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A Program Complex Equipped With a GUI for Investigation of 3D Structure of Solar Magnetic Fields

G. V. Rudenko, V. V. Grechnev

Institute of Solar-Terrestrial Physics, Lermontov St. 126, Irkutsk, Russia 664033, Email: rud@iszf.irk.ru

Abstract. A program packet is developed for the detailed research into the 3D structure of the magnetic fields of solar active regions as well as the overall solar magnetic field. The application realized in the IDL program environment is supplied with the graphical user interface (GUI) which ensures convenient and efficient manipulation with data.

1. Introduction

Solar activity is the result of motion and interaction of the coronal magnetic fields, so their study is of primary interest of solar physicists. We have developed a program packet for the detailed research into the 3D structure of the magnetic fields of solar active regions as well as the overall solar magnetic field.

The work with data includes two stages. On the first step, coefficients of decomposition are calculated for a selected magnetogram and recorded into special "weight" files. Then the viewing and processing of data after those coefficients is made using an application supplied with graphical user interface (GUI). The application is developed in the IDL[1] program environment.

2. Calculation of the coefficients of decomposition

2.1. Source data

Initial data are taken from daily magnetograms of arbitrary regions on the visible side of the solar disk, and synoptic magnetograms. On their basis, coefficients of decomposition are calculated.

Input data for the GUI-supplied application are the special files containing weight coefficients:

- of flat harmonic decomposition for the reconstruction of the magnetic field for selected active regions, and
- of spherical harmonic decomposition for the reconstruction from synoptic data.

Those "weight files" are computed and recorded separately by another FORTRAN program.

[1]IDL is the trademark of Research Systems, Inc.

2.2. Initial mathematical statements of boundary-value problems to be solved

a) for the reconstruction of partial frames:

$$\begin{array}{ll} \nabla \times \mathbf{B} = \alpha \mathbf{B} & + \\ \nabla \mathbf{B} = 0 & \end{array}$$

boundary conditions of the magnetic component along the line of sight (B_d) at the photopsheric level (at each point);

b) for the reconstruction of the whole surface of the Sun:

$$\begin{array}{ll} \mathbf{B} = -\nabla \phi & + \\ \Delta \phi = 0 & \end{array}$$

boundary conditions of the magnetic component along the line of sight (B_l) at the photopsheric level at the instant of passage of a point across the central meridian.

In the former case, it is possible to select the constant α of the force-free approximation. In the latter case, only the potential approximation is used.

The calculations of the coefficients of the plane decomposition are based on a new method (Rudenko, Altyntsev, & Lubyshev 1997) which allows, unlike the traditional ones, to reconstruct the magnetic field above small regions according to photospheric magnetic fields which are observed in an arbitrary site on the solar disk. In fact, it is possible to use the magnetographic data on active regions which are located close to the limb. This latter circumstance extends opportunities to study magnetic fields of active regions and the evolution while they passing across the solar disk.

The coefficients of decomposition are calculated from magnetograms. Magnetograms of separate active regions can also be processed. Precise scaling and positioning to fit the working coordinate system is accomplished automatically and can also be made in the interactive mode, as well as selection of a region of interest. Data of other types can be used.

3. GUI-supplied application

The program packet was developed in the IDL program environment. The program has GUI (Fig. 1) and provides the following facilities:

- Loading files containing coefficients of a decomposition of the magnetic field.
- Computation of all components of the magnetic field at arbitrary heights and in plane radial sections. Visualization of any (optional) Cartesian and spherical components of the magnetic field, modulus, B_l, and B_d. Images are represented either as a picture plane for any specified date and time, or as a synoptic map.
- Issue of all coordinates and the specified components of the magnetic field corresponding to the position of the mouse pointer.
- Rotation of images by the specified number of days from the current date, and setting the image to the current date and time.
- Selection of a region of interest by means of a flat rectangular box and zooming in to the selected part of the image.

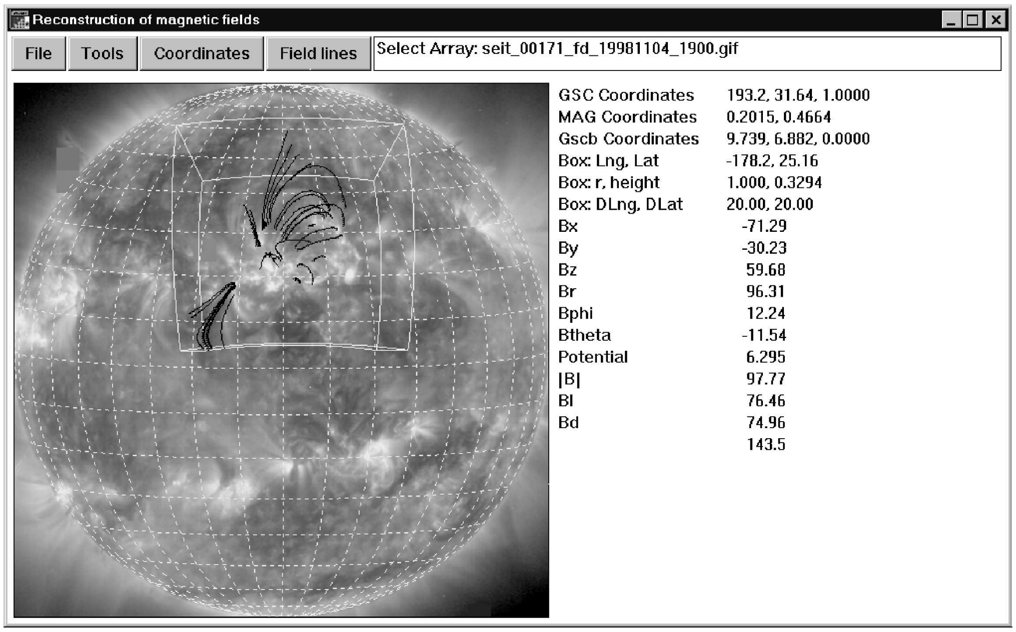

Figure 1. A screen dump of the GUI-supplied application.

- Computation and visualization of the field lines starting with the position on the photosphere specified by the mouse pointer.
- Highlighting an arbitrary field line, and issue of all coordinates and components of the magnetic field for any point along it. The point on the field line is specified by means of the mouse pointer, and its position is indicated by the marker.
- Erasing the highlighted field lines, retaining the 3D coordinates of all current starting points in a file, or loading them from a pre-existing file.
- Drawing and controlling the position and size of the 3D box for highlighting the bounded volume of computation and drawing field lines. All coordinates and magnetic components at the position of the mouse pointer are displayed which correspond to its either outer (depending on the mode) or inner surfaces. When computing the field lines, the starting points are taken from the boundary surfaces of the box.
- Provision is made for a joint processing with images loaded from standard format (FITS, GIF, BMP) files. For FITS files containing standard information about the centering of the image and the pixel size (Kitt Peak magnetograms, Nobeyama and SSRT radio maps, Yohkoh/SXT images), automatic attachment to the heliographical coordinates and to the current date and time is accomplished. For arbitrary images, the location of the disk center and the radius are determined in the interactive mode from three points on the limb. After that, rotational manipulations can be performed with this image, and it can be set to any date and time. It is also possible to overlay field lines computed from pre-loaded coefficients of harmonic decomposition of the magnetic field.

- If the additional image is a magnetogram, it is possible to highlight (by means of the 3D box) the desired regions of reconstruction of the magnetic field, and to record boundary conditions into a file. As the boundary conditions, the B_d component is used. This file is an input file for a FORTRAN program computing the harmonic decomposition coefficients of the highlighted area. When this file is generated, it is possible to specify the value of α in the equation $\nabla \times \mathbf{B} = \alpha\mathbf{B}$.
- It is possible to overlay onto the current image any other magnetic values as well as an image loaded from another file.
- Three-dimensional rotations of contours, all field lines, and of the 3D box are performed in the course of all transformations.

The program code has been checked under MS Windows 95 and UNIX with IDL versions since 3.0.1 to 5.1.

4. Conclusion

We consider a possibility to make calculations of magnetic fields for particular active regions after requests through Internet. In this case, files containing coefficients of decomposition would be calculated by our FORTRAN programs and made available.

We plan to develop a data bank and to supply it with files on the known active regions in the future.

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