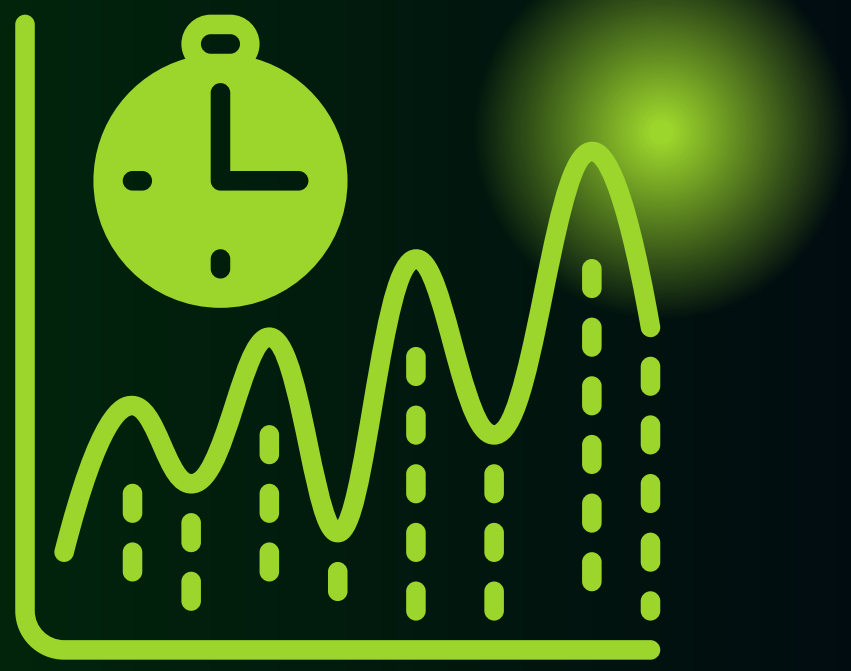
MACHINE LEARNING

FORECASTING DYNAMIC SYSTEMS WITH ARX MODELS



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UNDERSTANDING ARX MODELS

- ARX = AutoRegressive with eXogenous inputs
- Predicts current output y(k) based on:
  - Past outputs: $y(k-1), \ldots, y(k-n)$
  - Past inputs: $u(k-d), \ldots, u(k-d-m)$
  - Delay d
- Equation:

$$y(k) = \phi(k)^T \theta + e(k)$$

- Where:

$$\phi(k) \rightarrow regresor$$
$$\theta \rightarrow learned - parameters$$
$$e(k) \rightarrow noise\,(k)$$

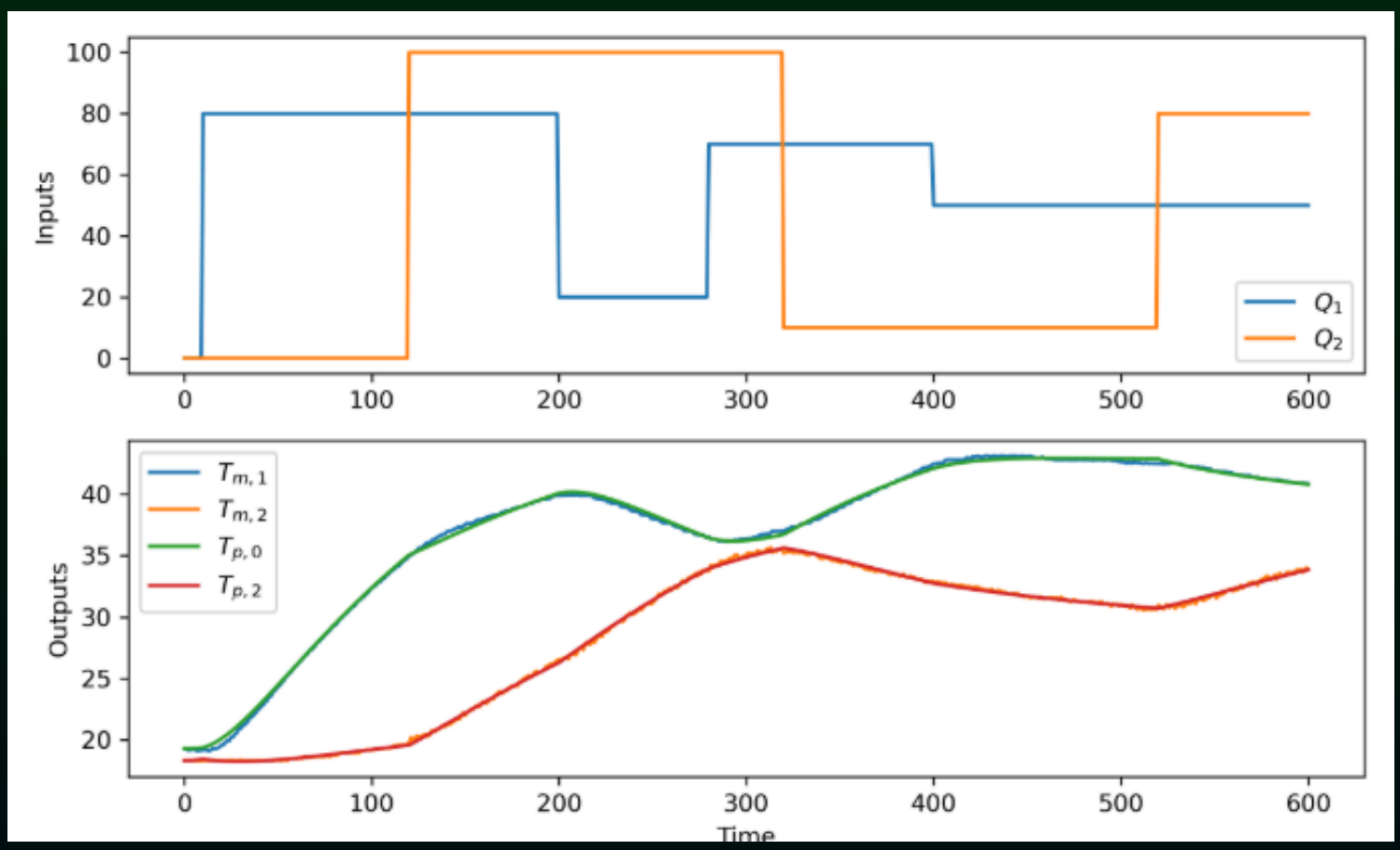

Illustration of an ARX model example

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HOW THE ARX MODEL WAS BUILT

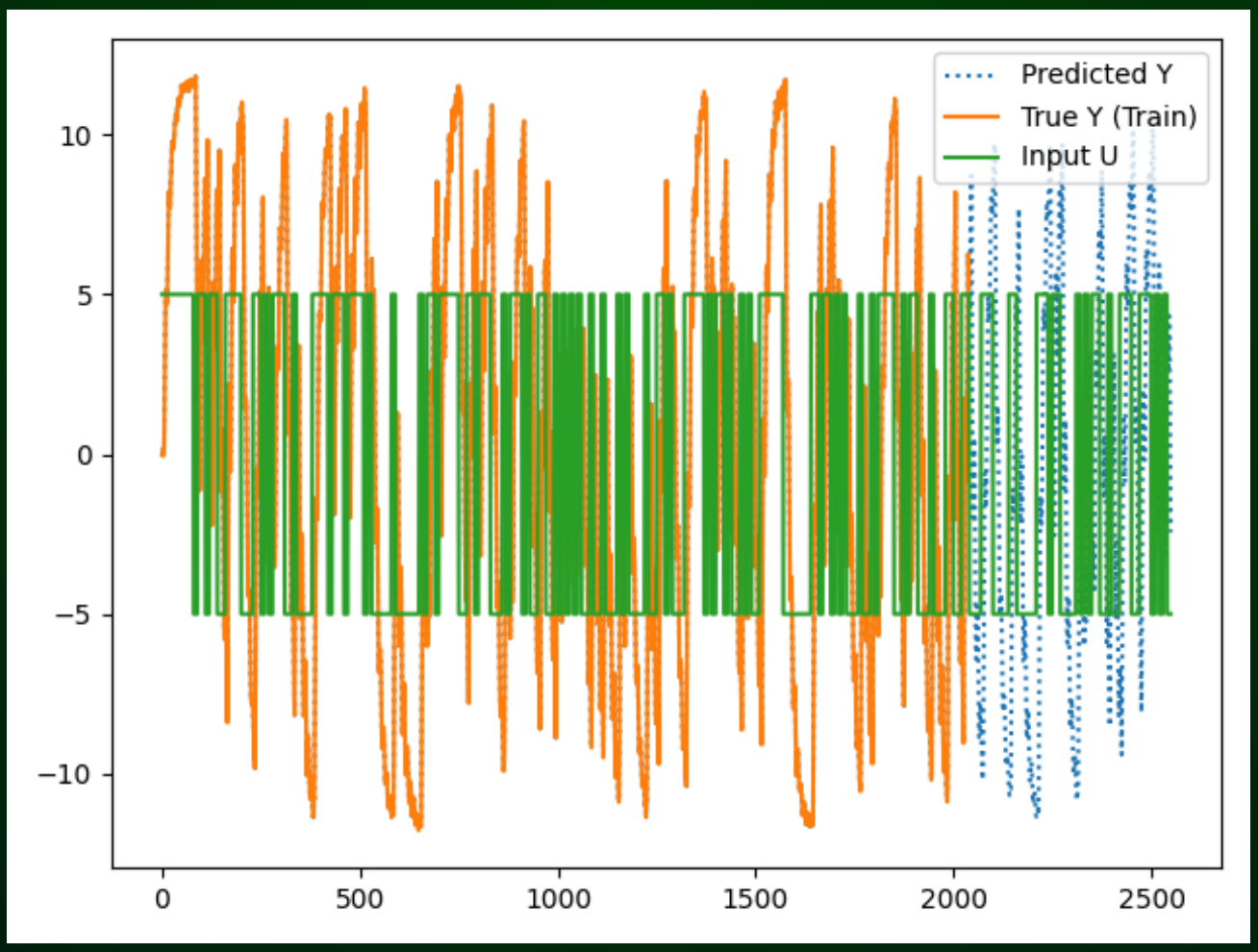
01 Load time series data (u, y)

02 Build regressor matrix φ(k)

03 Grid search for best (n, d, m) using R^2 score

04 Compare models: Least Squares, Ridge, Lasso

05 Recursive forecasting for test data



ARX Model Output vs. Input

This plot clearly illustrates the transition from observed behavior to model-driven prediction, showing how an ARX model uses historical patterns and input signals to extend system output into the future.

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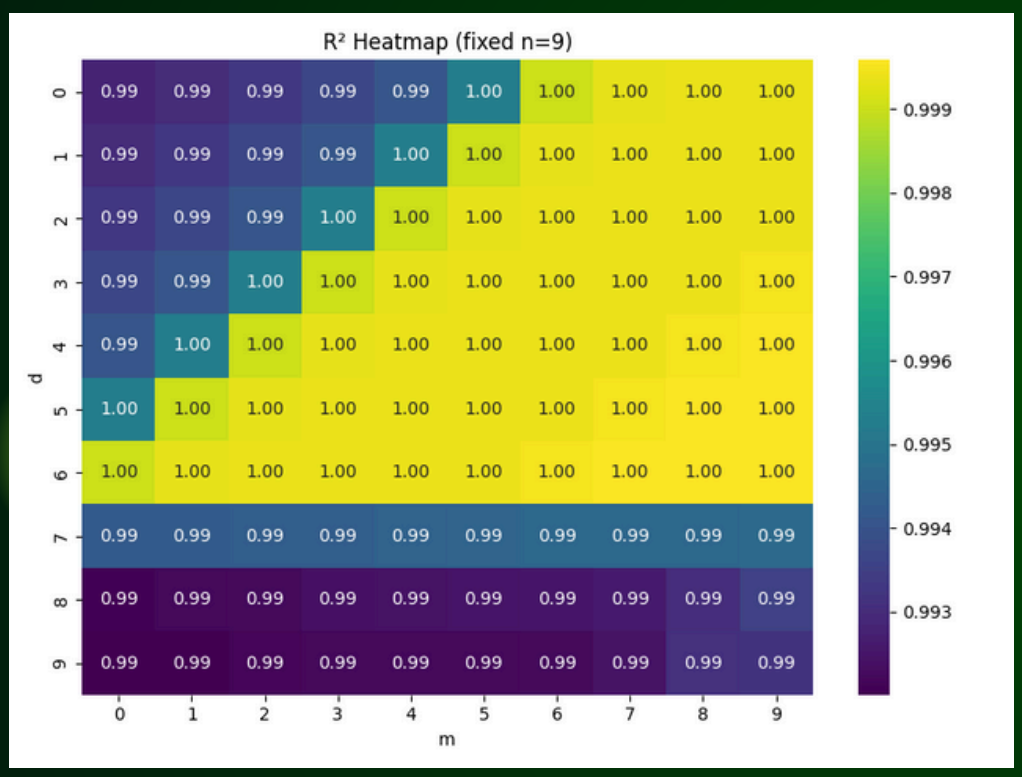
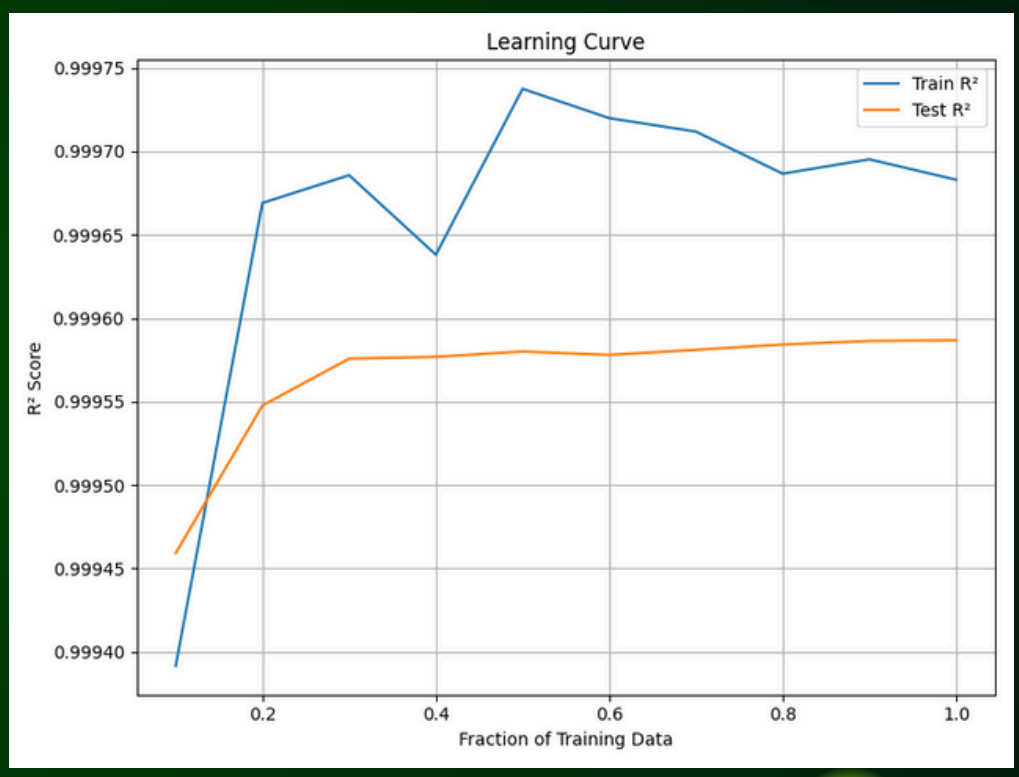
RESULTS – MODEL EVALUATION

PERFORMANCE ON TEST SET

After training the ARX model with the optimal parameters found via grid search, we evaluated its ability to predict future system behavior. The plot below shows how the model transitions from fitting the true training output to forecasting unseen outputs using only known input signals.



Heatmap Plot: R^2 scores over (d, m) for best n



Learning Curve

BEST PARAMETERS	
N	9
M	9
D	6

R2 SCORES	
Least Squares	0.9996
Ridge	0.9994
Lasso	0.9996

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KEY TAKEAWAYS & APPLICATIONS

- ARX models are simple but powerful for time series modeling
- Useful for system control, signal processing, energy forecasting
- Linear methods + visualization help ensure model interpretability
- Recursive forecasting enables future value prediction

From theory to practice, We learned how to model, evaluate, and forecast dynamic systems using ARX models — blending control theory with modern machine learning tools.

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