# MACHINE LEARNING PLASMA PROFILE PREDICTION FOR MODEL-PREDICTIVE CONTROL AT DIII-D

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We are developing an algorithm to allow DIII-D users to specify a set of desired plasma profiles. Our algorithm tunes the actuators in order to get there.

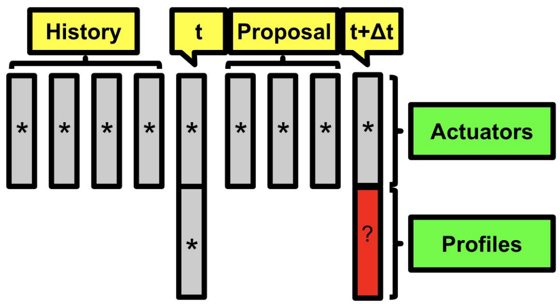
The most well-known profile evolution models, such as TRANSP [1] and ASTRA [2], use diffusion equations as their skeleton and get transport coefficients from physics-based models.

To allow these models to run in realtime for model-predictive control, various schemes have been proposed to **approximate the diffusion coefficients**. Some (e.g. [3]) use **quasi-physics-based models**, by training a model on a database of gyrokinetic simulation runs.

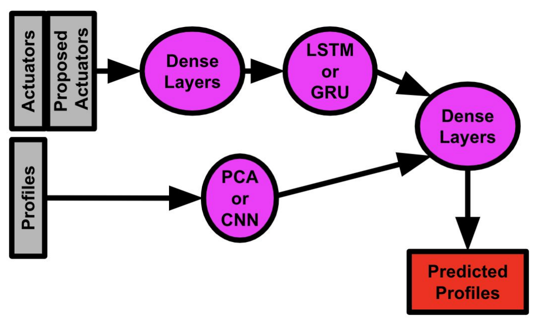
We attempt a **fully data-driven approach.** Rather than mapping from profiles to diffusion coefficients and using a transport model to evolve forward, we map directly from a profile at a given timestep to a profile at the next timestep, without assuming a transport model.

| <u>Relevant Profiles</u> | <u>Relevant Actuators</u> |
|---|---|
| Electron temperature | Neutral beam: power |
| Electron density | Neutral beam: torque |
| Ion temperature | Puffed gas |
| Rotation | Electron Cyclotron Heating |
| Pressure | Total plasma current |
| Safety factor (q) | |

Using data from ~5,000 DIII-D shots, we train a neural network architecture for this task.

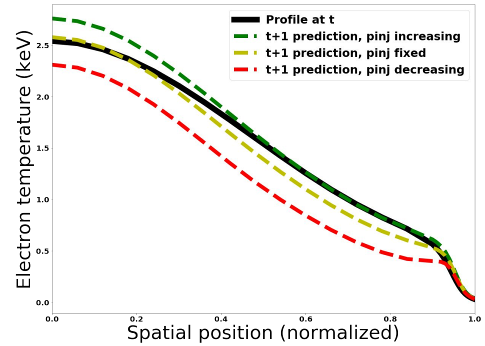



Format for the input to the model. Actuators (top) are specified by the operator and therefore are considered known at all timesteps. Profiles (bottom) are predicted by the algorithm 180 ms into the future.

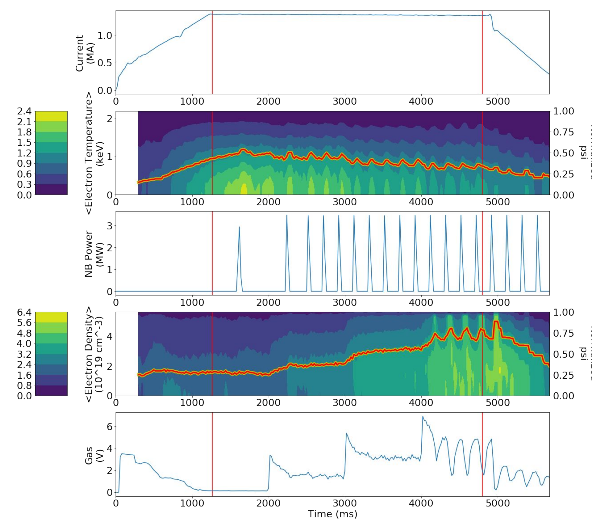



Model architecture: Principal Component Analysis or a Convolutional Neural Net extracts info from profiles, while a Recurrent Neural Net processes actuators.

The model prediction was tested in realtime on DIII-D and **ran in ~100 microseconds per prediction**. With profile evolution occuring on the order of 10s of ms, this would allow for ~100 different actuator proposals to be run for the purpose of model-predictive control.Control will be tested in an upcoming DIII-D experiment.




Cartoon of model-predictive control: algorithm chooses the actuators (here pinj) that yield the plasma closest to a user-specified target. .




Data for shot 160288 showing general scaling patterns.

**[1]** https://transpweb.pppl.gov
**[2]** Pereverzev, G., & Yushmanov, P.N. (2002). ASTRA Automated System for TRansport Analysis in a Tokamak (IPP--5-98). Germany
**[3]** Felici, F., Citrin, J., Teplukhina, A. A., Redondo, J., Bourdelle, C., … Imbeaux, F. (2018). Real-time-capable prediction of temperature and density profiles in a tokamak using RAPTOR and a first-principle-based transport model. Nuclear Fusion, 58(9), 96006.