AN012: Focus/zoom tracking

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1. Focus/zoom tracking

For varifocal lenses, changing the focal length will cause the image to lose focus. Setting best focus for a desired field of view (focal length) is an iterative process. Theia calibrated lens data sets for lenses that have focus and zoom motors will include this focus/zoom tracking data frame which can be used to keep the lens in focus while changing zoom position (depending on minimum and maximum motor speeds) or at least to set the focus at a known zoom position.

Once the lens is initially set up to give good focus at a known object distance (see application note AN004 BFL compensation) the focus and zoom motors can be moved together to keep the image in focus. Due to the very tight tolerances of optical systems the image may require fine focus even after the tracking curve is followed.

2. Read the data file

The calibration curve data is at the top level of the JSON data in the data file, found under the key "tracking". Like other data frames, the tracking data has coefficients for up to 10th order polynomial.

$$fs = \sum_{k=0}^{10} P_k * zs^k$$

Where *fs* is the focus motor step number and *zs* is the zoom motor step number.

If there is only one calibration curve in the data file ("count" = 1), it will be for object distance of infinity. There may be additional curves at closer object distances (specified as control point 1 with units 1000/object distance). Control points 2 are not used for this calibration type and can be ignored.

This example shows a lens with focus/zoom tracking curves at 4 different object distances: 100000m (infinity), 10m, 5m, and 2.5m. The polynomials are of 6th order.

```
"tracking": {
  "type": "cal",
  "idx": 1,
  "count": 4,
  "xAxis": "zoom step",
```

```
"yAxis": "focus step",
"cp1Type": "1000/obj dist",
"cp2Type": "none",
"cp1": [
  0.01,
  100.0,
  200.0,
  400.0
],
"cp2": [
  0,
  0,
  0,
  0
],
"coef": [
  [
    6140.61672728999,
    -12.113215071620946,
    0.010219524423251159,
    -5.332735123117498e-06,
    2.050534889128989e-09,
    -4.788298151762702e-13,
    4.7317803793283983e-17
  ],
  [
    5806.876641274431,
    -11.488398944115524,
    0.009449628416450896,
    -4.763452107675134e-06,
    1.8173485392841948e-09,
    -4.300060050111277e-13,
    4.3230409138833924e-17
  ],
  [
    5471.591221550629,
    -11.067660262392799,
    0.009055353111329227,
    -4.425787072184168e-06,
    1.6191863367316143e-09,
    -3.6931465683084445e-13,
    3.6093165041747784e-17
  ],
  [
    4509.826523399265,
    -8.542437483023217,
    0.002383839175701096,
    5.379537744553578e-06,
    -5.254028350139687e-09,
    1.8361836823602483e-12,
    -2.247304748713125e-16
  ]
]
```


Only 2 of the curves are plotted so the difference in focus step number can clearly be seen.

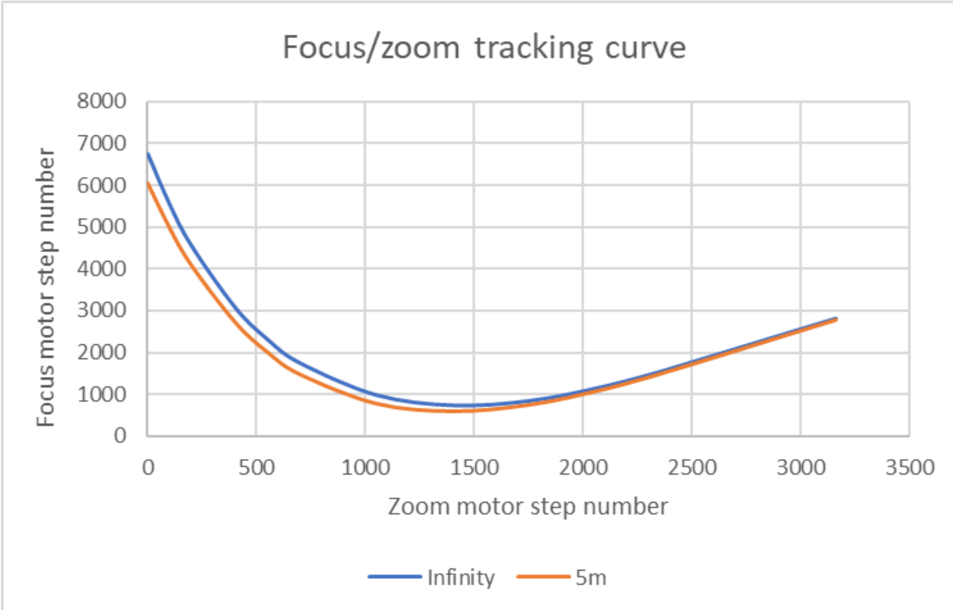

Fig 2.1: focus/zoom curve for 2 object distances for Theia's TL1250 calibrated lens.

In addition, the zoom motor step number can be calculated from the focal length using the inverse polynomial coefficients ("coefInv"). In the standard "FL" data frame, focal length is calculated from zoom motor step position. Using the inverse coefficients allows zoom step to be calculated from focal length.

$$zs = \sum_{k=0}^{3} Q_k * FL^k$$

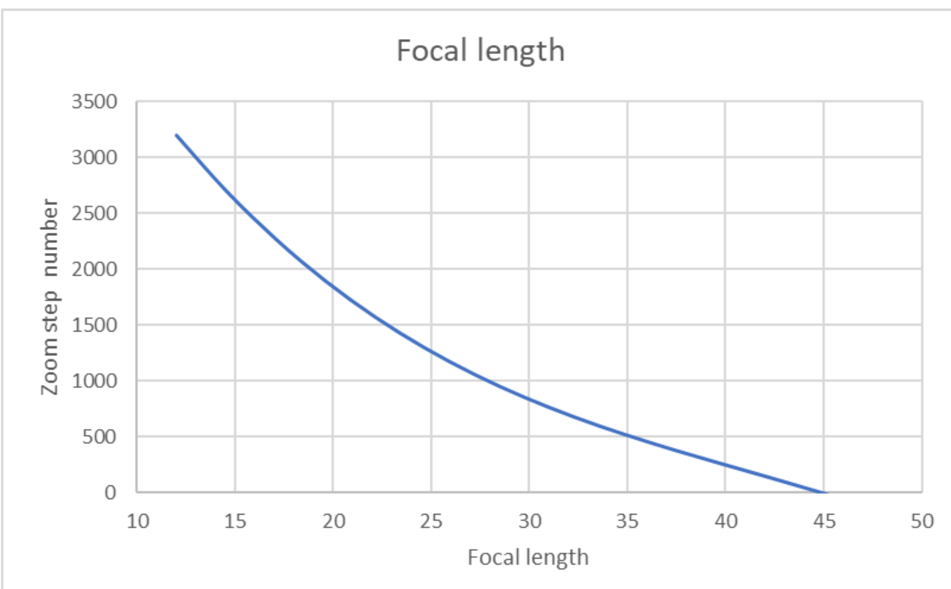

Fig. 2.2 inverse focal length calibration curve for Theia's TL1250 calibrated lens.

3. Calculate the positions

For example at a given focal length of FL = 25mm, the inverse polynomial coefficients are shown in table 3.1.

Inv. Coef.	
Q0	6.60454E+03
Q1	-3.67578E+02
Q2	7.71943E+00
Q3	-6.25441E-02

Table 3.1: Focal length inverse polynomial coefficients

The result is zoom motor step *zs* = 1262.

Because the object distance may be between measured focus/zoom curve control points, it may be necessary to interpolate between two curves. There are many ways to interpolate. A linear interpolation is shown here for a given object distance of 15m. The coefficients for the two closest focus/zoom tracking curves are for infinite object distance and 10m and are shown in table 3.2.

Coefficient	*Infinite object*	*10m object*
P0	6.75913E+03	6.34091E+03
P1	-1.32669E+01	-1.28075E+01
P2	1.29035E-02	1.36606E-02
P3	-7.82162E-06	-9.58119E-06
P4	3.10410E-09	4.31425E-09
P5	-6.79489E-13	-1.03005E-12
P6	6.07922E-17	9.76495E-17

Table 3.2: Focus/zoom tracking curve polynomial coefficients at 2 object distances.

At the given zoom motor step, the focus motor step positions are

$$fs|_{inf} = 790 \quad and\ fs|_{10m} = 717$$

Interpolation of the inverse distances (1000/∞, 1000/15, and 1000/10) gives a final result of *fs* = 741 at object distance 15m. Because of small tolerances in the lens, a fine focus adjustment may need to be performed to achieve optimal focus.

This focus step also assumes a lens mount position with perfect tolerances. See application note AN004 BFL compensation to learn more about calibrating the offset for the BFL tolerances in your camera.

4. Keeping the image in focus

The motors can be programmed to move in sync as long as the motor movement speeds are within the minimum/ maximum speed ranges for the focus and zoom motors. The focus motor will move faster than the zoom motor at most focal length settings so it should be used to set the maximum speed change in focal length.

A simple polynomial differentiation using the coefficients for focus/zoom tracking at infinite object distance from table 3.2 yields

Theia calibrated lenses

$$\frac{dfs}{dzs} = \sum_{k=1}^{5} k * P_k * zs^{k-1}$$

And shows that at small zoom motor step numbers the focus motor is changing very quickly and it will set the maximum focal length change to stay in focus while moving.

Zoom step	$\frac{d(focus\ step)}{d(zoom\ step)}$
1	-13.24
500	-4.88
1000	-1.54
1500	0.12
2000	1.13
2500	1.51
3000	1.65

Table 4.1 Focus/zoom tracking speed at infinite object distance

If the maximum motor speed is 1500pps and the lens should be kept in focus while changing focal length at close to 50mm (smallest zoom motor step) then the zoom motor should only be moving at ~1/13x the speed of the focus motor, i.e. 115pps.

5. Revisions

Version	Change	Reason
230308		Preliminary release