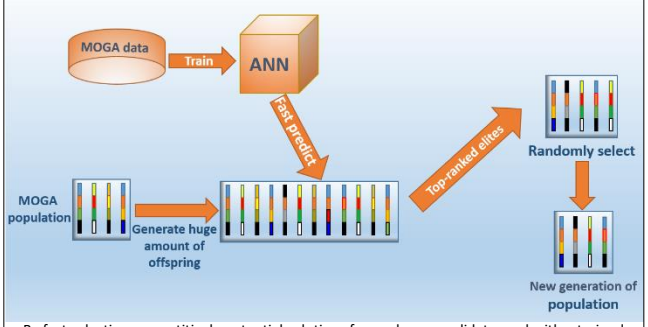
CURRENT STUDY OF APPLYING MACHINE LEARNING TO ACCELERATOR PHYSICS AT IHEP

J. Wan, Y. Jiao†,
Institute of High Energy Physics, CAS, Beijing 100049, P.R. China

Abstract: In recent years, machine learning (ML) has attracted increasing interest among the accelerator field. As a complex collection of multiple physical subsystems, the design and operation of an accelerator can be very nonlinear and complicated, while ML is taken as a powerful tool to solve such nonlinear and complicated problems. In this study, we report on several successful applications of ML to accelerator physics at IHEP. The nonlinear dynamics optimization of the High Energy Photon Source (HEPS) that is a 4th-generation light source is a challenging topic. In this optimization, we use a ML surrogate model to fast select the potentially competitive solutions for a multiobjective genetic algorithm that can significantly improve the convergence rate and the diversity among obtained solutions. Besides, we also tried to apply a generative adversarial net to solve one-to-many problems of longitudinal beam current profile shaping. Unlike most supervised machine learning methods than cannot learn one-to-many maps, the generative adversarial net-based method is able to predict multiple solutions instead of one for a 4-dipole chicane to realize several desired custom current profiles.

Neural network-based multiobjective genetic algorithm

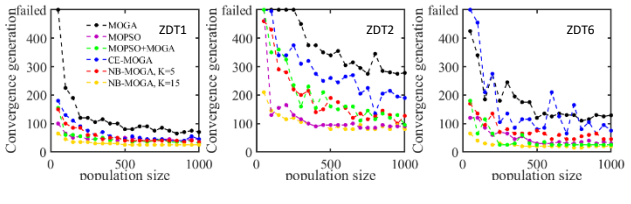
A neural network-based multiobjective genetic algorithm (NB-MOGA) is proposed for the optimization of nonlinear dynamics.



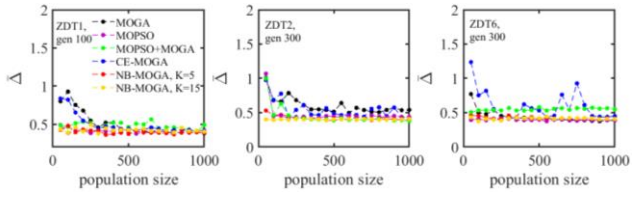
By fast selecting competitively potential solutions from a large candidate pool with a trained neural network, the convergence rate and diversity among solutions of the MOGA can be significantly improved.

NB-MOGA shows better performance on toy problems

As a diffraction-limited ring, the dynamic aperture area and the Touschek lifetime are two critical nonlinear dynamics parameters needed to be optimized.



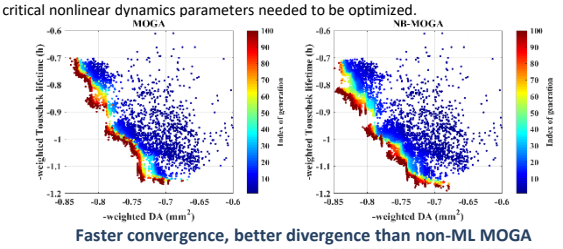
Faster convergence, better divergence than non-ML MOGA



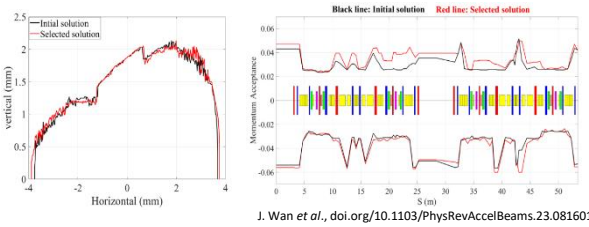
J. Wan *et al.*, doi.org/10.1103/PhysRevAccelBeams.23.081601

Optimization on the lattice of the HEPS with NB-MOGA

As a diffraction-limited ring, the dynamic aperture area and the Touschek lifetime are two critical nonlinear dynamics parameters needed to be optimized.



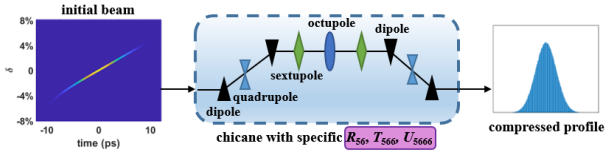
Faster convergence, better divergence than non-ML MOGA



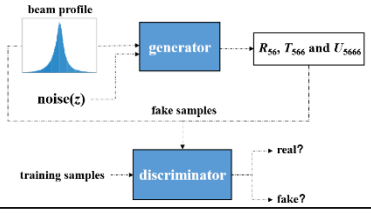
J. Wan *et al.*, doi.org/10.1103/PhysRevAccelBeams.23.081601

Conditional generative adversarial network solver for one-to-many problems of temporal shaping

Temporal shaping with chicane-type bunch compressor→one-to-many

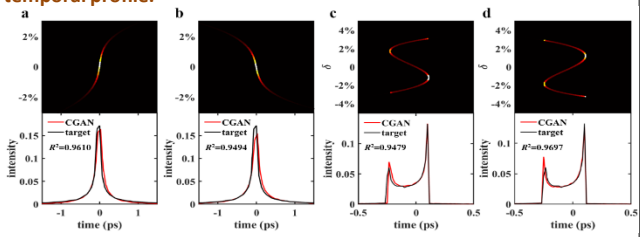


Conditional generative adversarial network (CGAN) → A semi-supervised machine learning method that can handle one-to-many problems

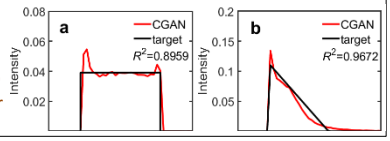


Realization of custom temporal profile with CGAN solver

The CGAN solver→multiple combinations of dispersion terms
The over-compressed and under-compressed beam result in the same temporal profile.



The flat-top and linearly-ramped profiles (desired in FELs and PWFAs)can be also solved with the CGAN solver



† jiaoyi@ihep.ac.cn.