Interferobot: Robotic Alignment of an Optical Interferometer

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Deep reinforcement learning is developing explosively nowadays, demonstrating breakthrough results in simulated environments. It can be used universally for control in robotics if transferred from simulations to real setups. This transfer is limited by data inefficiency - since reinforcement learning is heavily based on trial and error, it requires millions of agent-environment interactions to achieve a stable policy.

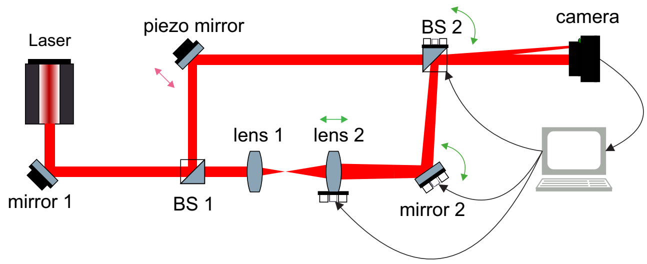

Figure 1: Conceptual scheme of the Mach-Zehnder interferometer. Lens 2, mirror 2 and BS 2 are motorized optical elements controlled by an RL agent

In this work, we apply reinforcement learning methods to a vision-based alignment of an optical Mach-Zehnder interferometer with beam divergence control and continuous action space. The goal of the alignment is to precisely overlap the two beams that propagated through the two interferometer arms, making their centers, wave vectors, beam divergences and radii coincide. Our agent observes images acquired by the camera and operates optical elements as shown in Fig. 1

We train our agent in a simulated environment, without any hand-coded features or a priori information about the physics, and subsequently transfer to a physical interferometer. To make the learned policy applicable in a physical environment, we use domain randomizations inspired by uncertainties in experimental measurements. To let our agent operate with actions of different amplitudes (for large initial alignment steps and small fine-tuning steps), we use exponential scaling. Thanks to a set of domain randomizations simulating uncertainties in physical measurements, the agent successfully aligns the interferometer. The trained agent's performance is comparable with that of a skilled specialist in terms of the achieved visibility but significantly faster.

Our approach can be easily extended to interferometers of various sizes, shapes and with additional optical elements. In the future, such a method can be applied for fully automated alignment of complex optical setups, which can significantly decrease the amount of routine manual work needed for complex experiments.

These results are partially reported in [1,2].

References

[1] D Sorokin, A Ulanov, E Sazhina and A I Lvovsky, arXiv:2006.02252 (2020)

[2] D Sorokin, A Ulanov, Sazhina and A Lvovsky, in: H Larochelle, M Ranzato, R Hadsell, M F Balcan and H Lin (eds.), Advances in Neural Information Processing Systems, volume 33, p. 13238, Curran Associates, Inc., 2020