Experimental validation of VAR2 LQG-based predictive control for LEO-to-ground optical telecommunications

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Optical communication links between space satellites and ground stations are impaired by atmospheric turbulence, that is inducing optical phase fluctuations and limiting the global link performance due to fadings and loss of coupling efficiency. Adaptive optics (AO) is the most advanced solution to tackle this issue. It consists in measuring the turbulence effects typically with a Shack-Hartmann wavefront sensor (SHWFS). Then, a real-time controller (RTC) computes a correction to counteract these effects, and the correction is sent to a deformable mirror (DM).
The quality of the correction depends on the control scheme applied in the AO loop. Usually an integrator control law is used in the RTC, as it is robust and easy to implement. However, it does not allow for a reduction of the intrinsic temporal error associated to the AO loop delay. A way to overcome this issue is to use predictive controllers, such as a Linear Quadratic Gaussian (LQG) controller. They use evolution models of the turbulence as well as SHWFS measurements to compute DM corrections.
In the case of optical downlinks with scrolling LEO satellites, improvements in the evolution models have been done in the recent years. P. Robles [2] proposed a Vectorial Auto-Regressive model of second order (VAR2), particularly suited for LEO tracking conditions. The simulations proved a better performance in terms of coupling efficiency and fadings compared to integrator control. However, no experimental validation of this improved control law has yet been carried out at the moment. In this presentation, we propose to test the VAR2 LQG on the PICOLO+LISA bench, which is composed of PICOLO, a turbulence emulator [3], and LISA, an AO system, as a first step towards implementation in the ONERA's FEELINGS optical ground station [4]. The experimental results are compared to simulations of this control law, and to traditional integrator control.

References

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