Continuous Exploitative Measurement Trajectories Using Bayesian Optimisation

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Abstract. Line-based sampling strategies aim to capture as much information as possible along a trajectory, whilst minimizing the trajectory's length. The current state of the art primarily contains exploration techniques that focus on uniformly sampling the measurement space. In this work, Bayesian optimization is used to create a novel exploitative line-based sampling strategy, that is able to guide the sampling process towards interesting regions.

Keywords: Bayesian Optimization · Line-Based Sampling · Design Of Experiments

1 Introduction

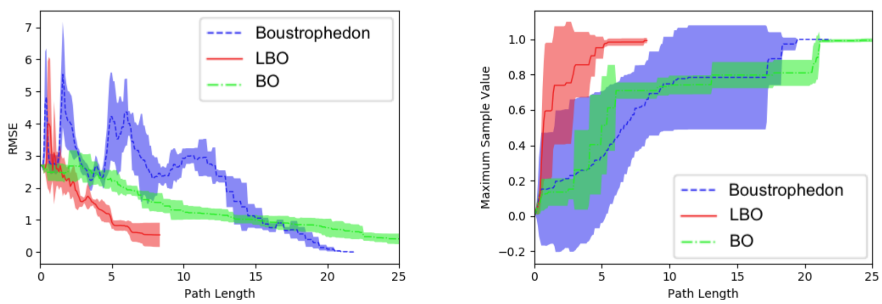
Automated data collecting, using robots and drones, is omnipresent in both scientific studies and engineering applications. In such a context, the length of the measurement trajectory is limited by battery restrictions or operating costs. As such, a line-based sampling strategy is used, which aims at minimising the trajectory length whilst maximising the information gained per step. The current state of the art primarily contains explorative techniques that uniformly sample the measurement space [1]. A model-driven approach allows the strategy to create a representation of the measurement space which can guide the sampling process towards interesting regions. In this work, Bayesian optimisation (BO) is used to create a line-based sampling strategy for global optimization that naturally deals with the exploration-exploitation trade off.

2 Line-based Bayesian Optimization

Classic BO aims to find the global optimum of the measurement space, using few data-points. This is typically quantified by evaluating an Acquisition Function (AF) over the entire space. Maximising the AF returns the sample location that has most potential to improve on the current global optimum. The maximum of the AF is iteratively acquired and recalculated in the search for the global optimum. The advantage of using an AF is that it naturally deals with the exploration exploitation trade-off.

In this work, BO is used to create a Line-based Bayesian optimisation (LBO) strategy. The AF's maximum is used as a waypoint for the measurement probe. To reach this point, the probe moves in small steps, straight towards the waypoint and samples at every step until it is reached. At every step, it is allowed to deviate from its trajectory by some angle if this results in the sampling of a point with a higher acquisition score. The stepsize and angle of deviation are parameters of the strategy. This LBO strategy can only be used in convex spaces and is deterministic if the underlying BO is deterministic as well.

3 Experimentation, Results And Discussion



(a) RMSE Between estimated space and the ground truth.

(b) Fraction of the maximum sampled value, compared to the global maximum

Fig. 1: Comparison of BO, LBO and Boustrophedon in terms of path length. Mean and standard deviation are calculated using 8 runs with different starting locations.

Figure 1 shows the results of Comparing LBO, BO and the Boustrophedon path [2] using the peaks function [3] as measurement space. Figure 1a compares the rate at which the error of the estimated space decreases with respect to the ground truth. Here the LBO outperforms the other strategies. In addition, Figure 1b shows that the LBO is able to find the maximum of the measurement space using a shorter path.

In conclusion, introducing a Line-based element into BO, creates a sampling strategy that is efficient and is able to explore and exploit the space using a shorter path than the other common sampling strategies.

References

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