Parallelization of the SIR code for the investigation of the dynamics of magnetic flux tubes

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Abstract:

A high-resolution 3-dimensional model of the photospheric magnetic field is essential for the investigation of magnetic features such as sunspots, pores or smaller elements like single flux tubes seen as magnetic bright points. The SIR code is an advanced inversion code that retrieves physical quantities, e.g. magnetic field, from Stokes profiles of one pixel. In order to increase the performance of the SIR Code we are implementing a parallelization for it. Furthermore we are extending the abilities of the SIR Code to reading and writing standardized FITS-files. After the upgrade the higher performance will allow us in addtion to treat non-convergence problems. Therefore we expect in addition a quality-improvment of the overall inversion process.

Introduction:

For the investigation of Magnetic Bright Points (MBPs, see Utz et al. 2009, 2010) and small-scale magnetic fields in general, we are using the SIR code (Stokes Inversion based on Response Functions, see Ruiz Cobo & del Toro Iniesta 1992 and Bellot Rubio 2003). This Stokes inversion code retrieves physical quantities (e.g. magnetic field vector) from spectropolarimetric data. Its main advantage is that it computes a stratification of plasma parameters. Hence it is possible to create 3-dimensional models of the lower solar atmosphere.

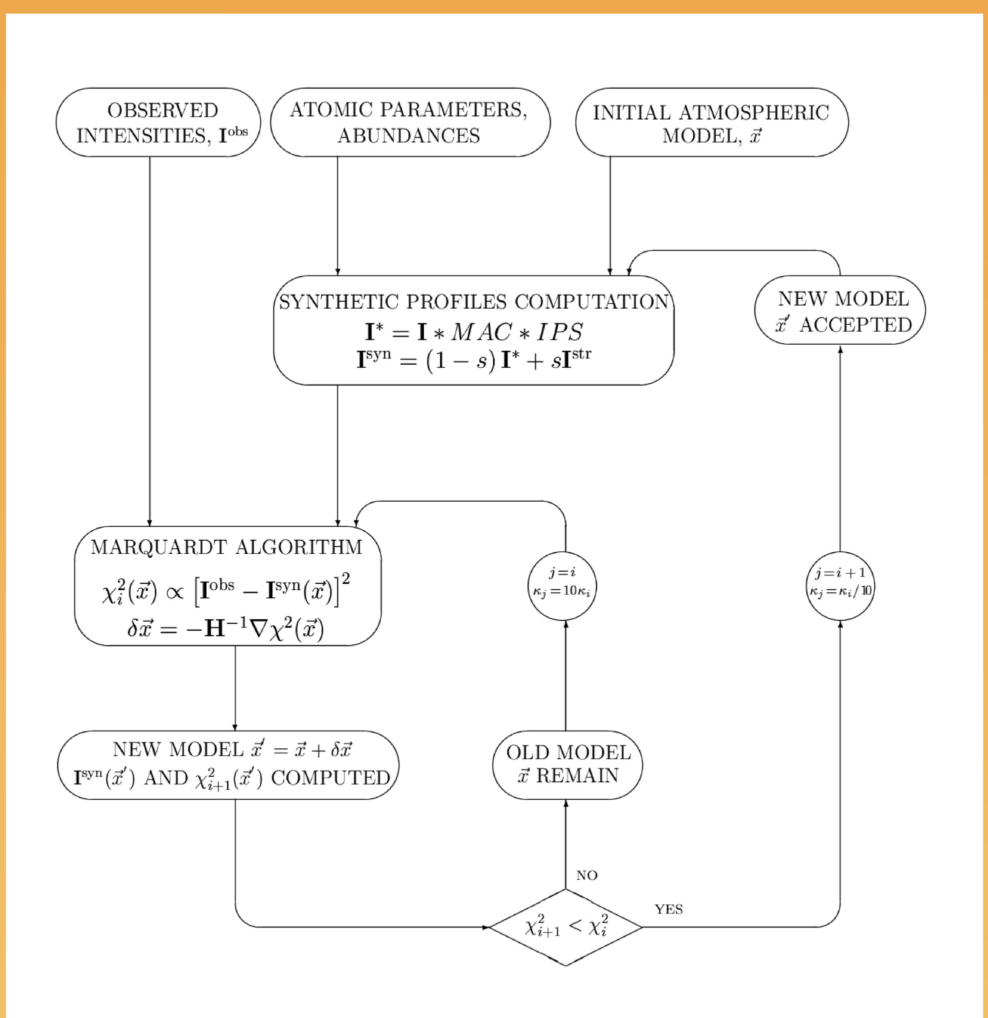

Fig.1: Flowchart of the (serial) SIR code. Modified from J. Koza 2003, doctoral thesis

The SIR code:

The current version of the SIR code uses a linearization of the RTE ("Response functions") to compute synthetic Stokes profiles of one pixel according to a first guess atmospheric model. In the following iterative process this model is changed until the synthetic spectra fit best to the observed ones. Usually this cycle is repeated several times with an increasing number of free parameters. The synthetic Stokes spectra, its errors, and, moreover, output files containting the best-fit 3-dimensional atmospheric model are created. Figure 1 shows schematically the inversion process. However, for some pixels the algorithm fails to converge, which can be avoided by using a different input model.

Data:

For the investigation of the dynamics of small-scale magnetic fields highly resolved data sets are needed. Those are provided, e.g., by Hinode SOT/SP (see Kosugi et al. 2007 and Tsuneta et al. 2008). The field of view of one scan in normal mode covers 4 x 82 arcsec^2 of the solar photosphere. Figure 2 shows as example one image taken on the 20th of January 2007 at UT 6:54.

The parallel SIR code (work in progress):

As one can see from Figure 2, even for the investigation of small-scale magnetic fields, a large number of pixels has to be considered and inverted. Due to the limited performance of the serial SIR code we are currently implementing an extension which parallelizes the inversion process. Such a parallelization can be done via the MPICH library (implements MPI2, see Message Passing Interface Forum). The subroutines provided by MPICH enable the program to interchange information (i.e. variables like the input Stokes parameters) between two calculation nodes ("node" corresponds in this context to a computational unit). Compared to other programs that require parallelization (e.g. PDE-solvers) the SIR code can be easily parallelized because there are no depencies between the single pixels, such that there is no communication required between the inverting nodes. The only communication routines needed are therefore sending all input data from the master to each of the working nodes and sending output data from the workers to the master. Figure 3 shows an overview of the new data flow. Figure 4 shows the details of the operation of the Master node and the slave nodes, whereas the original SIR inversion cycle (Fig. 1) corresponds to the part "Do inversion".

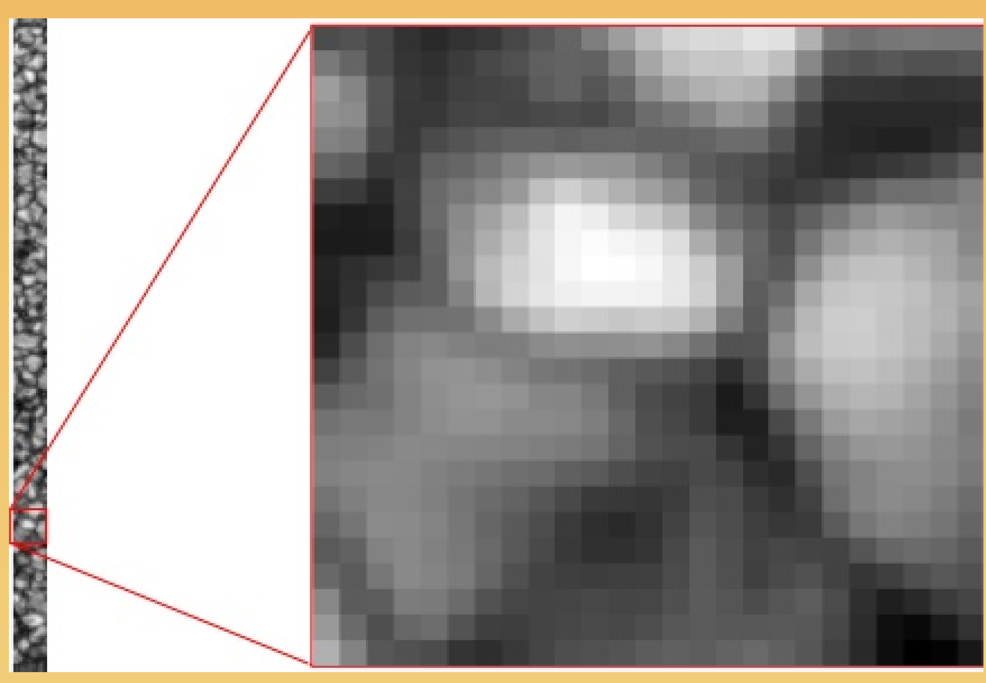

Fig.2: Stokes I map of a typical Hinode SOT/SP dataset. Left: complete image (25x512 pixels^2 corresponding to 4x82 arcsec^2), right: detail of 25x25 pixels^2 (corresponding to 4x4 arcsec^2).

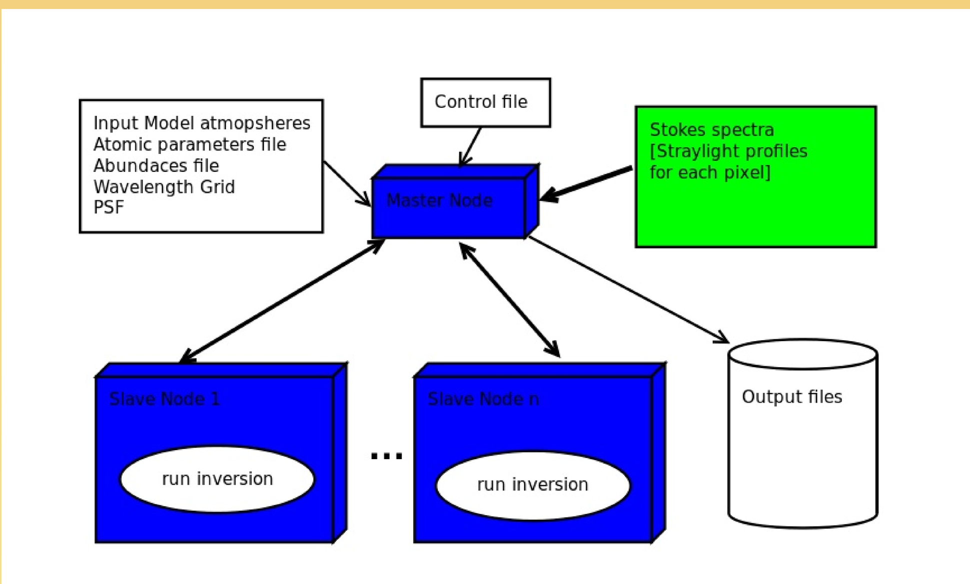

Fig.3: Schematic overview of the data flow of the parallelized SIR code.

Current status & Outlook:

Currently we are finishing the work on the parallelized SIR code. For a robust inversion tool it is additionally essential to read input data from a standardized format and produce corresponding output data. At the moment the code reads and writes FITS-files. After a testing period we plan to run the inversion on the IAA's cluster (28 nodes, each with 16 CPU cores). With the increased performance it will be also possible to run the inversion with different input models in order to avoid non-convergence.

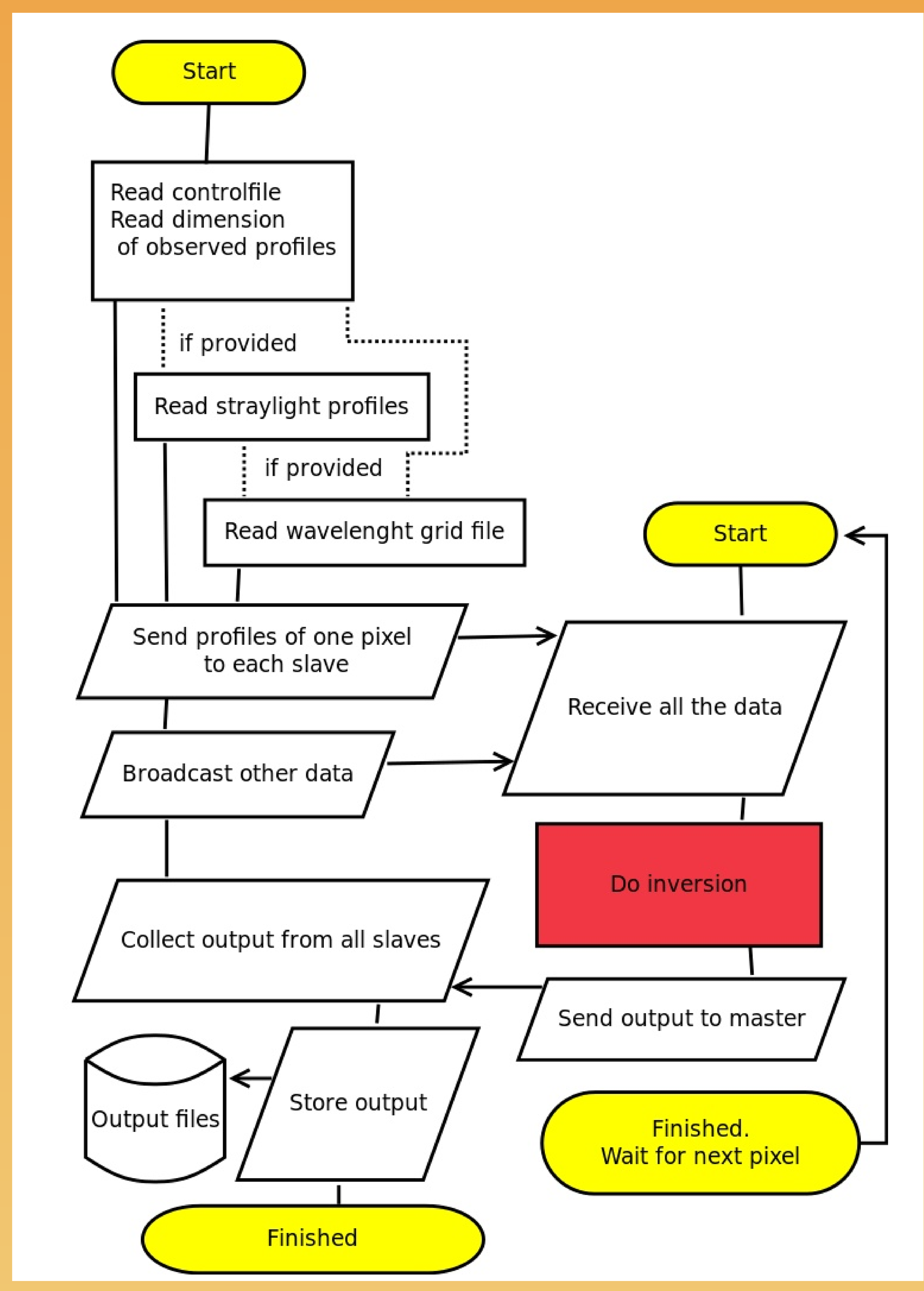

Fig.4: Detailed flowchart diagram for the parallelized SIR code. The tree on the left represents the master node, the tree on the right one of the inverting nodes.

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