# Software for Interactively Visualizing Solar Vector Magnetograms of Udaipur Solar Observatory

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**Abstract.** The Solar Vector Magnetograph (SVM) at Udaipur Solar Observatory saw its first light in April 2005. The retrieval of vector fields from the imaging spectro-polarimetric observational data requires a substantial amount of computer post-processing. The GUI-based data reduction and analysis software have been developed to make the data processing pipeline user-friendly and less time-consuming. In this paper we describe these software packages.

*Key words.* Instrumentation—polarimetry—spectroscopy.

## 1. Introduction

The magnetic field vector as measured by solar magnetographs can be displayed in more ways than one. The visualization of vectors is crucial to understanding the changes in field morphology. It is crucial to the transforming of vectors in heliographic co-ordinates and to applying corrections by performing geometric transformation for active regions especially when they are observed away from the disk center (Venkatakrishnan *et al.* 1988). These transformations are necessary before retrieving physical quantities from the observed magnetic field vectors like magnetic shear, etc.

## 2. The instrument

The schematic of the instrument is given in Fig. 1. The details about the instrument can be found elsewhere (Gosain *et al.* 2004, 2006). The instrument is basically a tunable Fabry–Perot-based imaging magnetograph which uses quarter wave-plates as polarization modulator and crossed calcites (Savart plate) as dual beam analyzer. The simultaneous measurements of orthogonal polarization components reduce the seeing induced spurious polarization signals. The straight and symmetric telescope design is used to avoid instrumental polarization to a great extent. The polarized profiles with single camera exposure can be obtained with rms noise level of < 0.5% in the continuum. The complete Stokes profile with 21 samples across the Fe I 6302.5 Å line can be performed in less than a minute with polarization sensitivity of < 0.5% of continuum.
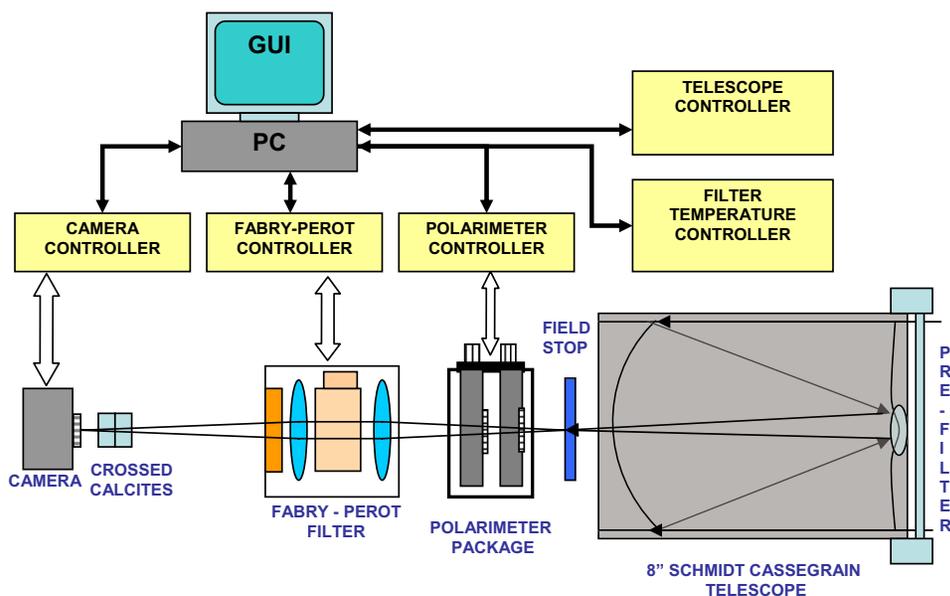
**Figure 1.** Schematic of Solar Vector Magnetograph (SVM) at Udaipur Solar Observatory.

## 3. Tools for data analysis and visualization

In order to facilitate data analysis and visualization of the calibrated data in a user-friendly way, we have developed two graphical user interfaces (GUIs). The first one is developed for performing interactive Stokes inversion of the observed profiles using a Milne–Eddington inversion scheme. While another GUI is developed for visualizing the magnetic field parameters retrieved by Stokes inversion. In the following sections we describe these software packages.

### 3.1 *Stokes inversion*

A GUI is developed for interactively inverting the Stokes profiles over the observed region (see Fig. 2) under Milne–Eddington atmosphere assumptions (Hector Socas-Navarro 2001). However, the complete inversion of the observed region is highly time consuming, taking about an hour for single dataset. A hybrid approach is being developed where weak field approximation (WFA) (Jefferies *et al.* 1991), is used for those pixels where the polarization signals are below a particular threshold. This threshold corresponds to the limit up to which WFA is valid. The threshold value is determined using synthetic Stokes profiles generated by MELANIE, whereas for pixels above this threshold, Stokes inversion is used to retrieve the magnetic field. This approach will save a lot of computational time since WFA is generally valid for a major portion of the observed area.

### 3.2 *Magnetogram visualization*

In order to visualize vector magnetogram a GUI has been developed (see Fig. 3.). The inverted data can be visualized in the form of arrows showing transverse field
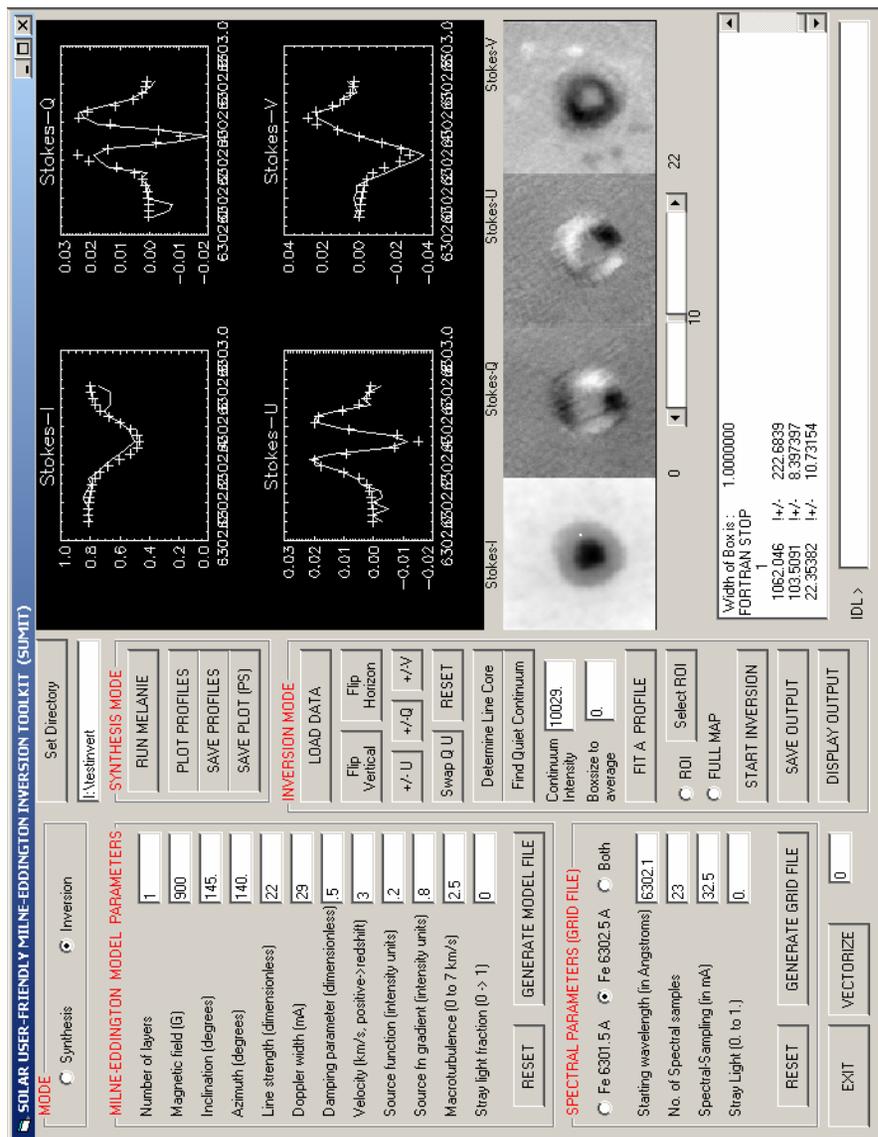
**Figure 2.** A graphical user interface for Milne–Eddington Inversion of SVM Stokes profiles.
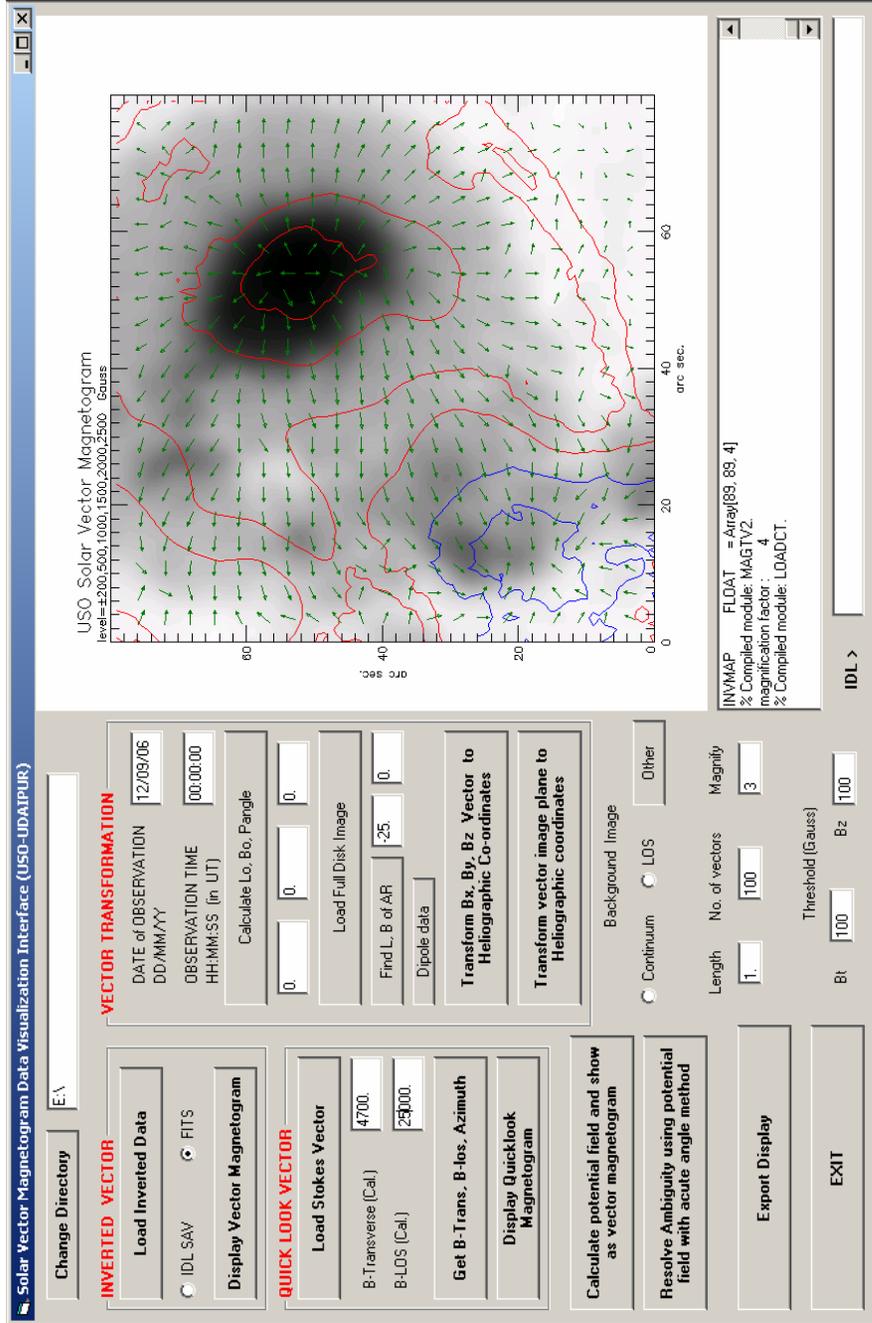
**Figure 3.** A graphical user interface for visualizing and transforming the inverted vector field data.

strength and direction while contours show line-of-sight magnetic field. The quick-look feature is also available for retrieving magnetic field vectors from polarized images in the line wing after determining suitable calibration constants. Further, the heliographic transformation of the vector magnetograms observed away from disk center can be performed interactively. The potential field can be calculated and displayed interactively. Also, the 180° ambiguity resolution can be performed using the acute angle method. The interface also provides utilities for calculation of L0, B0 and position angle for a given data and time. Also, one can load full disk images of the Sun and determine the L and B coordinates of active regions interactively by clicking on them.

## 4. Conclusions

These tools will prove to be helpful in future for a novice observer or user of the instrument to perform data analysis and generate its visualizations. Further, these tools are also useful for retrieving the magnetic field parameters at particular locations of interest without inverting the entire maps. Also, it will allow users to change the guess parameters of the models from the interface itself and there will be no need to edit the parameter file manually. These interfaces are quite general in their design and can accept any other solar observations as input with little reformatting. Thus, these tools will prove useful to other users of the solar community. Also, for new instruments developed henceforth at Udaipur Solar Observatory producing spectro-polarimetric data, these tools can be used with little reformatting in the input data. As, these GUIs are based on Visual Basic[TM] and IDL software, we can modify or upgrade the softwares by just replacing or adding new IDL routines.

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