

Sonja Vidojević

(Department of Astronomy,
Faculty of Mathematics,
University of Belgrade)

Dejan Sandić

(Faculty of Geography,
University of Belgrade)

Kristina Racković, student

(Department of Astronomy,
Faculty of Mathematics,
University of Belgrade)

STAR MAPS DIGITIZATION AND CONNECTION WITH DATA BASES

Abstract: The first results of application of geographical information systems (GIS) in astronomy are presented. The complete digitization of specific cartographic material – star maps – is performed. The next steps are done: scanning of cartographic material, managing metadata, removing deformations of the scanned material, transferring data from the scanned material into a specific spatial data base, and, at the end, connecting recognized celestial objects to astronomical and bibliographical data bases existing on the Internet.

Key words: digitization, astronomy, star maps, geographical information system

1. Preface

In “Theorema Egregium” (URL¹ 1), Gauss says that two isometric surfaces have the same curvature. As a sphere and a plane are not isometric surfaces, projecting a sphere on the plane produces deformation of surfaces, angles and distances. Coordinate grid which is made by projecting a celestial coordinate system onto a plane is called cartographic grid and it is used as a base for drawing cartographic (celestial) objects. Theoretically, there are infinite cartographic projections and they are sorted in separate groups, depending of deformation they eliminate (e. g. Hinks, 1921; Lee, 1944; Snyder, 1987).

The most important projections are azimuthal projections because majority of star maps are made in that projection. A particular fact about them is that the azimuthal angle in a sphere coordinate system projects onto the same angle of a polar coordinate system. Depending on the position of the projection center, azimuthal projections are classified:

- orthographic - the center of projecting is at infinite distance;
- stereographic - the center of projection is on sphere surface, at point antipodal to construction pole;
- gnomonic - the center of projection is at the center of the sphere.

¹ Uniform Resource Locator

Depending on the position of the construction pole, an azimuthal projection can be polar, equatorial and horizontal.

The main problem in star maps digitalization is how to find the projection map in which it is made because there is no such information for old maps. Recognition is made visually at first, considering the view of the cartographic grid. The distinctive characteristics of azimuthal projections are segments between nearby grid lines.

When the projection of map is known, the next step is to find the construction pole. Generally, it is the point nearest to the center of the space (celestial pole – equatorial coordinate system, or zenith – horizontal).

Known projection and a construction pole enable us to transform the coordinates of celestial objects into desired coordinate system. In astronomy, it is usually the celestial equatorial coordinate system - spherical coordinate system where the position of a point is determined with two angles: right ascension (α) and declination (δ). However, to make this information precise, it is necessary to find out in which epoch map is made (for details see: Grin, 1998). The fundamental catalogue FK5 (Fricke, 1988), data base of celestial objects position, is used for this project realization. The entire catalogue FK5 in electronic form is available on Internet (URL 2).

When a celestial object is identified, its FK5 identification is used to make query which is preceded to specialized databases on the Internet. We choose two databases: one is bibliographic, and the other is the base of astronomical data of celestial objects. An ADS (Astronomical Data System), URL 3, is a bibliographic data base which contains more than 5.9 million bibliographic units organized in three groups: astronomy and astrophysics, physics, and electronic editions and publication - arXiv (URL 4). The astronomical data base center in Strasbourg (France) CDS (Centre de Données de Strasbourg) is specialized in collecting and distributing data all over the globe (URL 5). It contains SIMBAD database (the Set of Identifications, Measurements, and Bibliography for Astronomical Data). The goals of CDS are to collect all useful informations considering astronomical objects in electronic form and to make them available to astronomers all over the world.

2 Practical realization

The geographical information system is a connection of computer aid design software package CAD and the software for database manipulation. The description of geometrical shapes of some spatial object and its position in the space of graphical elements (points, lines and polygons) which are generated by the CAD software package are stored in the database with spatial elements. Tables with alphanumerical data which describe it better are assigned to spatial elements. Every spatial element from the spatial data table matches one and only one single row in the alphanumerical table. Using a relation database model, other attributes can be attached to the main table that contains attributes of spatial objects. Spatial or alphanumerical as well as combined queries can be performed on the union of tables defined in this way. The graphical representation of spatial objects can be in the shape of bitmap or vector graphics.

Software package GeoMedia Pro R 6.0 (GMPro) was used for realization of this project. The Faculty of Mathematics at the University of Belgrade received it for use for the period of two years from the developer – the company Integrgraph (URL 7), as a donation intended for support of Universities, academic and scientific research institutes. Apart from program GMPro, additional module Geomedia Image was used as well, the application of which is expanding possibilities of the basic program GMPro. One of the options of this module – algorithm for fine transformations, is used to eliminate deformations of the paper used for printing scanned maps. Software package GMPro can store data in Oracle, Microsoft SQL

or Microsoft Access data base. Using relation data base enables centralization of data which can be simultaneously used and modified by multiple users. Besides this form of data storage, it is possible to store data in other formats which are industrial standard in GIS industry, like AutoCAD (.dwg), ESRI (.shp) or Mapinfo (.mif) file format. Program function library GeoMedia Objects was developed for the software package GMPro. GMPro is completely customizable with development tools such as Visual Basic or Visual C++ which offers the possibility of creating and developing proper applications.

Unlike digitization of monographic and serial publications where the digitization process can be terminated with creation of metadata on digitized material, or with the additional editing of the scanned material using computer programs for automatic text recognition, the problem of cartographic material digitization significantly increases because apart from visual information, the map also carries along the data which are used for different types of calculus and analysis. The need to store precisely this information during the digitization makes the digitization process of cartographic material additionally complex and requires certain number of decisions about what shall be digitized and in which manner.

In order to completely digitize cartographic material it is necessary to do the following steps: 1) scan the cartographic material, 2) arrange metadata related to the scanned material, 3) eliminate deformations in the scanned material, 4) transfer the data from the scanned material to the spatial data base, 5) link the data stored in the spatial data base with astronomical data bases.

The first two steps are identical to the digitization of archive documents – in this way analogous information is transformed to digital. Star maps have been scanned on a scanner HP Design jet 4500 with resolution 300 dpi in full color scale. It is necessary to pay attention that the scanning resolution is good enough to separate the minutest points, e.g. the thinnest lines on a star map. Since there are no adequate standards in Serbia, scanning was performed according to recommendations given in the Professional manual for creating digital cadastre project of the Republic Geodetic Authority of the Republic of Serbia which can be found on the website URL 6. The third step in the digitization process is the point where the digitization process of astronomical or any other kind of maps begins to differ from the classical digitization process, precisely for the plenty of information they contain. Besides the visual information, the maps contain information on space, relations between objects in space, as well as characteristics of each and every single object on the map. The Republic Geodetic Authority gives further recommendation here as well, to construct the data model that defines classes and their spatial display, attributes, rules, relations and cartographic representation, as well as corresponding operations with the data (URL 6).

One of the problems that occur in the digitization process is the paper deformation, as a consequence of time span, so-called curl up and outstretch of the paper. They manifest in change of dimensions of the paper the map was printed on. The scanning device enters additional deformation to the final scanned image itself. The influence of these errors is eliminated in the process of paper deformation removal and georeferencing of a star map. The term “georeferencing” has been taken from the cartographic practice and represents the procedure of linking positions of digital information (points) on the scanned image with the corresponding position on the terrestrial surface (for example, geographical latitude and geographical longitude); in the case of digitization of star maps, that surface is the celestial sphere.

In order to perform this process, it is necessary to determine the type of cartographic projection which has been used to create a star map. Since there is a great number of very similar projections it is necessary to determine the proper one. Only after that it is possible to approach the georeferencing process and elimination of deformation that exist in the scanned material. The procedure consists of firstly generating rectangular grid on the layer that defines the projection. Layer dimensions are 360x90 where the basic cell measures 1x1 and represents

one square degree. Defining certain type of projection makes the program generate the grid which is visually compared to the projection of a star map. When they coincide, “on the fly” transformation is performed, e. g. the recalculation of coordinates from one projection to another. This is performed automatically within the program itself, using internal mechanism. This completes the deformations of the scanned material and georeferencing process, e. g. assigning corresponding spatial coordinates to every pixel of a scanned map in the recognized projection. All the necessary information both for the deformation elimination and georeferencing are obtained in the same step. After performed georeferencing, begins the vectorization of the map on a separate layer using drawing tools of the program GMPPro. A vector image has been formed in this way. When the layer is vectorized, elements will be defined, a set of attributes that describe objects is being created (Fig. 1).

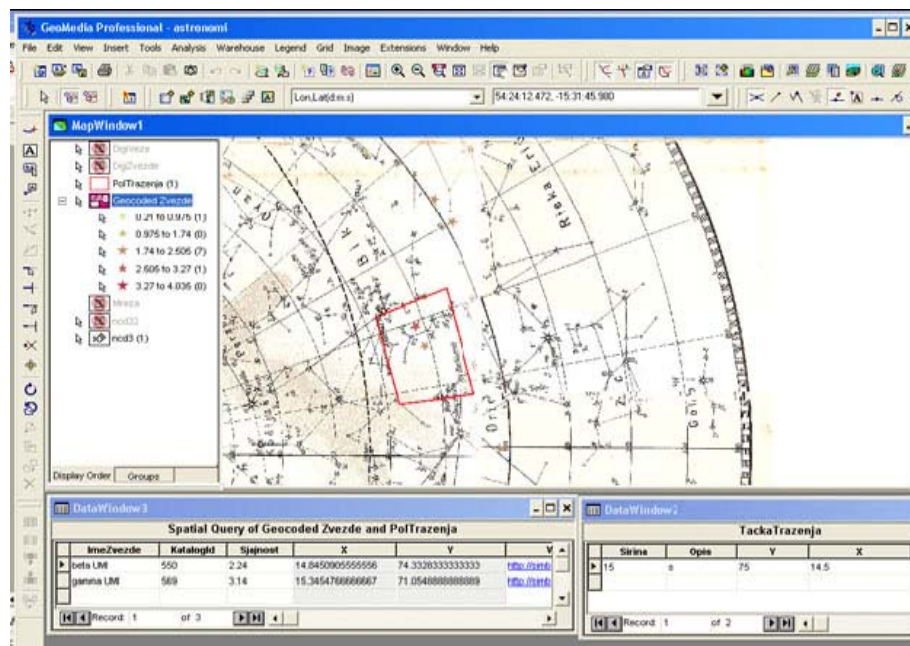


Figure 1. Screen display of the program package GeoMedia Professional with the query and result of star map look up.

The procedure of digitization of star maps doesn't end with the creation of vector graphics that represents paper map. If the epoch is not written on the map, the next step is to determine the epoch the map is related to. Fundamental catalog FK5 (epoch J2000.0) has been used for recognizing/determining the epoch. The catalog is loaded like an alphanumeric table, coordinates are transformed to the epoch we assumed the map was made for, for example B1900.0 or B1950.0, and the function of the program for drawing objects based on newly obtained data is launched. That is a coding process where the spatial object of pointy type is generated based on two chosen columns of the loaded table, which represent right ascension (α) and declination (δ). A circular buffer zone with the radius approximately equal to the shift between two epochs is created around the points representing generated celestial objects. In order to determine if the object positions from the digitized star map are situated within the buffer zone, the function “Spatial Query” of the program GMPPro is applied, which is used for spatial analysis. If the points that represent digitized celestial objects on the star map are contained within the buffer zone around the points originated from coding the catalog and if they are approximately in the middle, then the epoch is determined successfully, otherwise the whole procedure should be repeated for another epoch. When the epoch of a star map is determined, the points representing celestial objects are linked to the corresponding identifiers in

FK5 by adding one column to the table with celestial objects, where the identifiers are stored. That column is assigned as type hypertext. The value of this field consists of two parts: URL of a web page which performs the search, and identifier.

Another application of the “Spatial Query” function is the possibility to define the domain and obtain data list for all the celestial objects which are within the domain range. Well defined and carefully chosen sets of attributes for every single object in the latter phase of processing enable the creation of thematic maps. The program package allows using random number of attributes when creating thematic maps. For example, one can choose the range of apparent stellar magnitudes (one element from the set of input attributes), as an attribute to create the thematic map.

As an example, we chose a well known star Betelgeuse, α star of the Orion constellation. From the city or country sky, from almost any part of the world, the majestic figure of Orion dominates overhead in the winter time of year (northern hemisphere). High on his left shoulder is Betelgeuse (α Orionis 0549+07), the great red pulsating supergiant. When at maximum, Betelgeuse sometimes attains a magnitude of 0.4. At minimum brightness, the magnitude may drop below 1.2. The star is one of the largest known. Spectroscopic studies show that its diameter may vary by about 60% during the whole cycle. Its diameter, based on the distance (130 pc or 425 light-years) reported by the European Space Agency satellite HIPPARCOS, is about 1500 times the diameter of our Sun. Betelgeuse is not only among the largest, but also one of the most luminous stars of its class - it is the seventh brightest star in the northern hemisphere. Betelgeuse has a luminosity of about 14,000 Suns at maximum and 7600 Suns at minimum.

On the digitized star map, this star was not recognized automatically but manually. Within a circle with radius of 3 arc minutes, which is the mean square error of a mathematically generated grid, we could not find the star automatically because its position on the map was erroneous. The point representing Betelgeuse is manually linked to the corresponding identifier in FK5. In this way, one field was added to the table with celestial objects where the identifiers are stored. That field is assigned as a hypertext type. The FK5 identifier is used to make the most general query (without additional attributes and domain ranges) which is preceded to the data bases on Internet. At astronomical database CDS 772 measurements concerning Betelgeuse were found within 15 different measurement types (e. g. position, UBV data in Johnson’s UBV system, MK classifications in the Morgan-Keenan system, data from International Ultraviolet Explorer, radial velocity, rotational velocity, parameters concerning the variability of star, parallax, etc). In bibliographic database ADS 1051 bibliographic units between 1850 and 2007 were found. If one wants to obtain some particular data, it is necessary to add the corresponding attributes and domain ranges to the query.

These are the first results of application of geographical information system in astronomy generally. There is plenty room for extension and extrapolation of using GIS in different astronomy fields and also in many kinds of preservation of national scientific and cultural heritage.

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**Соња Видојевић,
Дејан Сандић,
Кристина Рацковић**

ДИГИТАЛИЗАЦИЈА ЗВЕЗДАНИХ КАРАТА И ПОВЕЗИВАЊЕ С БАЗАМА ПОДАТАКА

Представљени су први резултати примене географског информационог система (ГИС) у астрономији. Извршена је комплетна дигитализација специфичног картографског материјала – звезданих карата. Урађени су следећи кораци: скенирање картографског материјала, организовање метаподатака, отклањање деформација скенираног материјала, трансфер података са скенираног материјала у специфичну просторну базу података и, на крају, повезивање препознатог небеског објекта с астрономским и библиографским базама података које постоје на интернету.

sonja@matf.bg.ac.yu

dejan@gef.bg.ac.yu

mm03118@alas.matf.bg.ac.yu