background information from raster information which contains a “no data” value. 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 to add a comment to this coordinate. This data will be written into a text file which is accessible under Unix or Windows for further use. The next feature projects all raster information in a folder into a selected map projection. The DLR Toolbar could map automatically pour points for watersheds from special stream shape files (Fig 3.3). Furthermore it is possible to measure the area in an 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. Because ArcGIS has no implemented function to unify large polygon datasets the “union” function is a very useful function which solves the problem. With the function “measure volume” it is possible to determine the volume over large areas.

4.4 Runoff water and watersheds

We use ArcGIS ModelBuilder to optimize time consuming processes in ArcGIS. In this example we calculate stream network maps on Earth and Mars for comparison. These networks are classified by Strahler order by several ArcGIS tools. A perfect result can not be achieved since a stream is computed as the steepest downhill path in a digital elevation model (DEM). Thus the accuracy is limited by the resolution of the DEM. These maps are a very much suited for hydrological mapping. Fig. 3.1 show the stream network based on an improved HRSC DTM at 50m/pixel. Furthermore an automatic detection of potential flooded areas as a modified byproduct during the Stream classification (Fig. 3.2) is possible. To create watersheds we need pour points that will be automatically created from those Strahler classified stream network shape files, using ArcOBJECTS (Fig. 3.3) and the intermediate flow direction raster from the stream network process (Fig. 3.4).

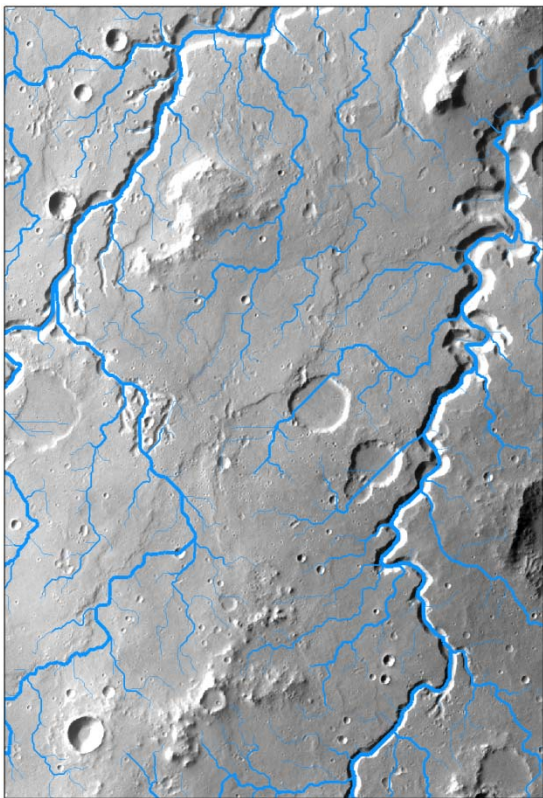


Fig. 3.1 The drainage system of Nani Valles computed using ArcGIS modules and classified using Strahler stream order. Background HRSC.

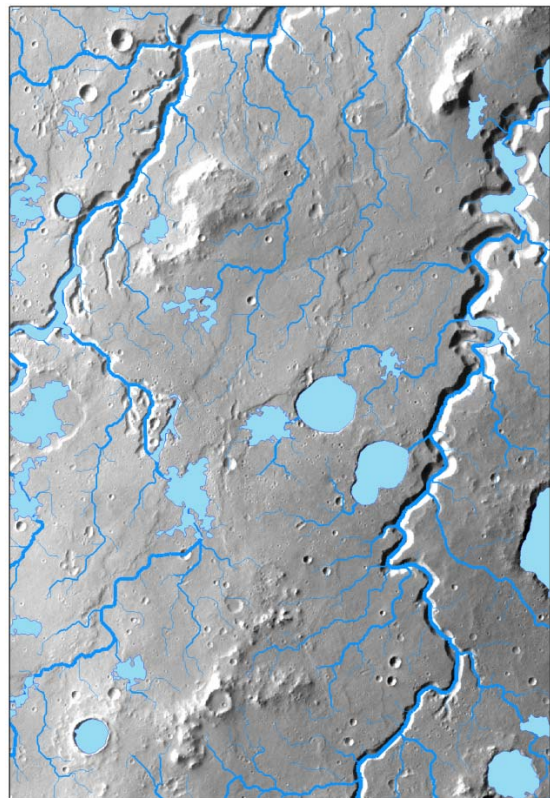


Fig. 3.2 Filled sink areas converted from raster to polygon vectors. The threshold from the polygon feature are cleared using a "minimum threshold area" criteria.

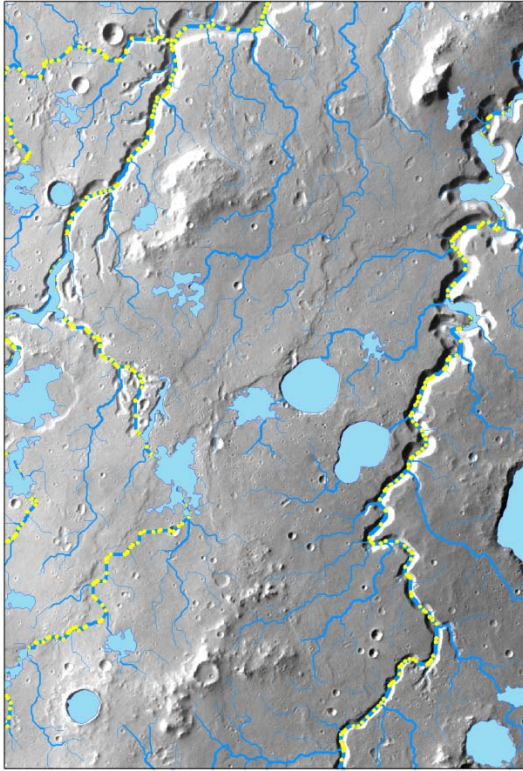


Fig. 3.3 The yellow dots show virtual pour points, the points at which water flows out, usually the lowest point along the boundary of the drainage basin. Here, we created the points from the endpoint of each line in the selected stream order.

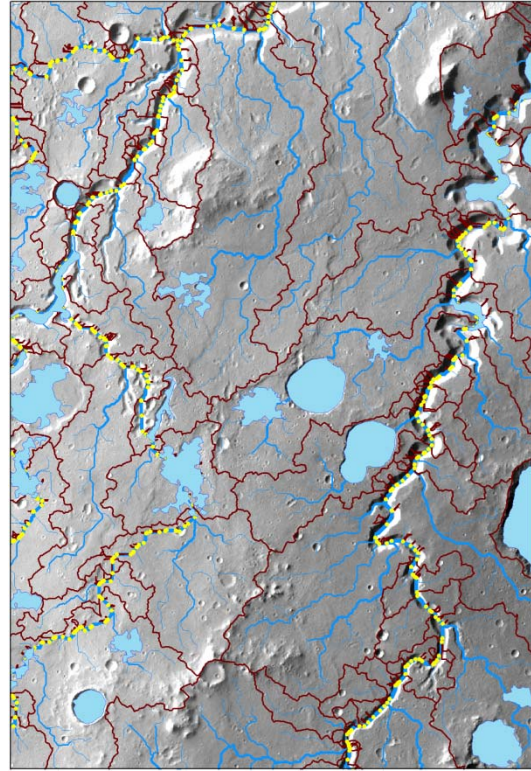


Fig 3.4. The HRSC image combined with the stream network (classified by Strahler order), the filled sink areas, the virtual pour points, and the watersheds.

The next step is to compare the results on Mars with data on Earth for exemplary areas on Earth. We compare our results with airborne photos and topographic maps (Fig. 4) to obtain information on resolution effects in image datasets from Mars and Earth.

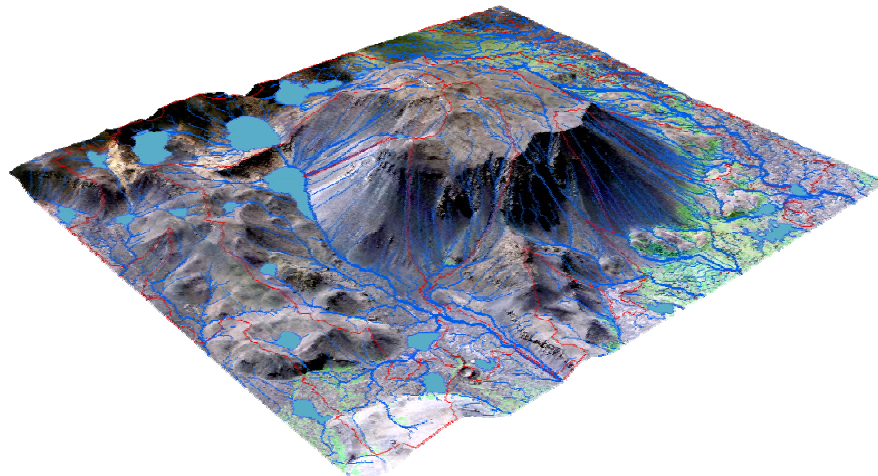


Fig. 4 3D HRSC-AX Color Scene, Bürfell, Iceland, rgb by 0,2 m/pixel, dtm by 0,5 m/pixel.

5. CONCLUSION

We have developed ArcGIS modules for import and handling of planetary datasets. The available modules are being continuously improved. Furthermore 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 said that many science applications in planetary cartography can be achieved ESRI's ArcGIS and ArcOBJECTS.

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