Integrated turbulence parameters estimation from NAOMI adaptive optics telemetry data

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Abstract

Context: Estimating turbulence parameters is important to e.g. site characterisation, adaptive optics (AO) performance optimisation and fringe tracking. The large number of AO systems now deployed on modern observatories makes them potential candidates to provide turbulence information complementary to dedicated seeing monitors.
Aims: We seek to estimate the atmospheric seeing from NAOMI wavefront sensor telemetry data installed on the four Auxiliary Telescopes of the VLT Interferometer. Since the system is replicated on all four telescopes, we achieve four times higher spatial resolution with simultaneous observations than an individual telescope analysis.

Methods: We perform a $\chi 2$ (chi-squared) modal fitting to the von Kármán turbulence model, namely variances expressed on a Zernike basis. The algorithm is modified, curated and optimised to operate correctly in a low spatial resolution scenario (4x4 Shack-Hartmann wavefront sensor). It estimates and compensates for measurement and remaining error using analytical expressions. Since the latter depends on the estimated turbulence parameters, we chose an iterative approach to jointly estimate the turbulence parameters and correct the remaining error. We also propose a Monte Carlo method to calculate the uncertainty, providing confidence levels to our estimates.

Results: We optimise, curate and validate the algorithm in simulation using typical atmospheric conditions for the Paranal Observatory. We achieved sub-per-cent accuracy in estimating the Fried parameter for a temporal horizon of (37±5) seconds. On the other hand, without the correction of measurement noise and remaining error, the accuracy in the estimation of the Fried parameter was 17%. Using non-overlapping samples for a 2% accuracy in the estimation of the seeing, we achieved a maximum time resolution of 20 seconds. Application to on-sky data (N=8170 samples) shows that the mean seeing between 2018 and 2020 at the Paranal Observatory was 0.69 arc seconds. The median uncertainty for an individual estimation of the seeing was 1.2%. We show that our estimates have a 0.70 Pearson correlation coefficient with DIMM estimates while estimating a 5% smaller seeing on average. By comparing simultaneous telemetry samples, we found that the spatial distribution of the ATs accounts for 1.6% of the median seeing.

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Considering the median estimation uncertainty, we find no statistically significant variation of the seeing across the Observatory.

Keywords: Turbulence parameters estimation, NAOMI on sky telemetry, Paranal turbulence