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# Gaussian Process Bayesian Optimization of an Isotope Separator Online system

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Isotope separator online systems (ISOL) are facilities constructed for producing radioisotopes used in multiple fields, such as nuclear & solid state physics and research related to medical applications. However, the quality (purity) and quantity (intensity) of the supplied Radioactive Ion Beam (RIB) depends on the proper tuning of the underlying process parameters and their mutual interaction. From experience with existing ISOL facilities like ISOLDE at CERN and ISAC at TRIUMF, the selection of initial design parameters to produce a RIB is performed by qualified operators. Here, the main concern is the long duration that the parameter tuning process demands due to the high number of control knobs that must be set. Therefore, incorporating online optimization techniques is crucial to reduce the initial parameter tuning time and provide an optimal performance of the ISOL system over the full running period. The optimization of this kind of system is challenging due to the high dimensionality, difficulty of modelling through physical laws, and the cost function being expensive to evaluate.
On that account, Bayesian optimization (BO) appears as an ideal technique to tackle the ISOL system based on the effectiveness of this method in optimizing highly costly objective functions using few iterations. In addition, to capture the complex dynamics of the ISOL system, Gaussian Process (GP) is proposed due to its ability to model non-linear multi-dimensional functions. Indeed, the combination of the Gaussian process and Bayesian optimization (GPBO) has been successfully applied to the online optimization of similar facilities like accelerator mass spectroscopy, linear particle accelerators, and recoil separator system.
One limitation for optimizing this type of process is the physical constraints imposed by the ISOL system itself. Therefore, strict measures must be taken to avoid the violation of those constraints. This contribution proposes a constrained GPBO to simultaneously learn the feasible design space and efficiently search for the parameters that allow an optimal operational regime. The method is tested through simulations of the transport beamline of ISOL@MYRRHA at SCK CEN.

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