ANN Training

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Introduction

This document details the initial ANN training scheme used on the CANARY bench with the two etched SILIOS phase screens. ANN training requires exposure to many independent turbulence realisations (of the order of 1000), however due to the size of the phase screens each screen contains only ~16 independent turbulence realisations. To generate more independent realisations we place the two phase screens as close as possible to one another and rotate the screens at slightly different rates.

This document details the training procedure and also provides a log for all the recorded datasets.

Screen rotation

The reimaged telescope pupil within the phase screen has a 12mm diameter. The rotation of the phase screens exposes the WFSs to different phase aberrations as the etched turbulence rotates past the telescope pupil.

We define angular velocities of the lower (screen 1)and upper (screen 2) altitude phase screens as ω_1 and ω_2 respectively where $\omega_2 > \omega_1$. To maximise the number of independent turbulence realisations, every time screen 1 rotates once, screen 2 must rotate by an additional pupil diameter. If the off-axis distance of the field centre from the point of phase screen rotation is r, and the pupil diameter is given by d_p we can define the following relationship between ω_1 and ω_2:

$$\omega_1 = \left({}^{2\pi r}/_{2\pi r + d_p}\right)\omega_2 \qquad \text{Eq 1}$$

Units of ω_1 and ω_2 within the CANARY ICS are in revolutions per minute and this convention is maintained here. Therefore time taken in seconds, t_f, for the system to return to a given state purely due to the differential rotational velocities is given by:

$$t_f = {}^{60}/_{(\omega_2 - \omega_1)} \qquad \text{Eq 2}$$

The CANARY instrument control system, STYC, has a software limit of recording 10000 frames of data. We can therefore define a maximum frame rate in Hz, f_{max} that the system must be operated at to ensure t_f fits within this 10000 frame limit

$$f_{max} = 1000/60t_f$$
$$f_{max} = 1000(\omega_2 - \omega_1)/6 \qquad \text{Eq 3}$$

Using Eq 1 and Eq 3 we can define what the screen rotational speeds should be for a given frame rate.

For the datasets presented here the parameters given in Table 1 were used. It should be noted that because the ICS only allows ω to be set to 2 decimal places, the values given in Table 1 err on the side of caution and the phase screens repeat in less than the 10000 frame limit. It should also be

noted that screen 2 rotates in the opposite direction to that of the screen 1, hence the negative value for ω_1 and ω_2.

Table 1 System parameters for training run datasets

Parameter	Value
Frame rate	50Hz
Screen 1 rotational velocity, ω_1	5 rpm
Screen 2 rotational velocity, ω_2	-5.32 rpm
Time for full dual revolution	187.5 seconds
Number of frames taken per dataset	10000
Time taken per dataset	200 seconds

Screen setup

Training datasets

The screens were placed 5mm apart within the turbulence emulator. This is as close as the screen mounts allow. With screen 1 conjugated to the ground, screen 2 is at a conjugate altitude of 500m. The maximum lower screen altitude is 4.6km, at which point the upper screen is at a conjugate of 4.9km.

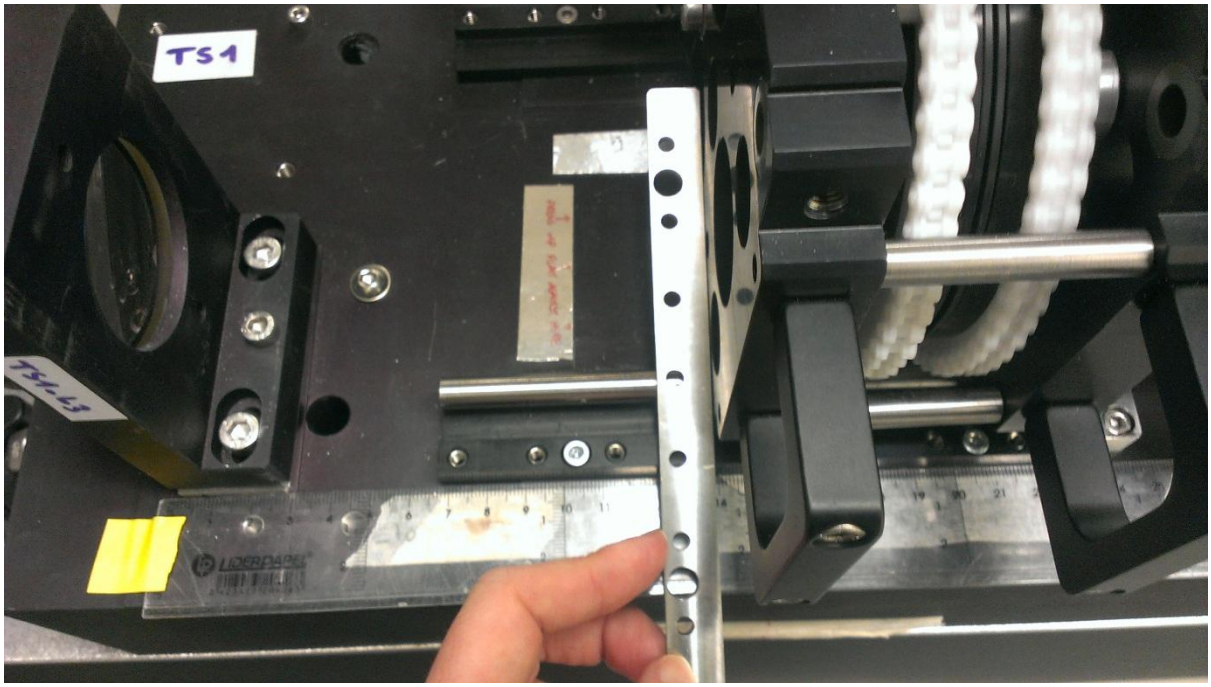

Figure 1 Phase screen positioning showing location of reference plane on lens mount and the reference plane of screen 1. The metal bar was held against the screen reference plan and used to determine the position of the screen on the ruler.

The position of the screen was referenced from the front of the final turbulence emulator lens mount (labelled TS1-L3 in Figure 1). The front surface of the lower altitude screen carriage was used as a reference. The conjugate altitude of the phase screens was increased by 1mm over a range of

40mm between each data set. This distance was measured to an accuracy of +/- 0.5mm, but the precise conjugate altitude is not required knowledge for the training process.

The distance between the reference (the front of screen 1 carriage) and screen 1 is 40mm. The screen 2 reference is the rear of the screen 2 carriage. At minimum spacing the distance between screen 1 and 2 reference surfaces is 85mm. When screen 1 is positioned at the marked 0km conjugate layer, reference 1 is at a position of 100mm. Placing screen 2 at the ground would require the screen 2 reference to be positioned at 180mm from the reference origin.

Calibration datasets

The light was blocked from WFS 1, 2, 3 and the Truth Sensor in turn and slopes recorded during this procedure. This is to ensure that the WFS subaperture mapping in understood

Test datasets

The first 4 test datasets place the 2 phase screens at different conjugate altitude. The frame rate was maintained at 50Hz for the first 3 data sets and increased to 150Hz for the fourth. The system background was recalculated whenever the frame rate was changed.

During the 5th dataset the screen 2 was varied in altitude whilst keeping screen 1 conjugated to the ground. The 6th dataset moved screen 1 in altitude whilst keeping screen 2 fixed. The 7th and 8th datasets repeated the variable altitude turbulence datasets but at a frame rate of 50Hz.

Additional data

The positions of the off-axis WFSs are recorded in /home/canary/data/annTraining/tas however they were not moved throughout the data recording procedure and were positioned in the locations listed in Table 2.

Table 2 WFS locations in the CANARY field of view

WFS	X position (arcsec)	Y position (arcsec)
1	-13.3	-45.72
2	-51.89	40.62
3	36.51	20.55
Truth	0	0

Datasets

All tomographic data files can be found on /home/canary/data/annTraining/datatomo/ (or datatomoraw/ for DARC format with interlaced subapertures)

Pos	Timestamp	Altitude lower (km)	Altitude upper (km)	Comments
00	12h24m31s	0	0.55	Screens rotating at 4pm – too slow
00	12h36m23s	0	0.55	Screen rotations increased to 5/5.32rpm
01	12h43m04s	0.15	0.65	1mm further up. Adaptive window error. junk
02	12h48m18s	0.25	0.74	Adaptive window error. Junk
03	12h53m36s	0.35	0.84	Adaptive Window error. Junk

04	12h58m51s	0.45	0.93	Adaptive Window error. Junk
01	13h09m40s	0.15	0.65	Could be okay. Several Subapertures saturated
01	13h16m34s	0.15	0.65	Changed source intensities and recalibrated
02	13h22m19s	0.25	0.74	
03	13h28m06s	0.35	0.84	
04	13h32m29s	0.45	0.93	
05	13h37m03s	0.55	1.02	
06	13h42m32s	0.65	1.11	
07	13h47m01s	0.74	1.20	
08	13h54m22s	0.84	1.29	
09	14h02m18s	0.93	1.38	
10	14h07m05s	1.02	1.46	
11	14h11m30s	1.11	1.55	
12	14h17m26s	1.20	1.63	
13	14h21m42s	1.29	1.71	
14	14h26m40s	1.38	1.80	
15	14h31m01s	1.46	1.88	
16	14h35m18s	1.55	1.96	
17	14h39m27s	1.63	2.04	
18	14h43m38s	1.71	2.11	
19	14h47m38s	1.80	2.19	
20	14h51m53s	1.88	2.27	
21	14h56m24s	1.96	2.34	
22	15h00m28s	2.04	2.42	
23	15h05m03s	2.11	2.49	
24	15h09m41s	2.19	2.56	
25	15h14m04s	2.27	2.63	
26	15h18m29s	2.34	2.71	
27	15h23m27s	2.42	2.78	
28	15h28m22s	2.49	2.84	
29	15h32m50s	2.56	2.91	
30	15h39m07s	2.63	2.98	
31	15h45m01s	2.78	3.11	This is actually at pos 32. Got it in the wrong place
32	15h50m55s	2.71	3.05	This is actually at pos 31. Retook the missing data.
33	15h55m10s	2.84	3.18	
34	15h59m47s	2.91	3.24	
35	16h04m15s	2.98	3.31	
36	16h08m17s	3.05	3.37	
37	16h12m49s	3.11	3.43	
38	16h18m20s	3.18	3.50	
39	16h22m39s	3.24	3.56	
40	16h28m16s	3.31	3.62	
41	16h33m02s	3.37	3.68	
42	16h38m01s	3.43	3.74	
43	16h43m08s	3.50	3.80	
44	16h48m50s	3.56	3.86	
45	16h53m23s	3.62	3.91	Slightly less than 45mm from marked 0km plane
W1	16h57m29s	N/A	N/A	Blocked WFS 1. Ignore file 16h58m57s_W1

W2	16h59m10s	N/A	N/A	Blocked WFS 2
W3	17h00m44s	N/A	N/A	Blocked WFS 3
WTS	17h01m29s	N/A	N/A	Blocked Truth Sensor
DS1	17h07m08s	0	2.63	Forgot to turn on truth sensor
DS1	17h12m04s	0	2.63	Remembered this time
DS2	17h17m14s	1.46	2.63	Moved lower screen to altitude
DS3	17h23m15s	0	1.46	Moved both screens to lower altitudes
DS4	17h26m27s	0	1.46	Changed to 150Hz
DS5	17h43m36s	0	1.02 - 2.63	Still at 150Hz, changed high layer altitude
DS6	17h47m28s	0.00 - 1.88	2.63	Still at 150Hz, changed low layer altitude
DS7	17h54m33s	0.00	1.02 - 2.63	Reverted to 50Hz, repeated DS5
DS8	17h58m34s	0.00 - 1.88	2.63	DS6 @ 50Hz