AUTOCAL User Manual

1. Installing and running the software

The installer will unpack all the required files in their correct locations. AUTOCAL requires the following software to be installed.

- Windows 7
- Microsoft .NET framework 4, which can be downloaded for free from https://www.microsoft.com/en-za/download/details.aspx?id=17851
- Microsoft Access, if any of the database functionality is to be used.

To run the program, right-click the AutoCal icon and click on *Run as administrator*. This is required to ensure that the FITS files are loaded correctly on some machines.

2. Do your first calibration in under a minute

Here follows only the most necessary steps required to perform a quick calibration:

1. Load the frame star list by clicking the *Load from file...* button in the top-left panel.
2. Load the catalogue star list by clicking the *Load from file...* button in the next panel.
3. Select the band for which the calibration is to be performed from the *Choose Magnitude* listbox.
4. Adjust the *Mag Cutoff* numeric up-down in the same panel to 99.9 in order to eliminate stars without proper magnitude values.
5. Click the *Load FITS file...* button and select the file that corresponds to the star lists that have been loaded. When asked, enter the plate scale of the telescope as 0.45.
6. The FITS image should now be displayed on the right. Select the target star by clicking on it, or by entering its x,y frame coordinates in the numeric up-down controls in the top-middle panel.
7. Click the *Calibrate* button to perform the calibration.
8. On the window that appears, click on the *Review graph...* button to refine the calibration.
9. Deselect outliers or faint stars by drawing a rectangle around these stars with the mouse cursor or by clicking on them. The deselected stars are designated with blue markers. The calibration results are updated automatically. All points more than a specified number of standard deviations from the linear fit can be removed in the top-right panel. The instrumental and calibrated magnitudes are displayed in the *Graph Information* panel on the right.

3. A more extensive overview of the graphical user interface

Here follows a more detailed description of all the options available from the user interface. Note that all options and windows that are database related have been excluded from the following discussion for review purposes. The catalogue star lists that are included in the package were created using these facilities and should be used to test the software.

3.1 The main window

The main window is the one that is displayed when the application is launched. All steps in the preparation phase are initiated from this window. The window has seven main sections, as indicated in Figure 1, and the function of each are discussed below.

1. The frame star list that the user has to create (usually with IRAF), is loaded here. Once a list has been loaded, its name is displayed along with the number of stars it contains. The magnitude and error in magnitude cut-offs for the frame star list can also be set here after it has been loaded. As the cut-offs are applied, the display showing the number of stars is updated accordingly.

2. All functions regarding the creation and loading of the catalogue star list reside here. The *Import new catalogue...* button opens the database table creation window and the *Query database...* button displays the database query window. The loading of the list, the magnitude cut-offs and star count display function exactly as they do for the frame star list. Additionally, if more than one magnitude field is contained in the query, the correct one has to be chosen in the *Choose Magnitude* listbox.

3. The FITS file is loaded here and some of its most important properties are displayed here.

4. The user-adjusted parameters can be adjusted here. When the application launches, all the parameters have the default values. See Appendix A for more information regarding these parameters.

5. Here the target star can be chosen by scrolling to its coordinates with the two controls at the top. All stars close to the position of the target, specified in this way or by clicking on the displayed FITS frame, are listed in the drop-down box, where the target can then be selected.

6. Feedback regarding the progress of the preparation phase is given here. The three lines of text, which are green in Figure 1, tell the user whether each of the three main requirements necessary for calibration to commence have been met. As soon as a requirement has been met, the appropriate text turns green. Once all three tasks have been completed, the *Calibrate* button is enabled, and once it is clicked, the initial results window is displayed and calibration starts.

7. Once a FITS file has been loaded, it is displayed here. The green cross-hair replaces the default mouse pointer when it is moved over the display. The user may select a target by clicking on the display. The coordinates below the display indicate the current x,y frame coordinates of the cross-hair. Once a target has been selected, it is marked with a small red circle.
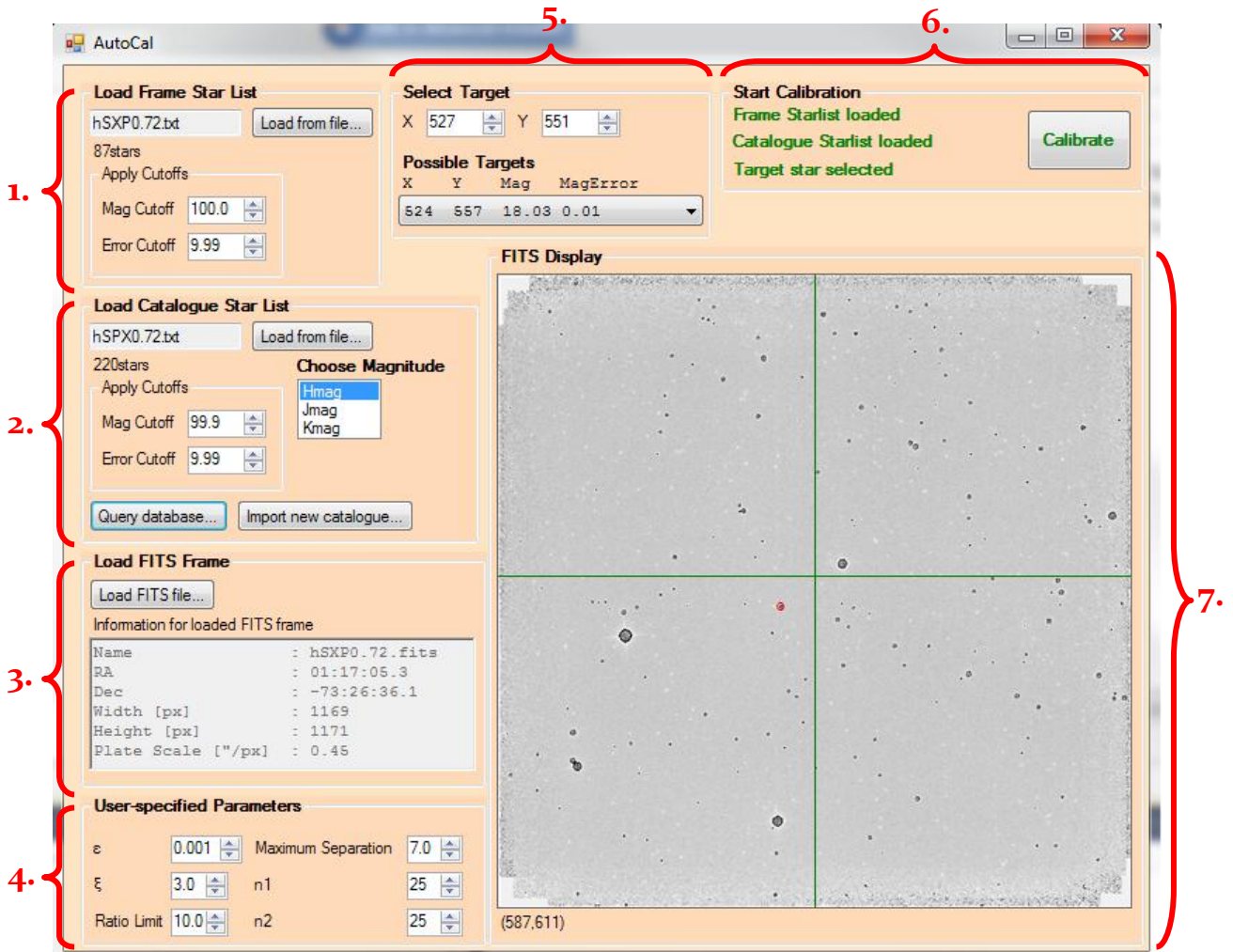

Figure 1. The main window of AUTOCAL.

3.2 Initial results window

The initial results window, shown in Figure 2, displays the initial results of the calibration process. The window has six main sections, and the functions of the controls in each section are discussed below.

1. A step-by-step text-based summary of the auto calibration process is shown here. The summary can be saved as a text file by clicking the *Save Summary…* button.

2. The FITS frame is displayed here with any combination of a number of different overlays. Each overlay represents a collection of stellar coordinates used during the calibration process. Yellow crosses indicate the positions of stars from the frame star list and red ones those of stars from the catalogue star list.

3. These buttons restarts or closes the application.

4. The overlays to the FITS display are selected here. The *Replot* button updates the display with the currently selected overlays and the *Save Image to File...* button saves the display to a bitmap file.

5. The initial calibration graph, showing the weighted least-squares data points and fit, is displayed here.

6. The apparent magnitude of the target, along with the mean and standard deviation of the distances between data points and the line are displayed here. The *Review graph...* button opens a window where the user can revise the calibration graph.

3.3 Graph revision window

This window, shown in Figure 3, allows you, the user, to manipulate which of the pairs of matched magnitudes are used for the calculation of the WLS fit.

The window contains three main sections. The purpose of each section and the functions of its controls are explained below.

1. The graph display allows for the selection or discarding of data points by clicking on a single point or by drawing a rectangle around a set of points. The selection of all points inside the rectangle is toggled. Red dots represent selected points and blue dots discarded ones. The WLS fit, indicated by the black line, its equation, and all other graph-related information are updated every time the selection of one or more points is changed. Apart from the data points, the WLS equation and the R^2 value of the fit are also displayed.

2. The three checkboxes at the top of this control group let the user choose whether all points or only those used for the WLS fit are displayed, whether the graph is scaled to include all points or all selected points, and whether or not gridlines are drawn on the display. The two *Deselect* buttons discard all data points more than a certain distance, which is determined by the values in the numeric controls, from either the original WLS fit or the latest version. The *Save Graph Data to File...* button saves all values relevant to the graph to a text file, while the *Save Graph to File...* button saves the current graph display to a bitmap file.

3. In the Graph Information group, the number and percentage of stars which were matched, and also the number and percentage of those that were used in the calculation of the WLS fit, are displayed. The average and standard deviation of the distances between the selected data points and the WLS fit is displayed for both the original and current fit. Finally, the instrumental magnitude and apparent magnitude of the target are displayed, along with the errors in those measurements.
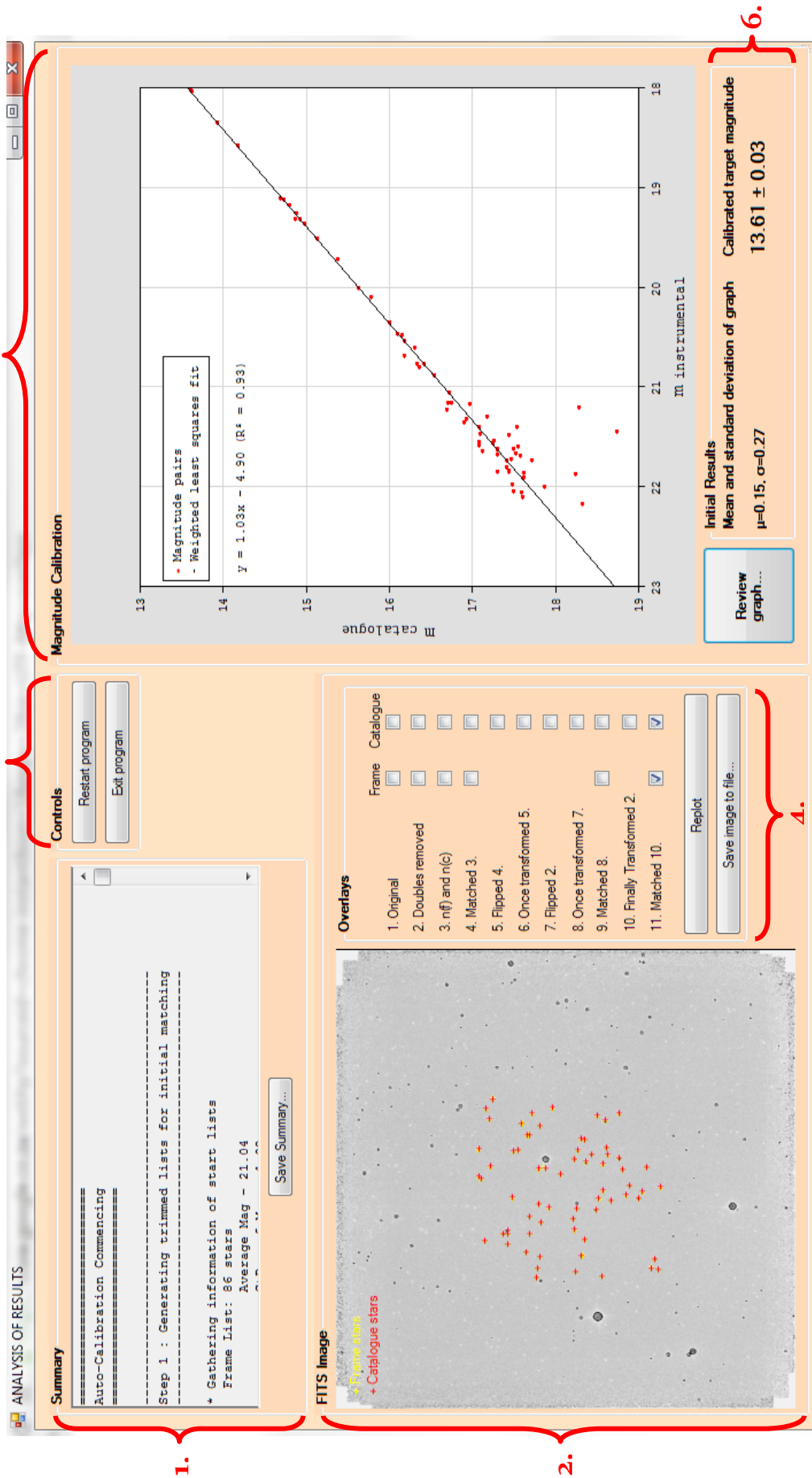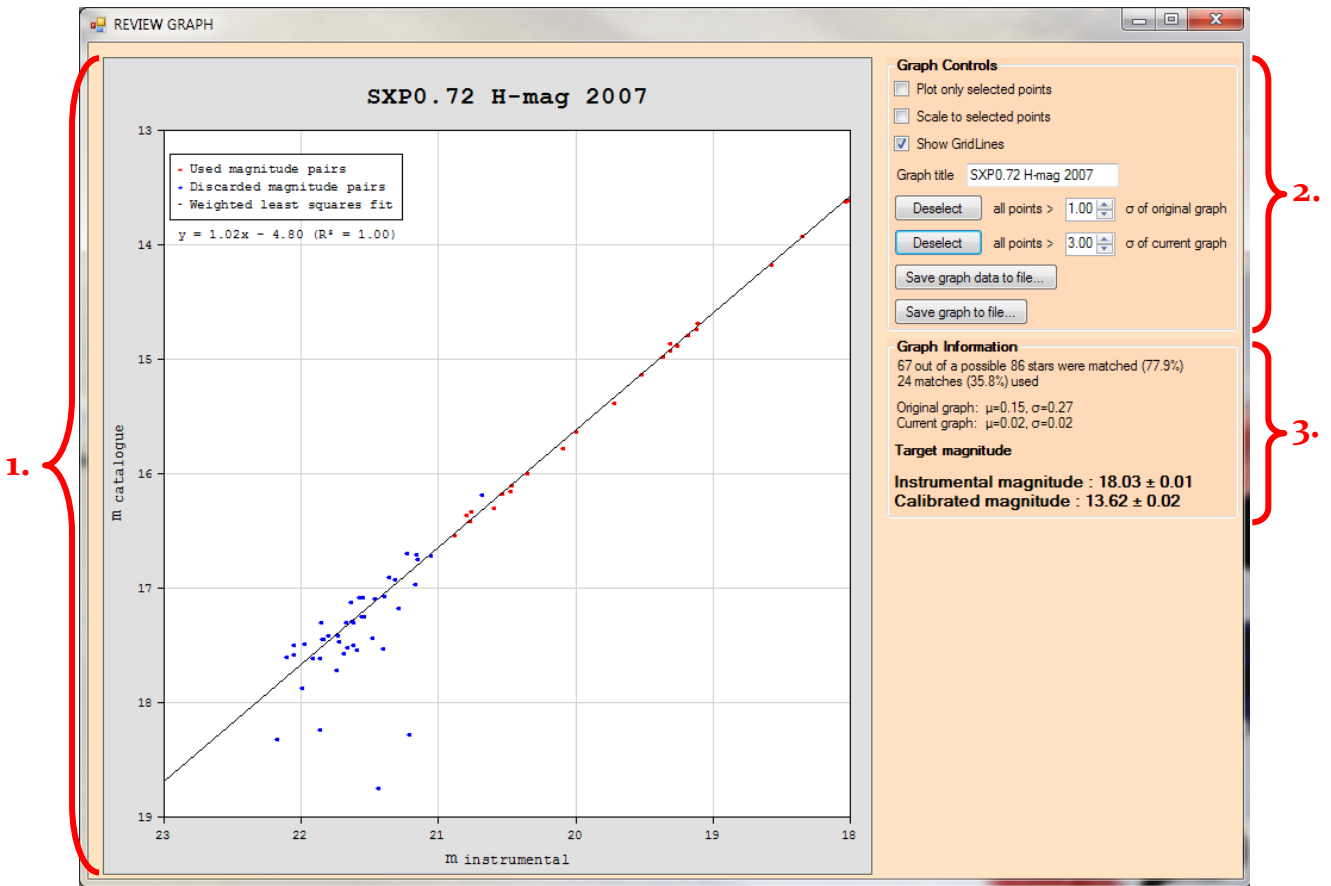
Figure 2. Initial results window.

Figure 3. Graph revision window.

Appendix A - User-adjusted parameters

- **ε** - Used in conjunction with ξ to determine the elimination threshold. All pairs of stars closer than the elimination threshold are eliminated from both lists. ε is measured as a fraction of the span of the stars in the frame star list, with $\varepsilon = 1$ meaning 100% of the span. I decided to use the square root of the sum of the squares of the span in x and y, namely

$$\text{span} = \sqrt{\text{span}_x^2 + \text{span}_y^2},$$

where span_x and span_y denote the span in the x and y directions. The default value for ε is 0.001.

- **ξ** - Adjusts the elimination threshold to a multiple of ε. The default value for ξ is 3, meaning that two stars with coordinates (x_1, y_1) and (x_2, y_2) will be considered to be doubles if

$$\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} < 3\varepsilon\sqrt{\text{span}_x{}^2 + \text{span}_y{}^2}.$$

- **Ratio limit** - Used to reduce the number of triangles used by the matching algorithm. The ratio referred to here is the ratio of the lengths of the longest and shortest sides of the triangle. The default value is 10, and all triangles with ratios higher than this limit are discarded.

- **Maximum separation** - Specifies the maximum distance allowed between stars from the two lists (after the catalogue star list was transformed to the coordinate system of the frame star list) for them to be considered as a match. It is measured in pixels and has a default value of 7.

- n_1 and n_2 - Integers indicating how many stars from the frame and catalogue star lists respectively are used for the initial matching. The default value is 25 for both, indicating that the 25 brightest stars (after doubles have been removed) from each list will be used.

DISCLAIMER

The Software is provided "as is" with no warranties, express or implied, including any warranty of merchantability, title or fitness for a particular purpose or any other warranty.