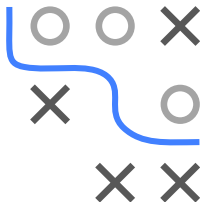


# Optimization in Machine Learning

## Bayesian Optimization Practical Aspects of BO

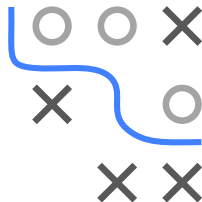


### Learning goals

- Size of the initial design
- Optimizing the acquisition function
- When to terminate
- BO Components and robustness

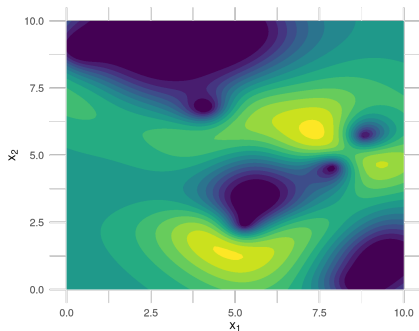
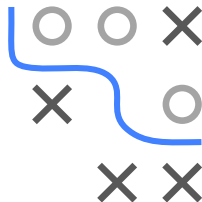
# SIZE OF THE INITIAL DESIGN

- Should not be too small
- Should not be too large
- Scale with the dimensionality of the search space
- Certain SM may impose restrictions on the lower bound of the size of the initial design
- Rule of thumb  $4d$



# OPTIMIZING THE ACQUISITION FUNCTION

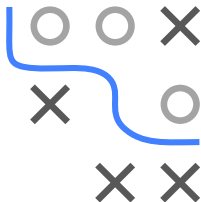
- Optimizing the acquisition function to find the next candidate point is comparably cheap
- Still can be a hard optimization problem: non-linear, multimodal
- Properly optimizing the acquisition function can be crucial for performance



Example EI landscape for a 2D problem.

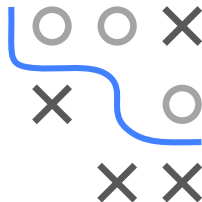
# OPTIMIZING THE ACQUISITION FUNCTION

- Optimizing the acquisition function to find the next candidate point is comparably cheap
- Still can be a hard optimization problem: non-linear, multimodal
- Properly optimizing the acquisition function can be crucial for performance
- Choice of optimizer depends on the search space
  - Numeric: L-BFGS-B with restarts, DIRECT, ...
  - Mixed: EAs, local search with restarts, ...
  - A random search can always be used but may not find a good solution (even if the budget is large)
- Sometimes, gradient-based optimizers can be used (e.g. when using a GP as SM)



# WHEN TO TERMINATE

- After a certain number of evaluations
  - Potentially scaling the budget with the dimensionality of the search space
- After a certain runtime
- Specify a target threshold (of the objective or acquisition function)
- Based on stagnation (of the objective or acquisition function)





# CHOOSING THE RIGHT COMPONENTS

- BO is modular: SM, acquisition function, acquisition function optimizer
- Different choices induce different overhead, e.g., GP vs. RF, entropy based acquisition functions vs. cheap to compute ones like EI, thorough acquisition function optimization with a large budget can be expensive
- Choosing the right components usually depends on the concrete application at hand and how expensive the evaluation of the black box itself is

