Pegasus Astro

NYX-101 Guiding Recommendations

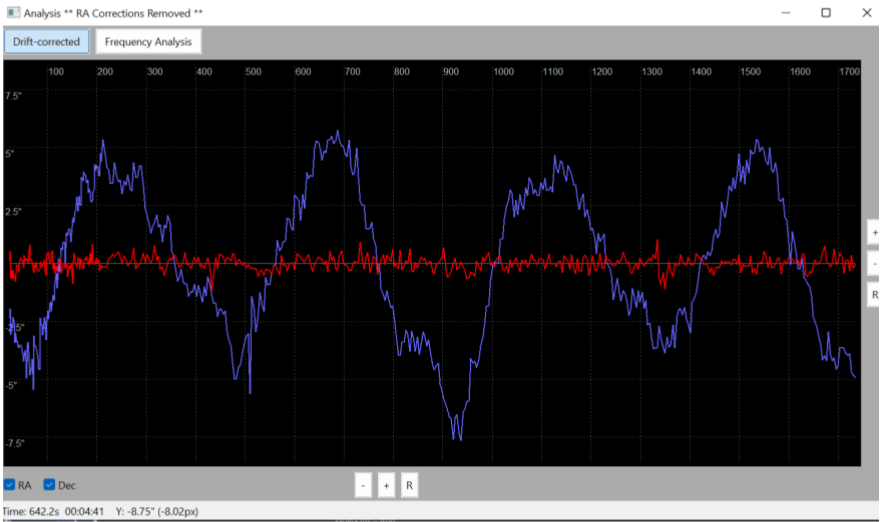
About Strain wave gearing

Harmonic reducers are gearboxes based on the so-called strain-wave principle in which a flexible tooth ring rotates via an oval drive shaft in an annular outer tooth ring. Because the outer ring has more teeth than the flexible inner ring, the rings will move relative to each other in relative terms.

Their main advantages over traditional gearing systems such as worm gears include high torque capacity, excellent positioning accuracy and repeatability, compact design, zero backlash, high single-stage reduction ratios, and high torsion stiffness.

Pegasus Astro has implemented a strain wave gearing reduction system (stain wave with belts in both axes) that offers low period errors and high torque. A guiding accuracy can be less than 0.5 arcsecs (usually between 0.4 - 0.8 arcseconds).

We have seen that the periodic cycle of the strain wave gear produces a higher PE offset during the two first minutes, a very calm tracking in the next 3 minutes, and a higher PE shift in the last 2 minutes. In total, the period is 7.16 minutes or 430 seconds. Our gears have a measured periodic error of +-20arcsec or less.



Measured Periodic error of NYX-101 (user submission)

A strain wave gear has different periodic error characteristics compared to worm gears. Strain waves can change the PE magnitude based on the load and direction of the telescope. Therefore, it is hard to apply a PE profile in each gear.

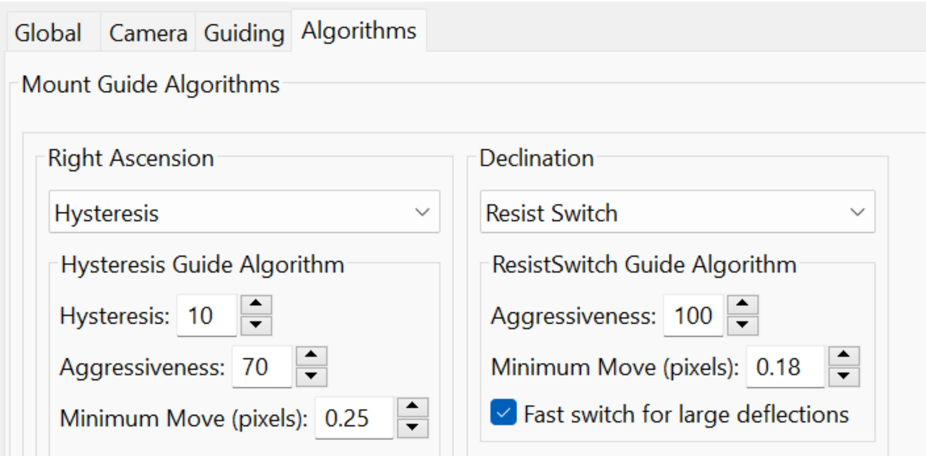
However, as the periodic error can be repeatable on the same load, we can train the guiding system to adapt and compensate this error. [check below for Predictive PEC]

In our tests, we used PHD2 (v2.6.11) software.

What we recommend:

- A multi-star guiding is preferable.
- Guiding interval is preferable to 1.0 – 1.5 seconds. You can use 0.5 seconds when your seeing is good. If seeing is bad you will "chase" the seeing and your HFR will be high, leading to blurry image results. Higher guiding intervals from 1.5-3 secs depend on the load and your setup.
- Make sure that your polar alignment is good enough. Try to have less than 30 arcsecs of error in your polar alignment. If you suspect that your polar alignment is way off, try to turn off DEC axis guiding and monitor the DEC curve in the graph if it quickly offsets in one direction from the zero axis.

The common mount guiding approach is to use the **Hysteresis** algorithm for Right Ascension and **Resist Switch** for the Declination axis.



The hysteresis algorithms keep a history of the guiding corrections that have been made in the recent past, and these are used to help compute the next guide correction. The hysteresis parameter, expressed as a percentage, specifies the "weight" that should be given to this history as opposed to looking only at the star deflection in the current guide frame. Consider an example where the hysteresis parameter is 10%. In that case, the next guiding correction will be 90% influenced by the star movement seen in the current guide frame and 10% by the corrections that have been made in the recent past.

Increasing the hysteresis value will smooth out the corrections at the risk of being too slow to react to a legitimate change in direction. The hysteresis algorithms also include an aggressiveness parameter, again expressed as a percentage, that is used to reduce over-correcting.

The Resist Switch algorithm behaves much as its name implies. Like the hysteresis algorithms, it also maintains a history of past guide corrections, and any change of direction must be "compelling" in order to issue a reversing guide command. This is appropriate for declination guiding. For that reason, ResistSwitch is the default algorithm for declination but not for right ascension, where valid direction reversals are expected.

PHD2 Predictive PEC Guide Algorithm (PPEC)

The PPEC algorithm is different from the others in PHD2 because of its modeling and predictive capabilities. The algorithm analyzes the tracking performance of the mount in real time and once that analysis is complete, it will compute guiding corrections even before a repetitive error is actually seen.

Issuing proactive guiding corrections reduces the time delay inherent in traditional guiding and can significantly improve performance. With the other algorithms, which are completely reactive, guide corrections are issued only after the error has been seen on the camera sensor.

Once guiding has begun**, the algorithm analyzes the performance of the mount and looks for tracking errors that are repetitive and thus, predictable.**

Since PPEC employs a learning process, it will usually take **about 2 worm periods to model the mount and become fully effective. During this training period, the algorithm will behave more like the 'hysteresis' algorithm, so you won't normally see a performance penalty** while the internal model is being built. Instead, you're likely to see a steady improvement in tracking as the model is refined and the algorithm shifts seamlessly from hysteresis to predictive mode. This improvement can usually be seen even before the medium-term mount behavior is fully modeled.

Since the PPEC model is implicitly tied to the state of the gear train, it must be re-learned if the mount is slewed by a substantial distance. For the same reason, it can't be retained across different guiding sessions, which is why conventional PEC is important. However, the PPEC model will remain intact during dither operations and while guiding is paused (via automation) for activities like focusing. For the most common use case, namely imaging the same target for multiple hours with periodic dithering, the PPEC model will remain valid. In any case, the learning process and transition from one mode to the other is handled automatically, so you won't need to pay it any attention.

The '**predictive gain'** and '**reactive gain'** parameters are exposed in the Advanced Settings dialog, and their default values for these parameters should work well for most mounts. You should be conservative about changing them because bad choices for these parameters can definitely make your guiding worse.

During the training period, the algorithm needs to identify periodic errors in the observed guide star movement. For initial trials, you can use the worm period of your mount as the starting point for the '**period length'**. This gives the algorithm a good starting point, but you should also leave the 'auto-adjust period' option checked. This tells the algorithm to adjust the period as needed to better control whatever periodic errors it finds. Once you have run the algorithm multiple times and are happy with the results, you can leave this field set to whatever value was computed in the previous sessions.

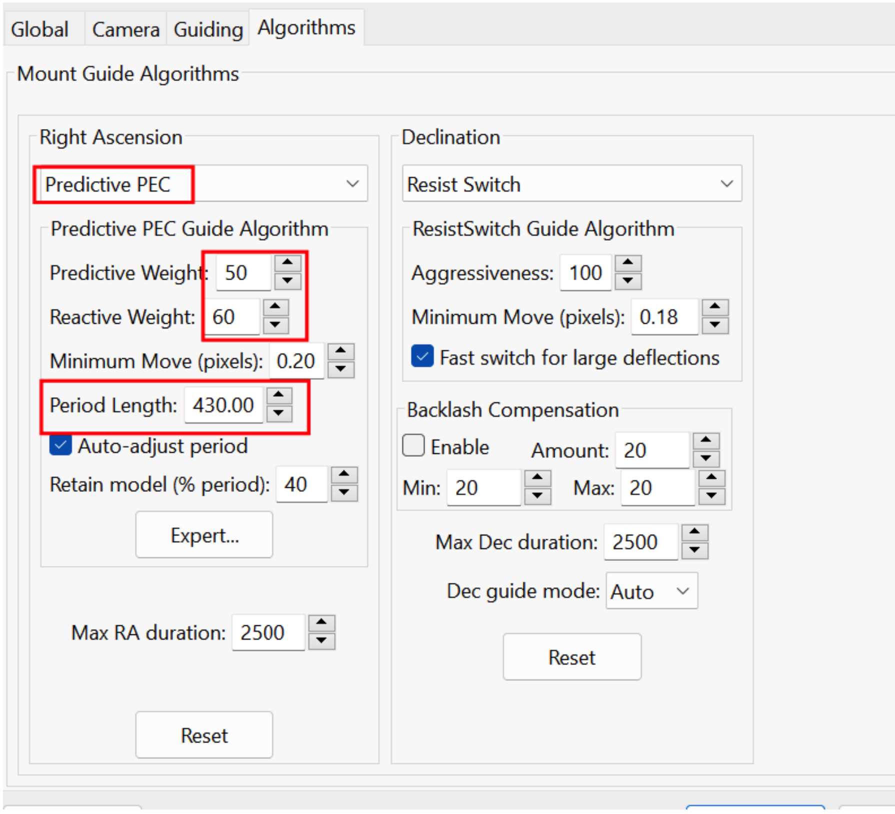
The '**Retain model (% period)**' parameter specifies how long the mount can track unguided before the PPEC algorithm will be reset. This is computed as a percentage of the current period length. This is useful in situations such as auto-focusing where the mount is continuing to track at the sidereal rate but guiding isn't being done. It also applies to westward changes in the RA pointing position from slewing.

Care must be taken if the default setting of 40% is adjusted upward. Running for extended periods of time unguided causes the PPEC model to lose accuracy, in which case a reset would be the best course of action. The point where that occurs is specific to the mount and the current seeing conditions, so you may need to experiment if you want to adjust this parameter.

Improve guide results of NYX-101 mount with PPEC

Predictive PEC (PPEC) Quick Guide:

- Enable Predictive PEC on Right Ascension Axis.
- Keep Predictive Weight and Reactive Weight to **default** values. We have tested them and they work very well with default values. A higher value tends to overcorrect the model, leading to higher tracking errors.
- Set the period length to **430** and have the auto-adjust period checked. The algorithm will automatically adjust and fine-tune the period based on the measured guiding PE cycle.
- Set your guiding exposure duration to 1 second.
- Let the guiding system run for 1-2 cycles. You will see a guiding improvement after the 1st cycle (7 minutes) that will gradually be improved as time passes.
- If you change an imaging target, the model will re-initiate its learning curve.
- If your seeing conditions are bad, we have seen, through our tests, that PPEC does not make an actual difference from the Hysteresis algorithm.



By using the settings above we achieved a tracking error of 0.3'' in RA by using the Predictive PEC algorithm in PHD2.

Mount = NYX101 (ASCOM), connected, guiding enabled, xAngle = -179.3, xRate = 2.840, yAngle = 89.9, yRate = 6.264, parity = +/+
Norm rates RA = 7.5"/s @ dec 0, Dec = 6.8"/s; ortho.err. = 0.7 deg
X guide algorithm = Predictive PEC, Control gain = 0.600
Prediction gain = 0.500
Minimum move = 0.290
Pixel scale = **1.09 arc-sec/px, Binning = 1, Focal length = 550 mm**
Telescope: **SW Esprit 100**
Guiding: **OAG**

For more information about Predictive PEC (PPEC):

- https://openphdguiding.org/man/Guide_algorithms.htm
- http://ieeexplore.ieee.org/document/7105398/