Karlsruhe Institute for Technology (KIT)
Institute for Beam Physics and Technology
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Master Thesis
Machine Learning-Based Accelerator Tuning

Efficient Beam-Based Alignment at Particle Accelerators using Bayesian Experimental Design

Institute for Beam Physics and Technology (IBPT)

IBPT operates the 110 m long electron storage ring KARA and the short-pulse linear accelerator FLUTE on Campus North. The construction and constant improvement of these large-scale research facilities offer a variety of exciting theses for physicists and engineers. Are you interested in particle accelerators, but you do not find a topic that you like at the moment? Just get in touch with us! Due to the many possibilities, we do not advertise every job.

Tasks and main topics

- Research current beam-based alignment techniques
- Implement response-matrix-based correction for comparison
- Implement BAX for magnet alignment
- Test the algorithms in simulation
- Test the algorithms during dedicated beam time at KARA

Requirements

- Interest in particle accelerator physics
- Previous knowledge in machine learning (ML) is advantageous, but not required
- Programming experience in Python
- A good level of written and spoken English

Motivation and Project Description

At particle accelerators we often face *multi-point query* measurements, where a physical quantity can only be measured indirectly by scanning or varying other parameters, which can often be very time-consuming. Some examples are the beam-based alignment of the magnets or emittance measurements using quadrupole scans. This thesis will tackle the beam-based alignment for the injection line at KARA. A transverse misalignment will lead to a deflection of the beam passing through the quadrupole, affecting the electron injection into the booster synchrotron. It requires human intervention and hinders the automation of the start-up process. Previously, this was done by iteratively changing the corrector magnets, and scanning the quadrupole strength to observe whether the beam orbit offset is decreased. Recently, the Bayesian Algorithm Execution (BAX)[a] has been proposed as an efficient method to solve such multi-point query problems[b]. During this thesis you will implement and further develop state-of-the-art algorithms, such as BAX, to solve the magnet alignment task at KARA. For example, additional constraints can be considered to keep the beam on the diagnostic screen during the alignment process. The developed method will be tested in simulation and in the real accelerator. After a successful deployment at KARA, it is possible to transfer the method and conduct additional tests at the linear accelerator FLUTE, and at other accelerators in external facilities.

[a] https://github.com/willieneis/bayesian-algorithm-execution
[b] https://arxiv.org/abs/2209.04587

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