# Notes on Bayesian Optimization

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## Introductory Notes

### Black-box Optimization

We have a function which has some optimum we are interested to know about. The problem is that we do not have a direct access to so we have no idea about how this function behaves in the search space. We write this as:

where is a black-box function for which the following is true:

* only the function value can be observed – that is, we can query at some input point ; this implies that we have no direct access to the function gradients
* the evaluation of is expensive – takes substantial amount of time and/or takes substantial computer resources
* the observation typically is noisy – it is corrupted by noise.

Black box,

*, noisy output*

input

* There is a true latent value which we would like to optimize but we do not have access to it.
* In order to optimize we need to design a sequential strategy/algorithm to query .

Examples of black-box optimization:

A/B testing

Users visit website which has two different configurations and . We want to find the best configuration to optimize specific metric (e.g. click rate, revenue, etc.).

Hyperparameter tuning

Machine Learning algorithm relies on hard-to-tune hyperparameters which we want to optimize with respect to validation data accuracy.

Black-box optimization

Figure: true latent for which we would like to find maximum in search space

On the Figure above it is shown the true function but the Optimizer sees something not quite detailed – it sees a subset of points only as show below

## References

[1] [Practical Bayesian Optimization, Danel J. Lizotte, U of Alberta, PhD thesis, 2008](https://github.com/dimitarpg13/probabilistic_machine_learning/blob/main/articles/bayesian_optimization/PracticalBayesianOptimization_lizotte_phd_thesis_2008.pdf)

[2] [A Tutorial on Bayesian Optimization of Expensive Cost Functions, with Application to Active User Modeling and Hierarchical Reinforcement Learning, Eric Brochu, Vlad M. Cora and Nando Freitas, 2010](https://github.com/dimitarpg13/probabilistic_machine_learning/blob/main/articles/bayesian_optimization/A_Tutorial_on_Bayesian_Optimization_of_Expensive_Cost_Functions_Brochu_2010.pdf)

[3] [Taking the Human Out of the Loop: A Review of Bayesian Optimization, B. Shahriari et al, UBC, 2016](https://github.com/dimitarpg13/probabilistic_machine_learning/blob/main/articles/bayesian_optimization/Taking_the_Human_Out_of_the_Loop-A_Review_of_Bayesian_Optimization_Shahriari_UBC_2016.pdf)

[4] [Bayesian optimization and multi-armed bandits, Nando de Freitas, 2013, youtube lecture](https://www.youtube.com/watch?v=vz3D36VXefI)

[5] [Bayesian optimization, Matthew W. Hoffman, DeepMind, UAI 2018, youtube presentation](https://youtu.be/C5nqEHpdyoE?si=qOUBK1ZhG2ih)