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Machine Learning Applications for Particle Accelerators

# Exercises



Build a Gaussian Process to model

 $f(x) = \sin(x).$ 

For this first exercise, build the GP with only numpy and scipy (i.e. do not use scikit-learn, BoTorch,...).

Choose a prior with any kernel and  $\mu(x) = 0$ , define a method to compute the posterior and plot the posterior and the true function with 5 test points.

Tipp:

e.g. RBF kernel

covariance matrix element  $K_{ij} = k_{RBF}(x_i, x_j),...$  build entire matrix.

# **Exercise 1a**



Build your own Bayesian Optimisation algo.

Use the GP and data from Exercise 1 and optimise it between  $[0,2\pi]$ .

- Define the Acquisition Function UCB method for a single data point
  - \* e.g. def acq\_ucb(x):...

Iteratively find the optimum of f(x) by optimising the Acquisition Function at each iteration.



Solve Exercise 1 and 1a with BoTorch.



Optimise the RMS of the AWAKE  $e^-$  in the horizontal plane with Bayesian Optimisation. Start with a random corrector settings (method initialise\_trajectory\_random()) Work with bounds  $\pm 300\mu$ rad





# **Exercise 3 - instructions (1)**



# **Exercise 3 - instructions (2)**



Install the following package and work with swan; choose awake-machine-demo.ipynb

1	Go to: <u>swan.cern.ch</u> and pick configuration	2 Clone from: <u>https://gitlab.cern.ch/mischer</u>	nk/rl-exercises.git
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The goal of this exercise is to understand Q-learning.

Choose the project rl-intro.ipynb



Implement model-free RL (based on SB3) with a Gymnasium environment to optimise the RMS of the AWAKE  $e^-$  trajectory in the horizontal plane.

Tipps:

Each episode should start with a new random trajectory and the agent needs to correct below RMS threshold (e.g. 1.5 mm).

The units of the example are: actors in radian, positions in m

Truncate the episodes: e.g. maximum number of iterations = 50