Digital Astronomy Eyepiece App

Version 0.200 beta, 02.09.2024

This version supports only ZWO ASI cameras

Libraries used (see also licenses folder):

- ASICamera2 SDK, copyright ZWO company
- OpenCV, Apache License 2.0
- CFITSIO, copyright National Aeronautics and Space Administration
- frugally-deep, copyright (c) 2016 Tobias Hermann
- OpenCV reg module, copyright (C) 2013, Alfonso Sanchez-Beato

This app is developed for fast and ultra-fast EAA observations (Electronic Assisted Astronomy), mainly to be used with very fast optical systems in range F1.0-F3.0. It meant to be somewhere in between EAA and night vision, providing more real-time feeling and using exposure times in range 50ms .. 2s and integration times under 1 minute. The app can be of course used also with slower optics and longer exposures, and also with night vision devices, equipped with cameras.

Installation

No installation needed, simply copy the release folder. Check the exe file after download with antivirus SW!

Folder content

Digital_Eyepiece_APP.exe – the app itself, start this file.

ASICamera2.dll, opencv_world480.dll, cfitsio.dll, zlib.dll – libraries needed for the app (accordingly ASI SDK, OpenCV, cfitsio).

config.txt – configuration file with parameters.

533_dark_400ms_g500_off100_25C.fits, 533_dark_4s_g400_off100_25C.fits, MasterFlat_hyperstar_bin2.fits – calibration files, darks for “video” and “foto” mode, flat for both modes (filenames are examples).

Readme.pdf – this file with description and instructions.

saved_pictures – folder, where images will be saved during observation. If not exists, will be created.

licenses – folder with licenses.

log.txt – debug output file. If not exists, will be created, if log/debug option is activated.

train_03.jason – neural network configuration for AI noise reduction, in frugally-deep format.

Controls

The key idea of control is simplicity. Control of the app during execution is done via keyboard or simple GUI. Control keys can also be changed in configuration file.

For key control to be active focus must be on the image window.

“x” – for “eXit”, close the app

“m” – for “Mode”, switches between fast, “video” mode, and stacking, “foto” mode

“+”, “-“ – control of stretching and brightness, similar to gain of night vision device

“f” – for “Focusing”, image zoom for focusing

“p” – for “Palette”, switching between normal RGB and alternative (for example dual-band) palette

“s” – for “Save”, save images

“h” – for “Histogram”, shows histogram of RAW image from camera

Alternatively, GUI with on-screen buttons can be activated.

There is unfortunately no separation between control/GUI and image processing threads in this version. Control and GUI are not responsive, and basically react one time per image exposure. The SW is still usable, just don’t rush.

Modes, key “m”

There are two modes, first “video” mode meant for searching for the object, constellation, stars, also for focusing, etc. Typically, short exposure, high gain, strong noise reduction can be activated. Second “foto” mode (from German Foto=photo) is for stacking. Typically, but not necessary, longer exposure, lower gain, less noise reduction.

Stretching, keys “+”, “-“

Control of non-linear stretching, works also similar to gain of night vision devices, but without changing the “gain” parameter of the camera.

Focusing, key “f”

Activates zoom of the image with separate RGB parts, for more convenient focusing.

Switching palettes, key “p”

One of the key features of the app, activates 3x3 matrix of RGB channel mixing. This way, for example for observation with dual-band filter, the red of H-Alfa can be shifted to orange-gold, cyan of O-III to deep blue, enhancing the colour contrast dramatically, and making H-Alfa objects better visible. There are also other uses of this function, i.e. black/white from colour, H-Alfa to black/white, imitation of greenish or blueish screen of night vision device, etc.

Save images, key “s”

Saves three images – one as seen on display, second with processing, but with full resolution, third only stacked image without processing, and one text file with some used parameters. Images are saved in the folder “saved_pictures”, which is automatically created, if not exists.

Show histogram, key “h”

Shows histogram of RAW image from camera, to control the exposure. Particularly under light polluted sky by wideband observations it is important to not overexpose the image.

Important features

One of the most important features of the app is automatic background subtraction, with two variants: constant level and gradient. Black level subtraction and stretching is based on iterative approach, described by Roger N. Clark, clarkvision.com. Black level is determined (for each of RGB colours separately) as a point with relatively low threshold of histogram from left side, the value is configurable. Automatic background subtraction allows high offset parameter in the camera to not loose dark details and also wideband observations under light polluted sky. For background subtraction precise flat frame is essential, also precise dark frame is important to apply flat frame properly.

For systems with image circle smaller, than the sensor size (i.e. “Ultra-fast EAA”) and for systems with strong vignetting a circular mask can be defined to limit the region for black level calculation. This circular mask can be temporarily shown for adjusting purpose.

Image can also be zoomed to display small image circle in full image height.

AI noise reduction can be very effective for EAA. The app contains experimental version of AI noise reduction filter. It is trained on my own images – can be less effective on others, and still produces some unwanted artefacts.

The app can output images on a second display, used as electronic eyepiece. Different types of electronic eyepieces can be configured, for bino or mono mode.

Other features

Banding filter can be activated, if brightness bands are visible, which sometimes happens at short exposures.

Image rotation, resize to display size, zoom can be used to adjust displayed picture.

Bilateral noise reduction filter can be activated, separately for video and foto mode.

Color correction matrix for RGB mode is available – can be very helpful to reach natural color rendition of the sky, but needs special calibration with color chart.

Highlight protection feature is available – sort of HDR tonemapping for highlights, prevents saturation of bright objects.

The app can be called from command line with a parameter, containing filename for config file. This way many different configurations can be switched fast. If called without parameters, default config file is “config.txt”.

Filenames of calibration files can be changed in config file. Combined with config filename in command line parameter, many different configurations can be switched fast.

Some other interesting features

Optical mask – black circular mask, makes picture more optic-device-like. Can also be used with small image circle to hide the white background after flat frame correction and reduce visible image to image circle. If activated, image is always cropped to square.

Enhancing bright stars – can make bright stars more visible and colorful, somewhat similar to starglow filter, or halo by night vision devices.

Further ideas and future plans.

One can make an Arduino-based or other simple DIY keyboard, USB or Bluetooth®, with only the keys needed to control the app, and use it as a hand controller.

Planned features: hot pixel detection without dark frame, stacking only N last pictures with image shift to last position – for untracked systems, support of telescope moving detection for automatic switching between modes, choosing camera, if many cameras are connected.

Configuration file

Contains parameter, that can be adjusted to adapt the app to your system.

If you need configurations for different systems, simply copy the whole app folder or use command line parameter as config filename.

0 // debug output, screen and log file: 0 - none, 1 – active

Debug output into log file. Activate, if problems occurring, log file can be analyzed or sent for analysis. Performance is worse, if this option is activated, don't use, if not needed.

//--------------- Camera and preprocessing Parameters for video mode

400 //exposure time for video mode, ms

500 //gain for video mode

50 //White balance Red for video mode

50 //White balance Blue for video mode

100 //offset for video mode

0 //high speed mode for video mode, 0 - not active, 1 – active

Usual parameters of a camera. I prefer to have high gain here, exposure as a balance of visibility of objects and reaction speed. Check for overexposure with histogram. Offset is always high to not loose dark details, histogram of single dark frame must be checked in other software, that no (few) black pixels are produced. White balance adjusted ideally to produce same peaks for all colours in dark frame.

1 //use dark frame for hot pixel correction, for video mode, 0 - don't use, 1 - use

0 //subtract dark frame from light frame, for video mode, 0 - don't use, 1 – use

Dark frame calibration can be activated with two variants: only interpolating of hot pixels, based on dark frame (only first parameter activated) or complete dark frame subtraction (both parameters activated).

0 //use flat frame for video mode, 0 - don't use, 1 – use

Flat frame correction can be activated here for video mode.

1 //banding filter, 0 - disabled, 1 - rows, 2 - columns

100 // banding filter window size, 3..200

1.2 // banding filter threshold, 1.0 .. 2.0

Banding filter can be activated here, good working strength is about 100 for now. Threshold must be started with 1.0 and slowly increased till banding filter is effective. Too high values of threshold are causing dark bands on bright objects.

//--------------- Camera and preprocessing Parameters for foto mode

4000 //exposure time for foto mode, ms

400 //gain for foto mode

50 //White balance Red for foto mode

50 //White balance Blue for foto mode

100 //offset for foto mode

Usual parameters of the camera. Exposure depends on your system and preferences, gain must be adjusted to get comparable brightness between two modes, without changing the stretch. Check for overexposure with histogram. Offset is always high, histogram of single dark frame must be checked in other software, that no (few) black pixels are produced. White balance adjusted ideally to produce same peaks for all colours in dark frame.

1 //use dark frame for hot pixel correction, for foto mode, 0 - don't use, 1 - use

0 //subtract dark frame from light frame, for foto mode, 0 - don't use, 1 – use

Dark frame calibration can be activated with two variants: only interpolating of hot pixels, based on dark frame (only first parameter activated) or complete dark frame subtraction (both parameters activated).

1 //use flat frame for foto mode, 0 - don't use, 1 – use

Flat frame correction can be activated here for foto mode

//--------------- Calibration files

533_dark_400ms_g500_off100_25C.fits //dark for video mode

533_dark_4s_g400_off100_25C.fits //dark for foto mode

MasterFlat_hyperstar_bin2.fits   //flat for both video and foto mode

Filenames of calibration files can be changed here. Filenames are examples.

//--------------- Parameters for both video and foto mode

0 //monobin for both video and foto mode - only 0 supported for now!

2 //bin for both video and foto mode, 1, 2, ..

Bin recommendation is to get image in range of 700-1500 pixels. For (Ultra-)fast EAA it is generally a good idea to sacrifice resolution for sensitivity. Performance of the app is better with smaller pictures.

2 //bytes per pixel, 1 for RAW8, 2 for RAW16 - only RAW16 supported for now!

90 //bandwidth

No need to change.

//--------------- Other parameters

10 //cooler target temperature, °C

0 //cooler activation, 0 for cooler off, 1 for cooler on

Self explanatory.

800 //display size, display window height in pixels

The vertical size of the image to be displayed.

0 //image flip horizontally: 0 - none, 1 - flip

2 //image rotation for display: 0, 1, 2, 3 (0, 90°, 180°, 270° clockwise)

Flip and rotate to adjust image orientation.

2 //background subtraction: 0 - none, 1 - constant level, 2 - gradient

0.1 //normalised histogram level from left, for background subtraction

Gradient method is recommended. 0.1 in the second parameter means the very left part of histogram is assumed as black level – preferred for showing dark details. If you want to set black level near the peak of histogram, use 0.8, but this is not recommended.

1 //circular mask as area for background subtraction (for small image circle): 0 - none, 1 - active

0.9 //circular mask for background subtraction diameter, parts of image height

0 //show circular mask for background subtraction for test: 0 - none, 1 – active

It is recommended to set parameters like this per default, to limit area of black level detection. You can change the size of the mask with the second parameter, and make the mask visible with the third parameter.

1 //noise reduction, for both video and foto mode: 0 - none, 1 - bilateral filtering

0.3 0.0 //noise reduction strength for video and foto mode, 0..1

Self explanatory. Zero in the second parameter also deactivates noise reduction.

1 //circular mask for display (optic like): 0 - none, 1 - active for both video and foto mode

Here the black circular mask can be activated, making picture more optic-device-like, or hiding not usable parts of small image circle.

50.0 //initial stretching factor: 1.0 is neutral, higher value is more stretching

Initial stretching, can be adjusted to preference. 50.0 is already a strong stretching, recommended as default.

1.0 1.0 1.0 // White balance correction for RGB palette

White balance correction for default RGB mode. Can be adjusted to have natural or preferred colours of sky objects, or calibrated with color chart.

1.43 1.0 1.77 is an example for ASI533MC with Optolong UV/IR filter.

```
0  // use color correction matrix for RGB palette, 0 - don't use, 1 - use
 1.387698   -0.37278958 -0.07946052   // R = a*R + b*G + c*B, RGB palette
-0.40483978  1.69918117 -0.27936073   // G = a*R + b*G + c*B
 0.05144559 -0.74390103  1.66072276   // B = a*R + b*G + c*B
```

Color correction matrix for default RGB mode. Can be calibrated with color chart. RGB sensors normally can not produce natural colors without calibration – very useful function to see real colors of the sky. Here example for ASI533MC with Optolong UV/IR filter.

```
1.0 0.0 0.0   // R = a*R + b*G + c*B, dualband palette
0.8 0.1 0.1   // G = a*R + b*G + c*B
0.0 0.8 0.4   // B = a*R + b*G + c*B
```

Here the alternative palette can be configured. As defined here, should be good for dual-band filter.

```
0  // enhance bright stars, 0 - disabled, 1 - star "blobs"
20 0.05  // enhance bright stars: star "blob" radius in pixels, star "blob" strength 0..1
```

Size and strength must be adjusted carefully to achieve pleasant effect. Can also be distracting.

1 // highlight protection: 0 - disabled, 1 - active

sort of HDR tonemapping for highlights, prevents saturation of bright objects.

4.0 // zoom value for focusing mode

Self explanatory.

1.0 // zoom value for display, if needed, 1..x

Self explanatory. Can be also used to zoom a small image circle to full height.

x m + - p s f h // control keys for eXit, Mode, stretch +, stretch -, Palette, Save, Focusing, show Histogram

Here the control keys can be changed, if needed.

1 // screen GUI: 0 - none, 1 - active

GUI with on-screen buttons can be activated here. Useful also, if no keyboard is used, e.g. for tablet PC with touch screen.

//--------------- AI noise reduction

1   // AI noise reduction activation, 0 - none, 1 - active

2   // activate AI noise reduction after n-th stacked frame

train_03.jason   // AI noise reduction model file

AI noise reduction activation and parameters. Active only in stacking mode, and applied only after n-th stacked frame.

//--------------- Eyepiece display

0 //Eyepiece display activation, 0 for disabled, 1 for single picture, 2 for stereo

Activation of image on second screen in full-screen mode, meant for digital eyepieces. 1 is for single picture in the middle, 2 is for stereo picture for binocular eyepiece.

2560 1440 //Eyepiece display resolution in pixel, bigger dimension, smaller dimension

Physical resolution of eyepiece display.

121 68 //Eyepiece display dimensions in mm, bigger dimension, smaller dimension

Physical dimensions of eyepiece display in millimetres.

61 //interpupillary distance in mm

Interpupillary distance of observer in millimetres, needed for correct placing of stereo images on display.

3 //image rotation for eyepiece display: 0 (same, as main screen), 1, 2, 3 (0, 90°, 180°, 270° clockwise)

Rotation of the whole eyepiece image, e.g. for displays with vertical orientation.

2500 500 //coordinates of a point on second display to move image window (opencv specific)

This is a dirty hack, because opencv has no mechanism to work with second display. These are the coordinates of a point, that should be on second display to move the image window there. The eyepiece window first moved to these coordinates, landing on second display, and then goes full-screen. Shown configuration is good for Full-HD main screen, and second screen placed to the right of the main screen.