PARot polar aligner

Motto: If I have to bring a computer to the observation, then let it compute!

1 What is it good for?

For a fast and precise polar alignment of equatorial mounts.
PARot (Polar Align Rot) is inspired by a popular program for polar alignment PAM (Polar Align Max). PARot aims to be faster and more convenient. PARot, in contrast to PAM, performs corrections for precession and atmospheric refraction (in the future, the not-so-important correction for nutation will be added). PARot should also work on the Southern Hemisphere (not tested). With PARot, one can align the popular EQ-6 mount with precision better than 1 arcmin in less than five minutes of time. In fact, precision and speed is limited by the imprecise mechanics of the mount adjusters more than the software. The current version of PARot is dependent on MaxIm DL and its embedded sub-program PinPoint LE. PARot accesses some functions of these programs by simulating mouse clicks and sending keyboard shortcuts.

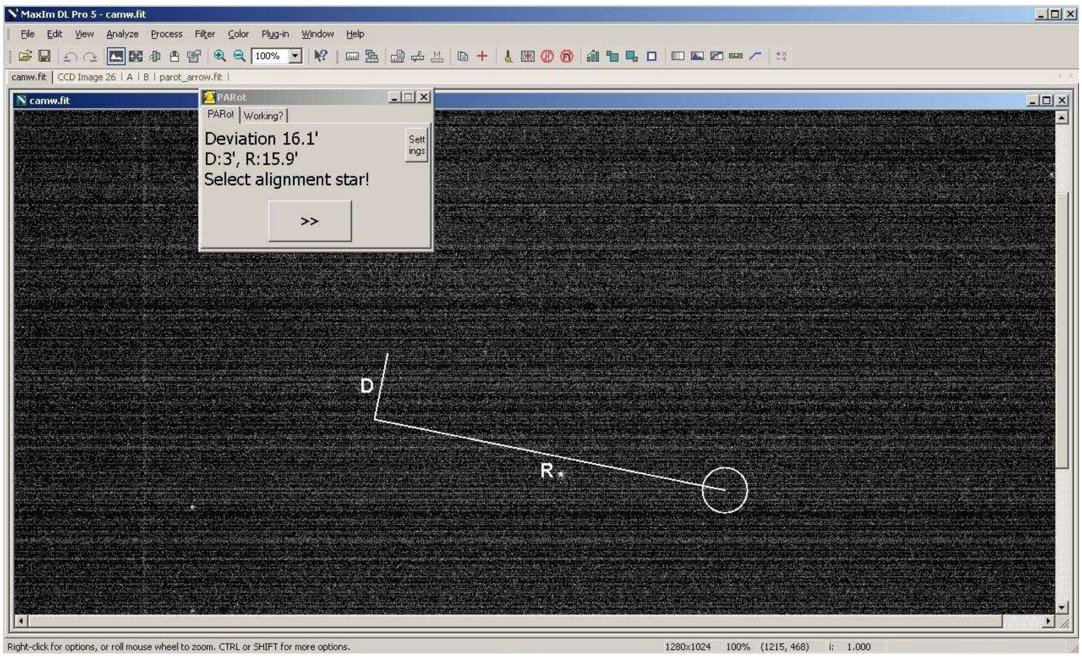
2 What does PARot require?

- Maxim DL version 5 (version 6 will be possible in future)
- A computer with Windows OS (tested with WinXP x64, Win7 x64, Win7 x86).
- A camera which can be controlled from MaxIm. PARot could have problems if you don't use a camera producing 16-bit RGB or B&W frames – not tested.
- A scope/lens for the camera. The combination of the scope and the camera must be such that the camera can "see" a star in any field using the exposure time of a few seconds.
- A view of the celestial pole. The view can't be blocked by ground objects or clouds.

3 How does it work?

PARot automates one of the variants of the rotation alignment method:

0. The user roughly polar aligns the mount.
1. The user points the scope to the celestial pole and positions the camera such that one of edge of the field-of-view (**FOV**) is parallel with the vertical direction. PARot takes over, exposing frame A. PARot uses this frame to find the position of the celestial pole.
2. The user rotates the mount around the polar axis. PARot then exposes frame B. PARot compares Frame A and B to find the position on the sky the polar axis points at.
3. PARot displays live-view from the camera on the computer screen. The user then selects a star in FOV and clicks on it. PARot shows where the user has to shift the star so that the precise alignment



is achieved. (The shift is made by moving the azimuth and elevation using the mount adjusters, not the hand paddle).

When the shift is done, you can repeat the process to make sure that everything is OK and to measure the alignment accuracy. For some combinations of cameras and telescopes, another iteration might be necessary, because the program doesn't correct for the optical geometric distortion of the image.

4 Download and "installation"

Download the program from `http://sourceforge.net/projects/parot/`. Save and extract it in a folder in a remote corner of your computer where it can live without disturbing you. The program will save its settings and temporary files here. The download includes PARot, the settings editor (`parotsettings.exe`) and this manual. Create a shortcut for PARot at your Desktop or another convenient place. Print the manual.

5 Before the first use...

...it is necessary to set up PARot, MaxIm and PinPoint properly and to adjust your mount and scope a little. The steps in this section are to be done only once, before the first use of PARot.

Definitions

Rotation center – The point the polar axis points at. When the mount is turned around the RA axis, all the objects in the camera's FOV rotate around the rotation center. The goal of polar alignment is to match the rotation centre with the celestial pole.

Alt-Az position – A position of the mount meeting the criteria: 1) The rotation center is in the FOV of the camera. The rotation center is not required to lie exactly in the center of the FOV. 2) One of the edges of the FOV is parallel with the vertical direction (the direction of gravity, not with the directions of RA or Dec).

Hardware settings

1. Remove the cone error – If you can't set the rotation center into the camera's FOV, you have to correct this cone error. Shims under the appropriate place on the scope/dovetail, or other adjustments, are possible. The best way to check it is to point the polar finder of the mount on a distant ground object at the daylight and try to get it in the FOV.
2. Set the mount in an Alt-Az position. At daylight, you can use ground objects. At night, you can recognize the vertical a horizontal directions when shifting the mount by the altitude and azimuth adjusters. Draw marks on the RA and Dec axes of the mount that indicate this position. If your camera can be rotated with respect to the telescope, or the telescope can move with respect to the mount, draw marks on them, too. These marks can be used for easy setting the mount, camera and scope to the Alt-Az position at night.

Software settings

1. When doing the alignment, the program will tell you to move the mount left, right, up or down. So, you must determine which altitude and azimuth adjuster movements move the mount in those directions. The "up" direction is moreover necessary for making the correction for atmospheric refraction. If you determine the up direction incorrectly, PARot will make this correction in a wrong direction, which will decrease the alignment accuracy by up to a few arc minutes.
   Start MaxIm (without PARot) and connect the camera. If possible, do this step at daylight and point the polar axis at a ground object using the polar finder. Set the mount in the Alt-Az position.
   Determine the "up" direction with respect to the screen of your computer. "Up" means "against the direction of gravity". If you do this step at daylight, this direction is evident from the orientation of the objects imaged by the camera. At night, "up" is the direction a star moves when you decrease the altitude of the mount (even if the star moves left, or right, or down on the screen).
   Similarly, determine the direction of "right". It is simply a direction perpendicular to "up". There are two possibilities and it's up to you which of them you choose. For example, "right" can be the direction in which objects move on the screen when you tighten the right azimuth adjuster.
2. This step must be done at night under the stars. Connect the camera via MaxIm and point it to the celestial pole (at least roughly). The goal is to make PinPoint work near the celestial pole (in MaxIm:

pull-down menu Analyze - PinPoint Astrometry). You have to 1) find the appropriate exposure time; and 2) find the appropriate PinPoint settings, like star detection settings, plate scale, etc., so that PinPoint works correctly on the images of the pole with this exposure time. The initial guess of the frame center in PinPoint MUST be RA = 0, Dec = 90 (or -90 if in the Southern Hemisphere). After you get consistent plate solves in PinPoint, do not change its settings until you complete step 5!

3. In MaxIm, invoke the Stack dialog (Process - Stack). Choose Add Files in the first roll button. A window appears, but you can close it immediately. Go to the Align tab and set Mode to Auto - star matching. Now be careful that the button doesn't change its label from Add file to something different until you complete the step 5 and similarly the setting of Mode.
4. In MaxIm, connect the camera with the Camera Control dialog. It is recommended to connect to one camera only. Do not change the settings until you are done with the step 5.
5. Close MaxIm, run PARot for the very first time. If you happened to run PARot earlier, go first to the PARot folder and delete the folder `parotsettingsf` and the file `parotsettings.ini`, if they exist.
6. PARot will ask you to fill in its settings. You will probably guess the meaning of the parameters from their names, otherwise you will find their explanation in 7 below. To start one needs to enter only the most important fields: The up and right directions found in the step 1; The exposure time of the astrometric frames found in the step 2. into the field Exp time; A check in the appropriate box for a color camera; And finally the **path to the folder with MaxIm settings**. This is usually the folder `...\MaxImDLXXX\Settings` in your Documents. It contains, for example, the files `Curves.txt`, `Crop.txt` or `Calibration.txt`.

6 Using PARot

General notes

The alignment process in PARot consists of phases performed by the program automatically and by phases when the program waits for the user to make an action. PARot shows information what it is doing or what the user has to do. The actions to be performed by the user are ended by the exclamation mark. It is just a mnemonic device to remind the user of the steps described below. The tasks for the user should be done in the order from top to down as listed in the PARot window. When you are done, you tell PARot to resume the automatic actions by clicking the button >> (Next) or by pressing the space bar. There is no command to step back. When the user closes PARot, MaxIm closes too. PARot works by sending simulated keystrokes or mouse clicks to MaxIm and PinPoint. Do not operate other applications not to interfere with PARot. When you successfully finish the alignment with PARot and close it with a final press of >>, PARot will remember the just-used settings of MaxIm for the next time you run it.

Alignment procedures

0. Align the mount roughly, e.g., by the polar finder. You will need to find the necessary precision by yourself. Then switch on the mount tracking.
1. Run PARot, which automatically starts MaxIm, and starts the camera. MaxIm starts displaying continuously the image from the camera on the computer screen creating Live-View like a DSLR camera. Set the mount into the Alt-Az position using the marks on the mount and make sure that the rotation center lies in, or close to, the FOV by rotating the mount around the RA axis. If the rotation center is far from the FOV at this point, PinPoint can fail to plate solve.
2. Press Next (>>). PARot will expose frame A. PinPoint finds the coordinates of the FOV. While PinPoint is solving, the user rotates the mount at least about 10 degrees in RA. Do not move the scope in the Dec axis. The mount can be rotated in RA either by hand or with the handpaddle/controller. If the camera has low sensitivity, rotate until a bright star gets into the FOV. If you see that PinPoint can't complete a plate solve because too little or too many stars have been detected, click on the "Stop" button and change the PinPoint settings. Then, press the "Process" button. When PinPoint succeeds, close its window manually and the automatic part of the alignment procedure will continue.
3. When PinPoint is done and the user finishes the rotation, the user presses the Next button. PARot exposes frame B.
4. When the frame B is done, PARot invokes the Stack dialog and finds the rotation center. It calculates the translation needed to match the rotation center of the mount with the celestial pole. It displays the current alignment error and the sizes of the required corrections in the directions Up, Down,

Right and Left. It draws an arrow showing the necessary shift of the mount, so that the user may visualize the change. If necessary, the user can move the mount in the Dec axis a little (no more than a few degrees) now to get the alignment star (see the next step) to a better position in the FOV.

5. The user clicks on a bright star to use for the alignment. The arrow in the frame shifts so that it starts at the star and ends at the point where the star is to be shifted using the azimuth and altitude adjusters of the mount. The displayed shift is broken down into the azimuth and altitude directions so that the arrow consists of two perpendicular lines. The radius of the circle at the end of the arrow corresponds to the alignment accuracy required by the user.
6. Watching the Live-view from the camera, the user shifts the alignment star into the circle.
7. The mount is aligned now. Press >> to exit PARot. You can repeat the procedure from the step 1. to make sure that the alignment is correct and to measure its precision.

7 PARot settings

The Settings dialog can be invoked by pressing the Settings button. The settings are designed to be set once and for all after the first few runs. The first four boxes can be changed at any time during the alignment and the effect will be immediate. It is recommended to restart PARot after changing the other parameters. Use decimal points, not commas.

Here is the explanation of the individual boxes:

Loop time – The exposure time for making the Live-view.

Exp Time – The exposure time for the astrometric frames A and B.

Stretch min and **Stretch max** – Operates the Screen stretch dialog in MaxIm (indirectly).

Arrow brightness – Brightness of the arrow in the ADU units.

Up direction and **Right direction** – The directions up and right in the alt-az position with respect to the computer screen.

Alignment tolerance – The required alignment accuracy (the size of the circle on the arrow's end).

Axes adjustment order – Choose whether you prefer to adjust the mount first in azimuth and then in elevation or vice-versa.

Latitude – The latitude of your location. The error of a few degrees makes no effect. If you choose the Northern hemisphere, the program will align the mount automatically to the Northern celestial pole; analogously for the Southern hemisphere.

Path to MaxIm Settings folder – See Chapt. 5 above.

Color camera – Check if you use a color camera, uncheck if it is B&W.

Temperature and **Pressure** – The temperature and atmospheric pressure used for the calculation of the atmospheric refraction. Don't care about them unless they are really extreme or you want an alignment better than a few arcseconds.

Binning – Clear.

8 Formulas

The required alignment accuracy

Can be calculated using the formula:

$$45000 \times x \,/\, (t \times F \times D), \tag{1}$$

where x is the tolerable magnitude of the field rotation expressed in microns, t the intended exposure time of one sub-exposure in minutes, F the focal length of the photographic (not the guiding) telescope in millimeters and D the distance between the guide star and the farthermost point of the photographed field in degrees. The result comes out in arcminutes.

Plate scale

It is good to know how many arcseconds corresponds to one pixel on a camera attached to the telescope of the focal length F. That many:

$$206 \times d \,/\, F. \tag{2}$$

The symbol d denotes the pixel size in microns.

9 Reward

PARot is free. If you find it useful and you want to repay the author, you can. Click on the button in the second tab of PARot. You get to PayPal where you can donate either by using your PayPal account or by your credit card. However, the donation won't bring you any material benefit. The author will never ask you how much you donated. If you think about how much to donate, start your considerations at 1% of the price of the aligned setup.

10 Note for avast! antivirus software users

PARot is incorrectly evaluated as harmful by avast! antivirus. This antivirus evaluates any program written in the AutoIt language as malware, even the simplest piece of code. You have to believe the author and the other users of the program. You have to switch off the antivirus before you run PARot for the first time. The author can provide the source code if you are in doubt.