Hierarchical intelligent real-time optimal control for LLRF using time series machine learning methods and transfer learning

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Nonlinear Model predictive control

System: LLRF nonlinear model

MPC's optimization: Nonconvex optimization

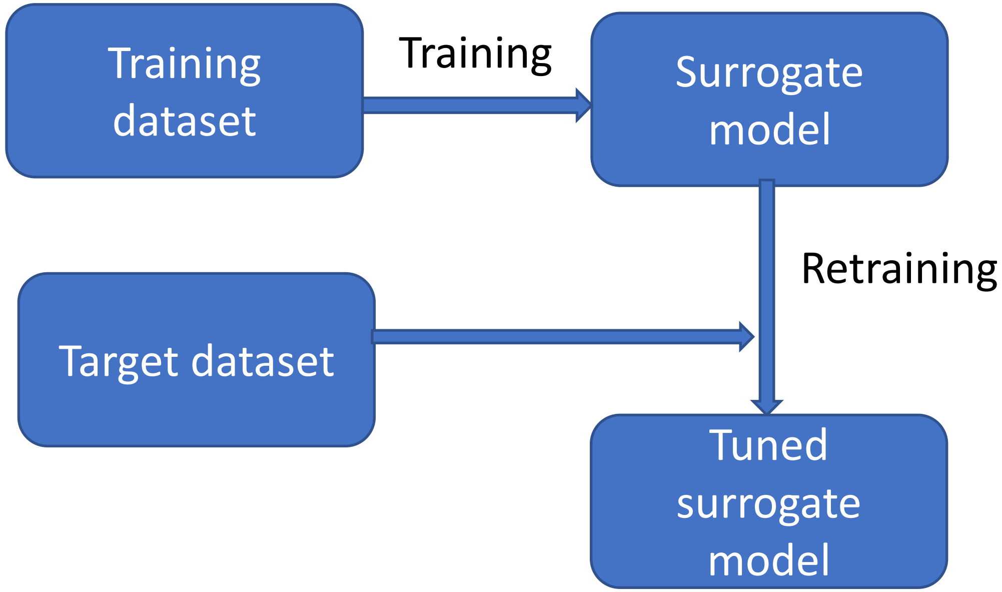
MPC's constraints: Constraints on RF amplifier, constraints on voltage and phase

MPC's cost function: State-error and energy

Hierarchical intelligent learning algorithm

- 1)Do MPC offline and produce states and control input data
- 2)Obtain deep learning surrogate model (LSTM, RNN) from the data in step1
- 3)Apply the surrogate model to the cavities and do the optimal control online
- 4)If the difference between the measurements and the predicted states is more than a threshold for each time step:
    - A)Apply transfer learning to fine-tune the surrogate model with the measurements of the cavities
    - B) Do MPC offline and produce states and control input data
    - C) Apply transfer learning to fine-tune the surrogate model with the data from step B
- 5) Go to step 3

Transfer learning



Conclusion - Future Work

- 1) Online optimal control is going to be obtained with MPC and surrogate model
- 2) The Constraints are going to be satisfied for LLRF
- 3)Accurate system identification, optimal control, and reduction of computational cost are going to be obtained through surrogate model and transfer learning
- 4) In the future, this approach will be updated for Microphonics and each cryomodule
- 5) In the future, this approach will be updated into distributed intelligent hybrid control for all the components of particle accelerator.

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