Predicting and Controlling the Behavior of Dynamical Systems under Uncertainty

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RESEARCH INTERESTS

- Optimization and decision under uncertainty

And in particular:

- Optimization: global, nonlinear, under constraints
- Constraint solving: nonlinear, complete and correct, under uncertainty
- Interval computations
- Argumentation networks
- Combinatorial testing

PROBLEMS OF INTEREST

- Large systems of nonlinear equations – possibly from dynamical systems
- Either full control on these systems for simulations or some uncertain knowledge about it

RELEVANCE

- Understanding how / under which circumstances-parameters a vehicle can best withstand an underbody blast
- Understanding how a disease spreads depending on, e.g., the number of affected people and the policies put in place
- Understanding how efficient a combustion system is, what performance different mixes of fuel yield
- Identifying parameter values that yield a given outcome
- *etc.*

TECHNIQUES WE USE

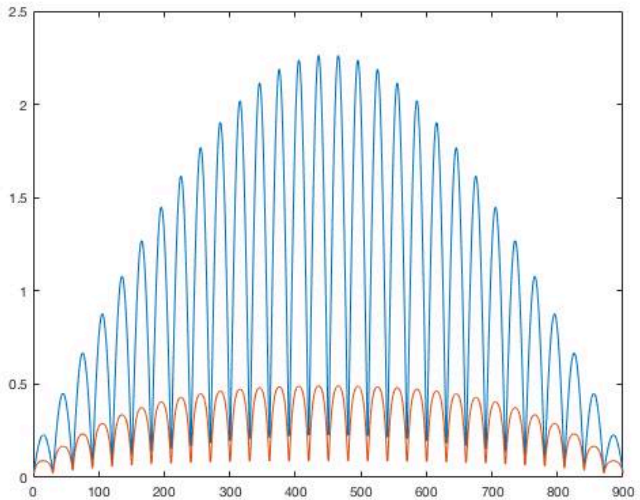
- Interval global optimization under constraints
- Constraint solving techniques
- Reduced-Order Modeling
- Argumentation network

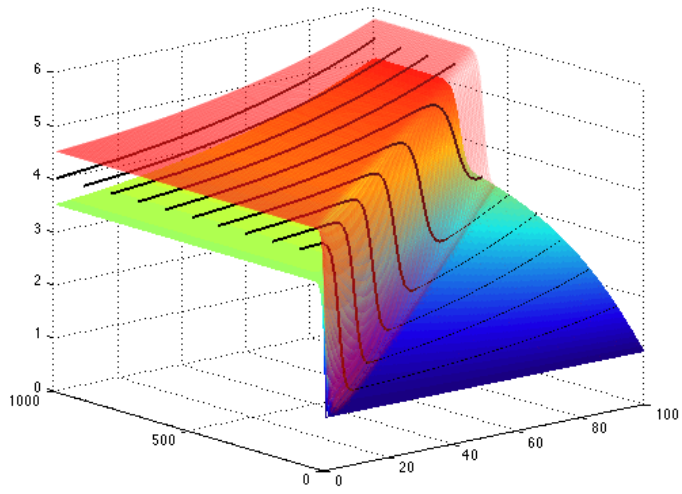
EXAMPLES

Let’s look at a few examples:

- Simulation of dynamical systems under uncertainty (Interval constraint solving techniques)
- Comparison between Full-Order Model and Reduced-Order Model simulations under uncertainty
- Observation-based prediction of dynamical systems’ behavior
- Parameter recomputation under constraints and uncertainty

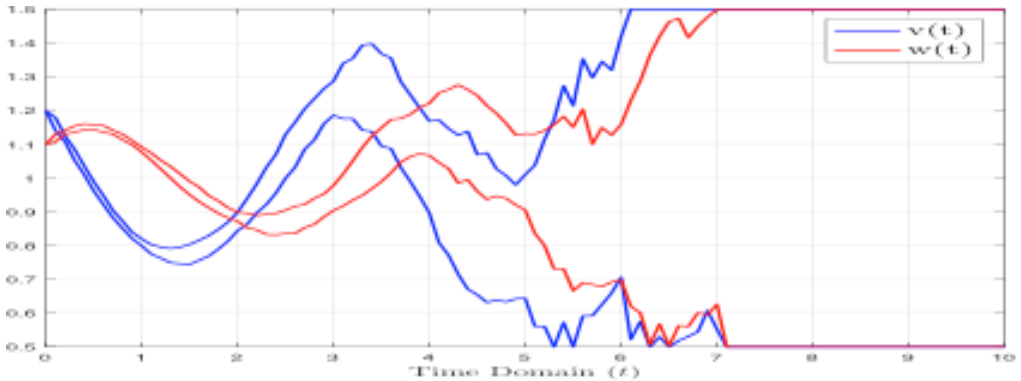
INTERVAL CONSTRAINT SOLVING UNDER UNCERTAINTY





INTERVAL ROM VS. INTERVAL FOM

- Lotka-Volterra: FOM (size 200) and with ROM (size 3).



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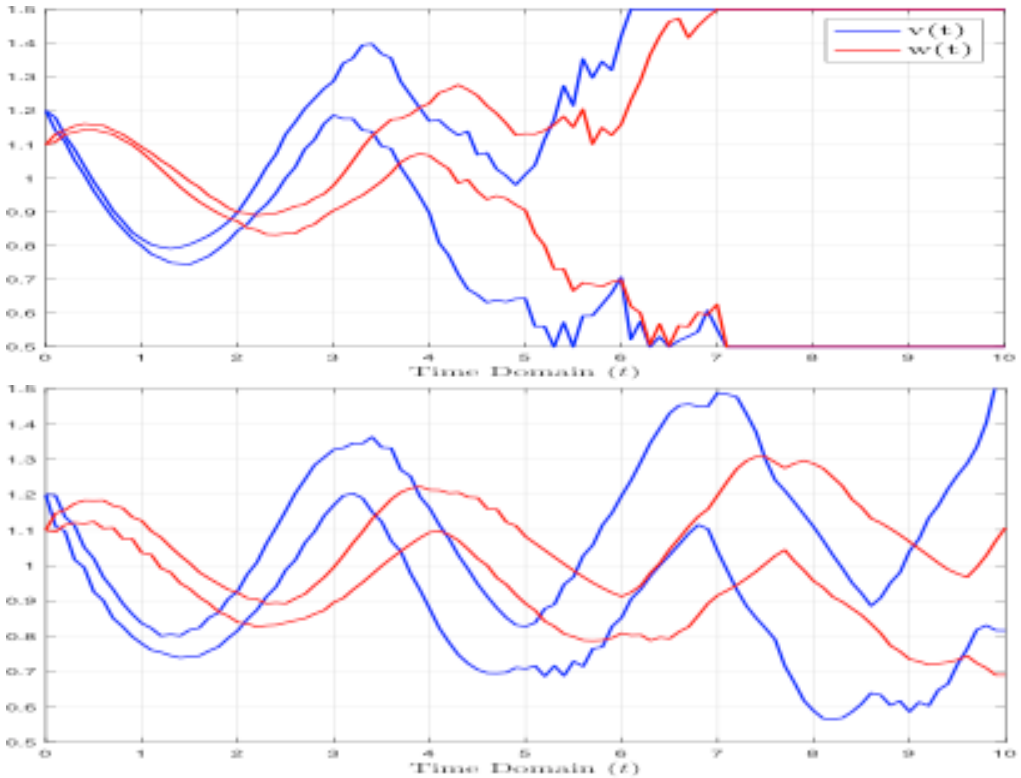

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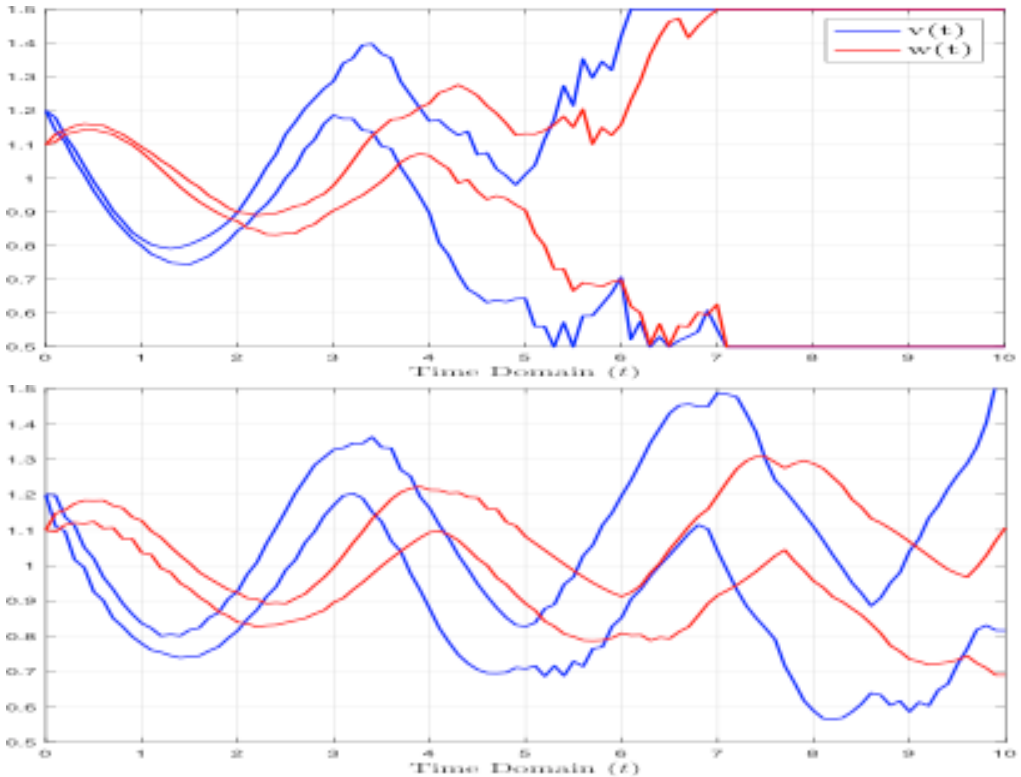

The runtime is 74,596ms for FOM and 4,616ms for ROM.

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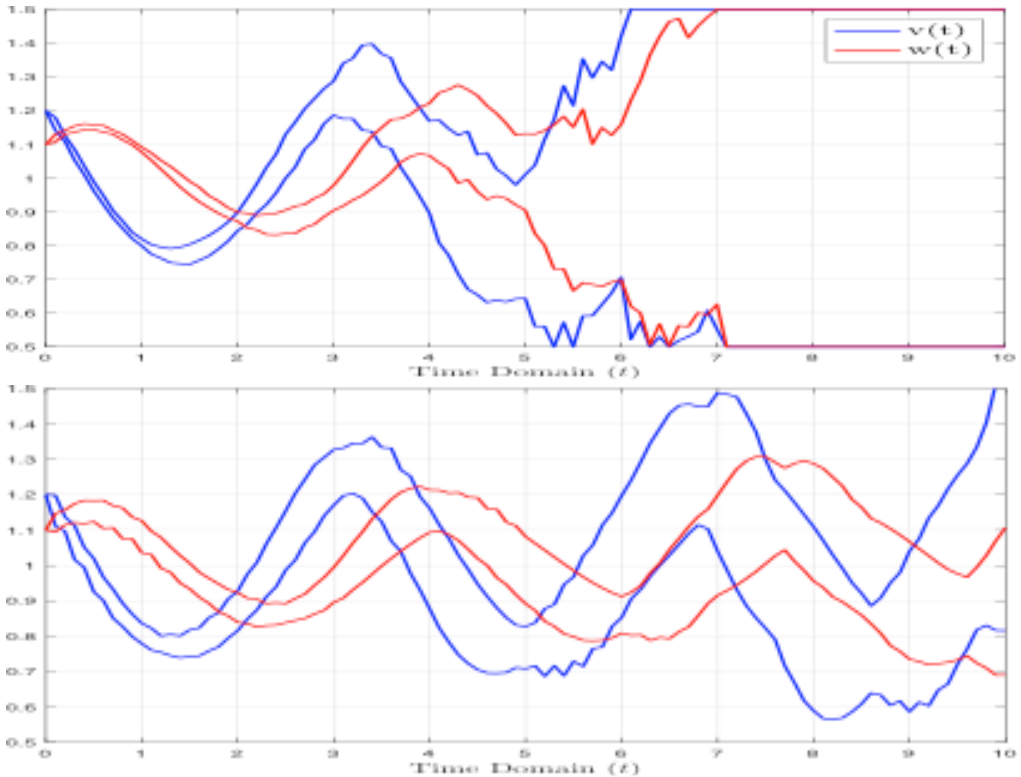

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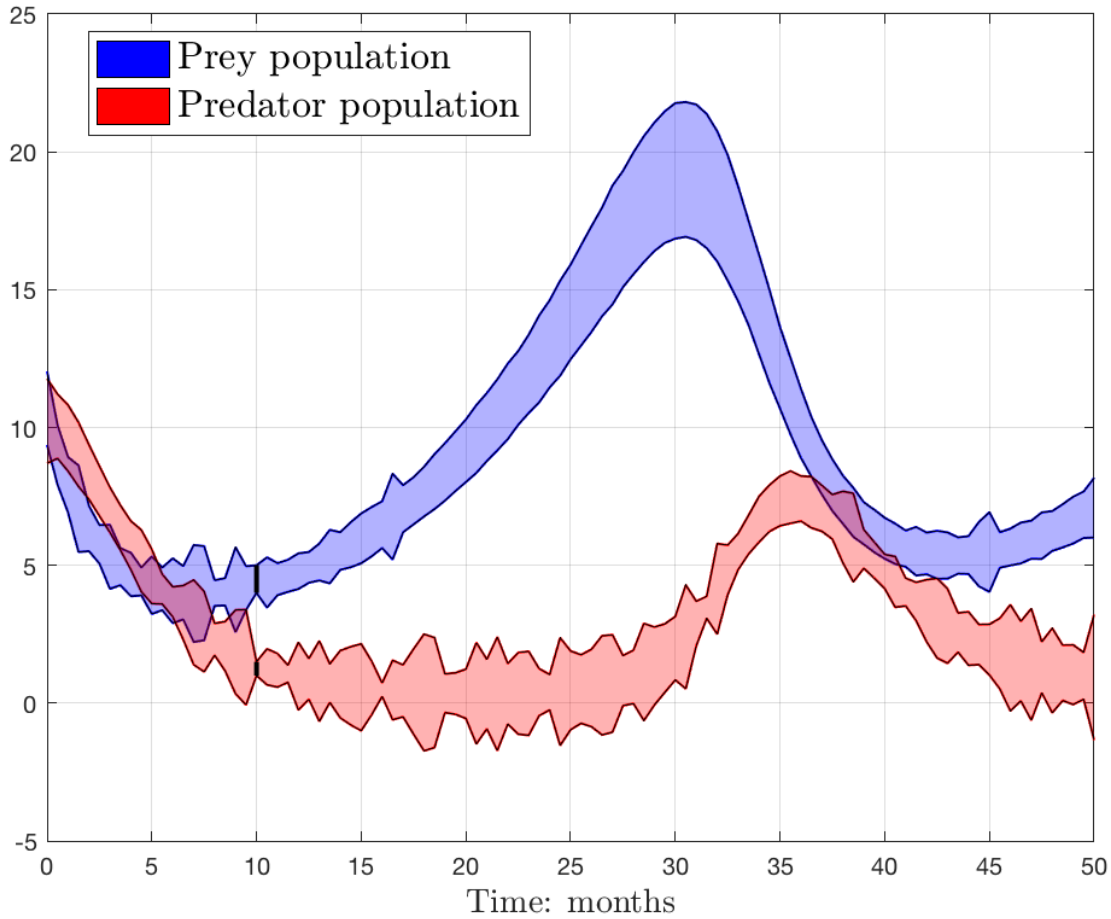

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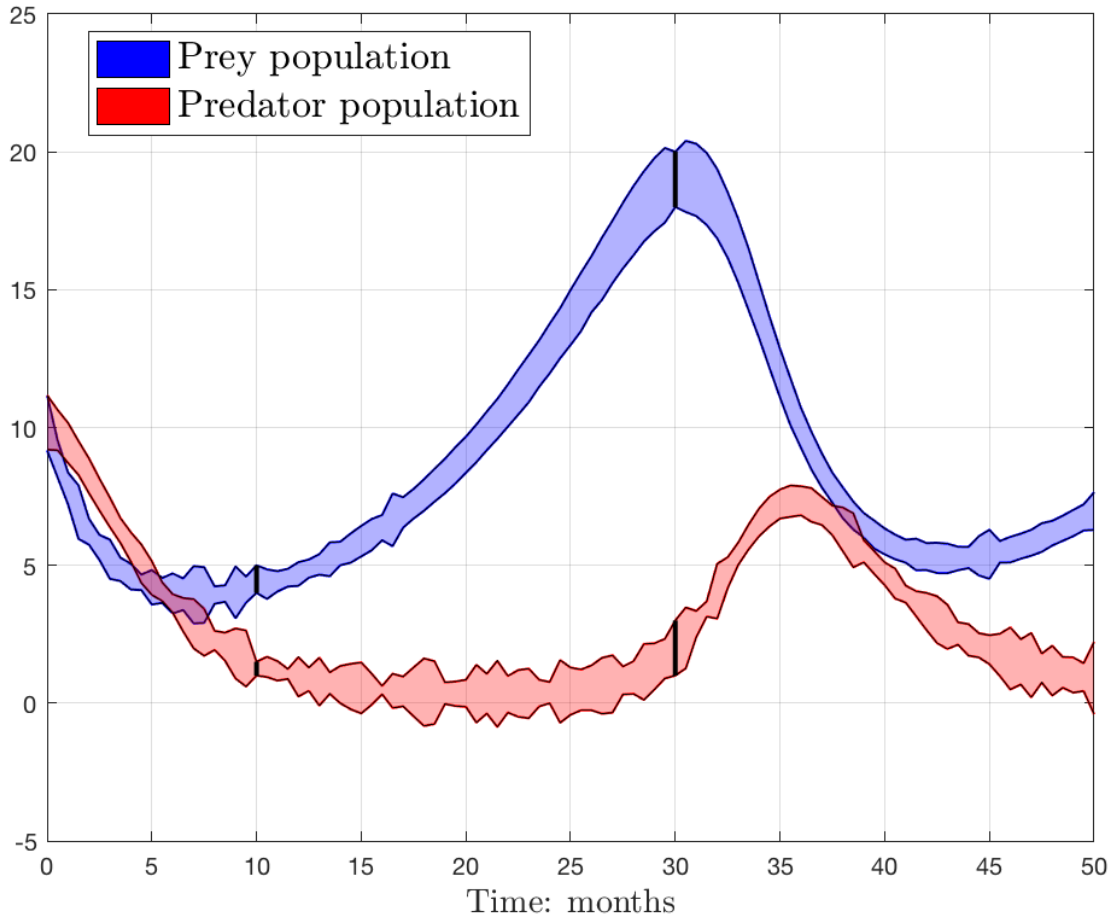

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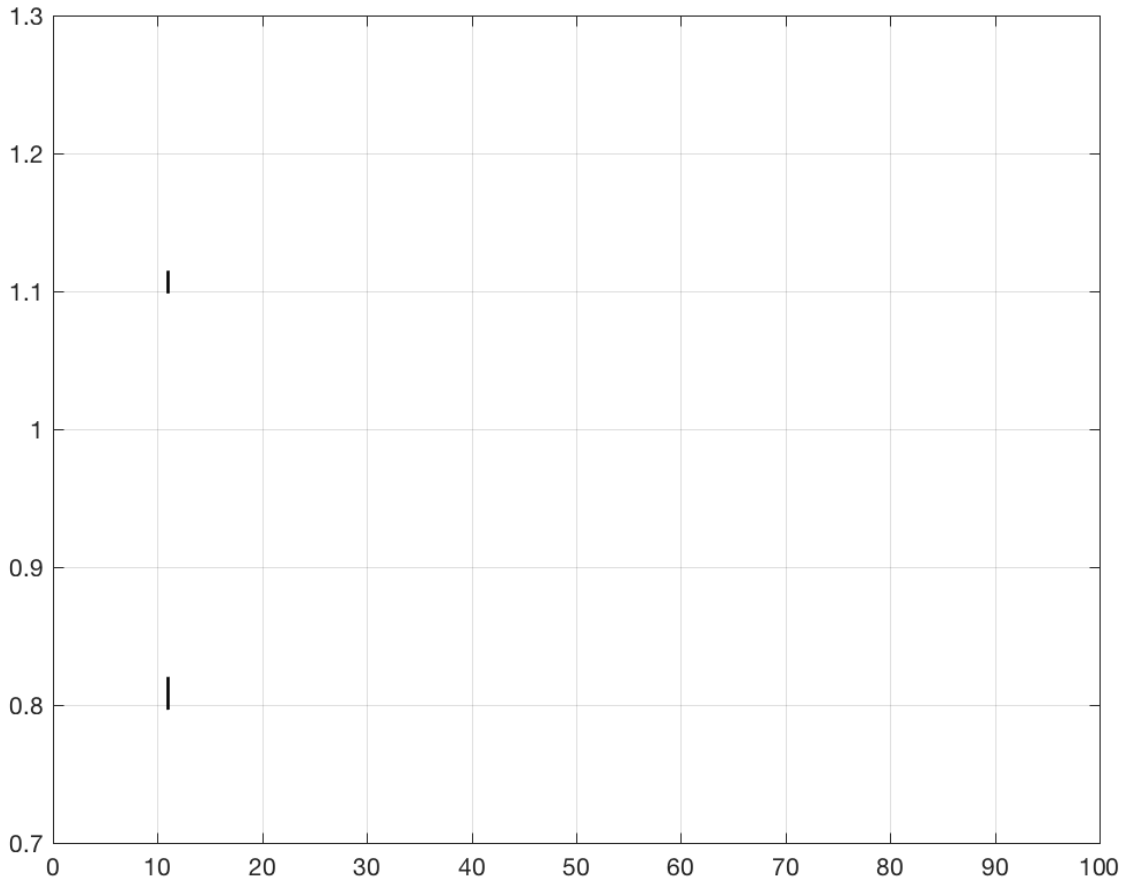

What we know: one observation set and $\theta_1 = \theta_2 = [0, 6]$.

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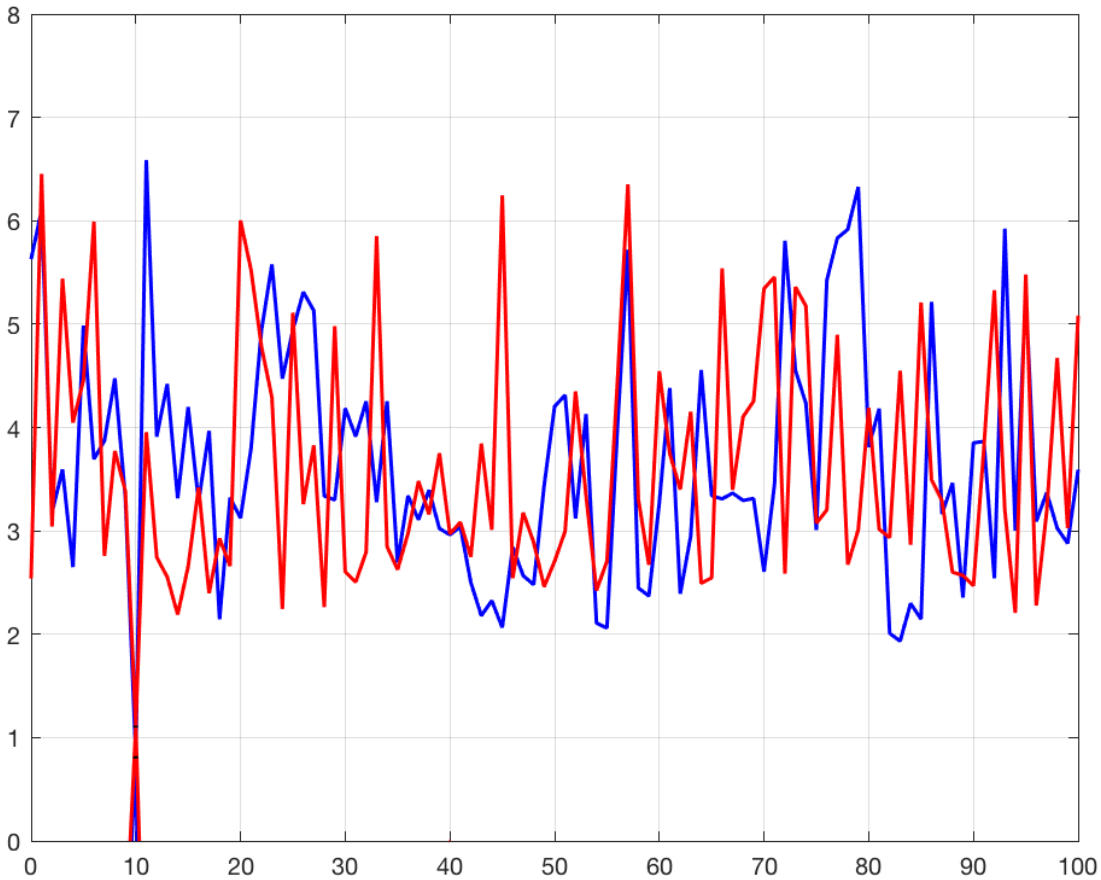

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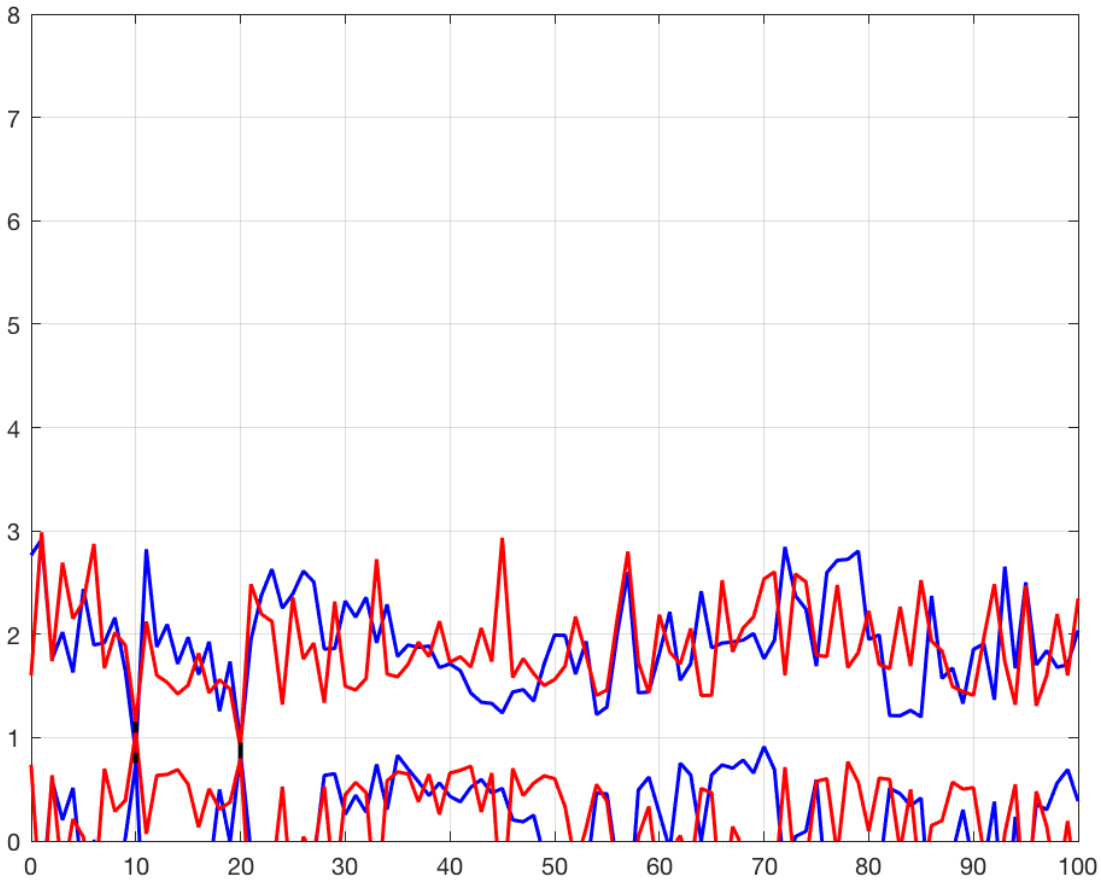

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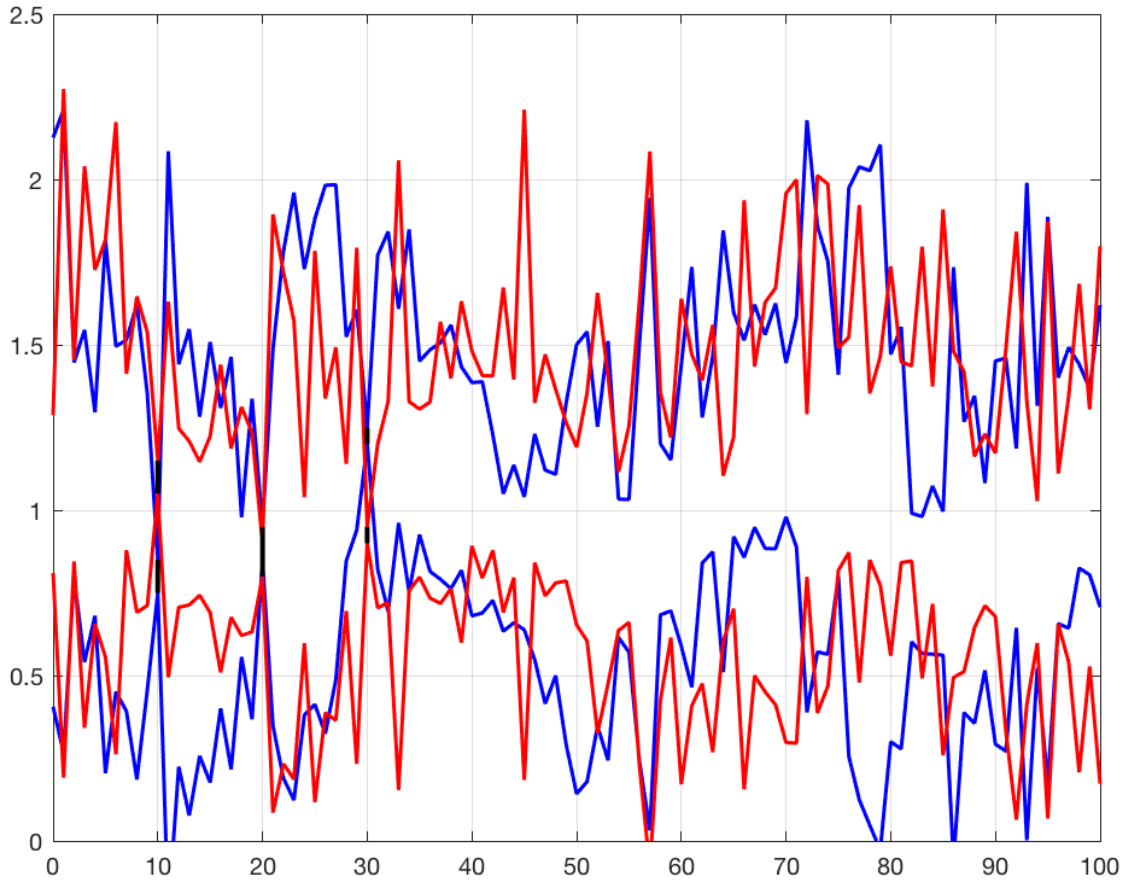

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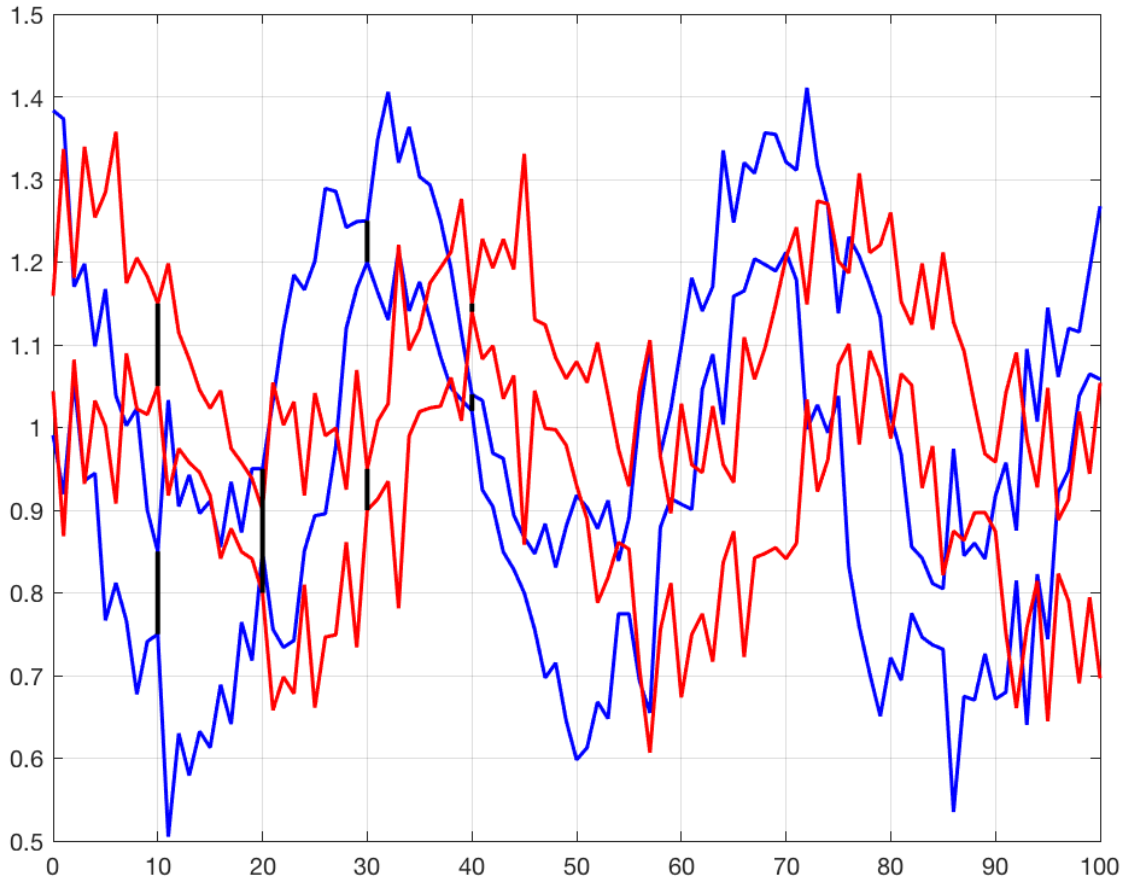

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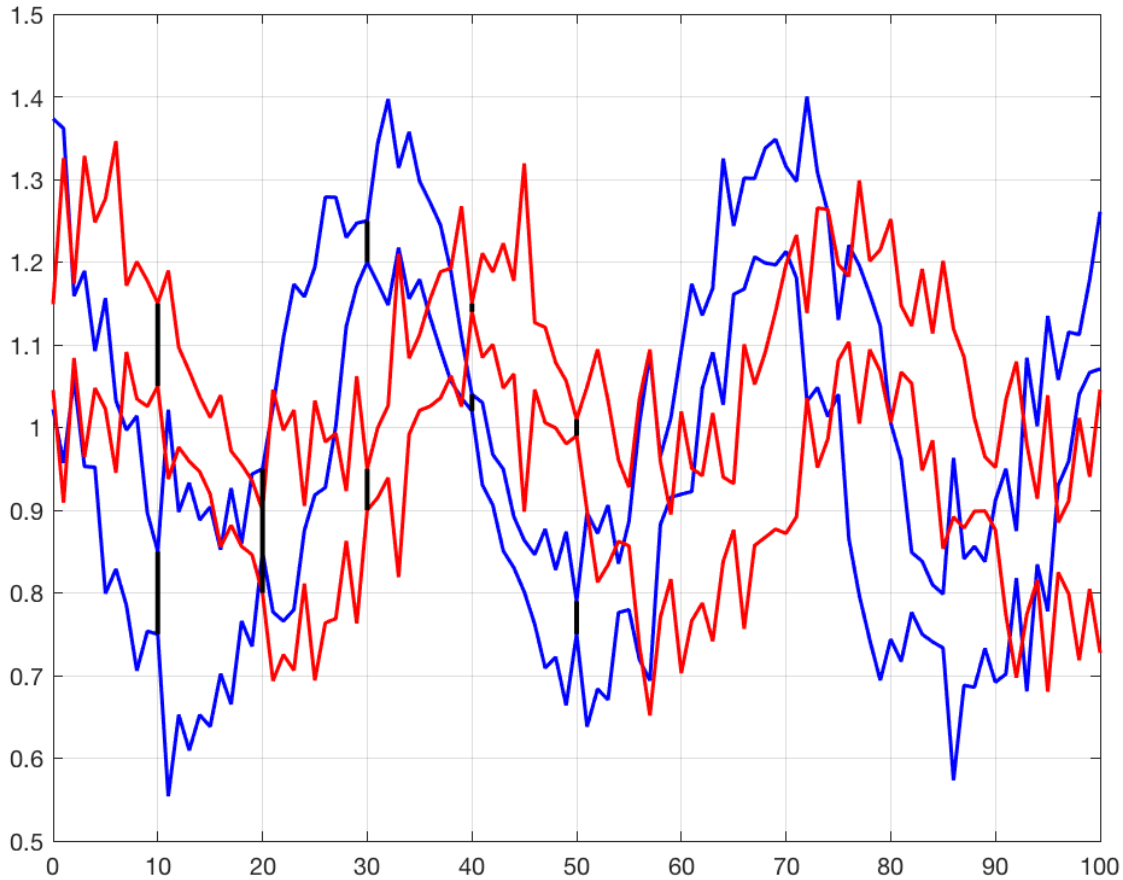
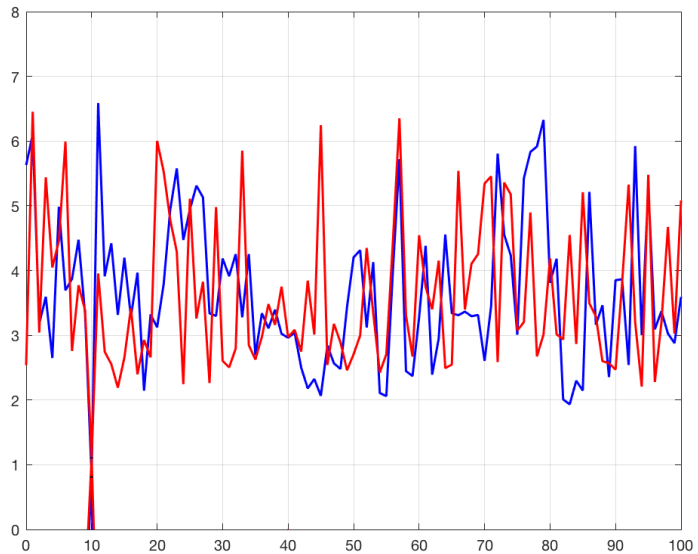
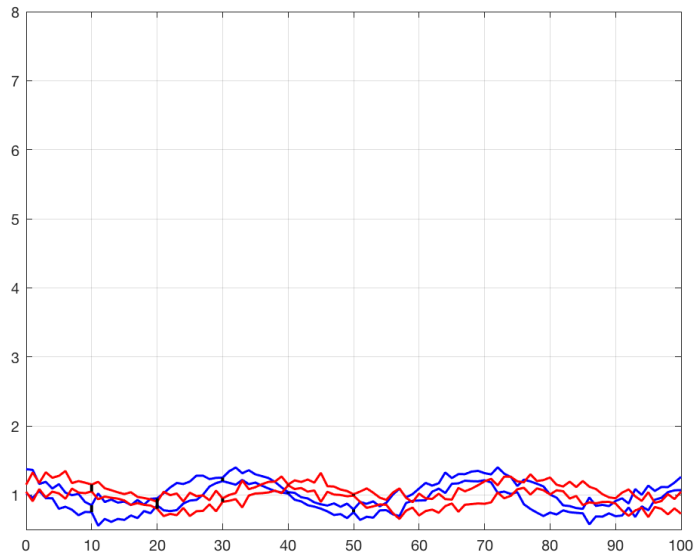


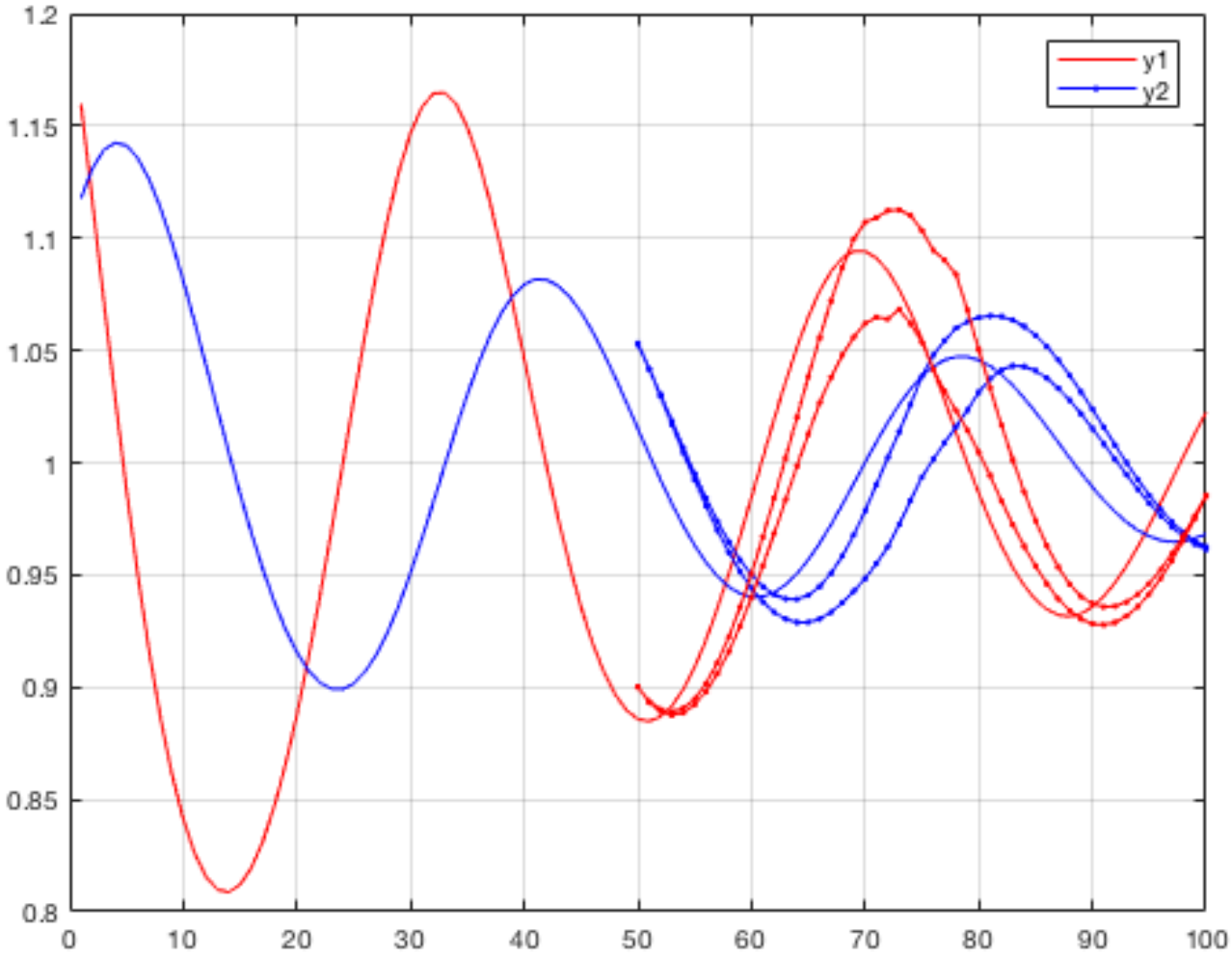
OBSERVATION-BASED PREDICTIONS

A look at the improvement from start to finish on the same scale:





RECOMPUTING DYNAMIC SYSTEMS' PARAMETERS



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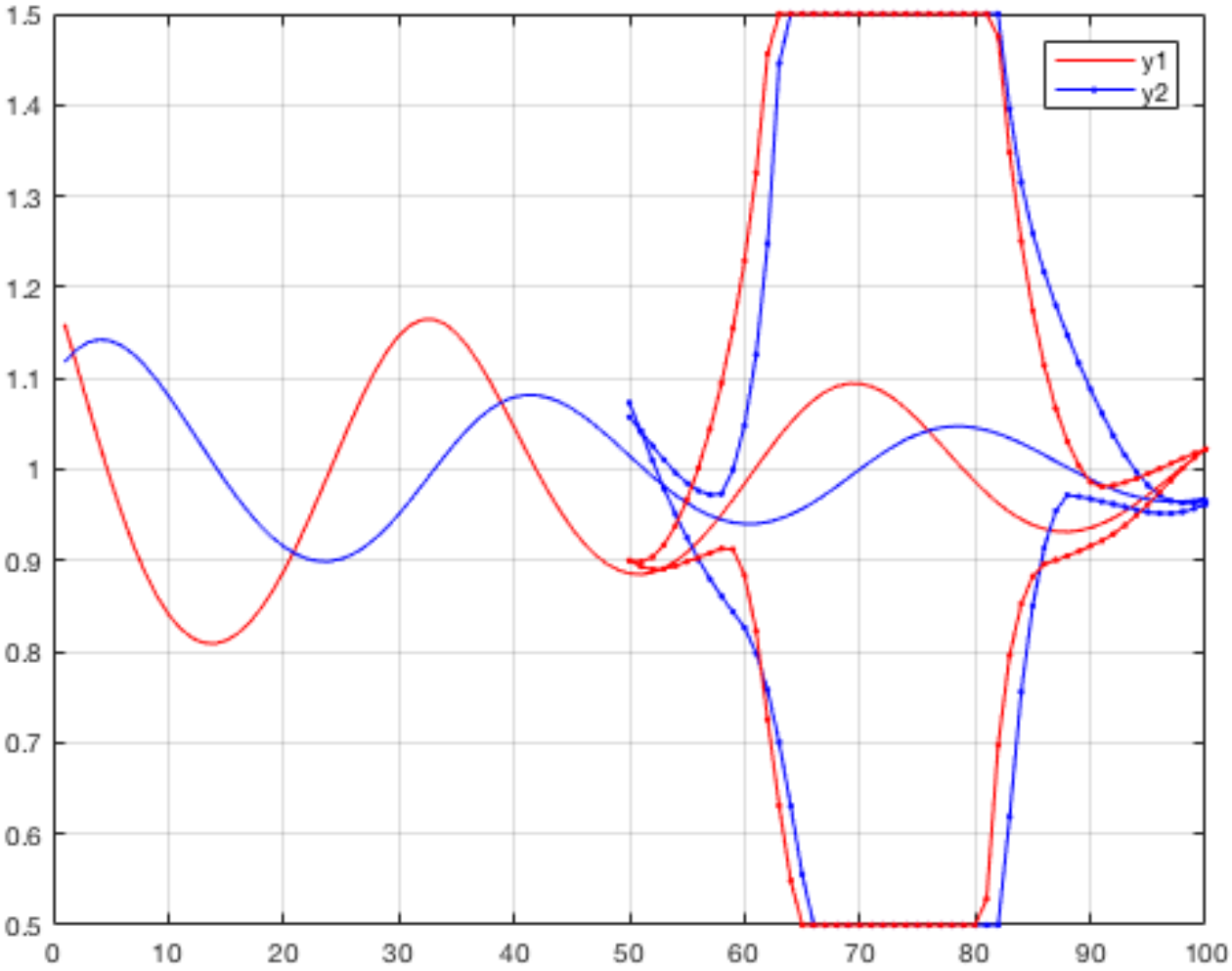

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  - Time horizon
  - Observation times
  - Recomputation time
  - Control prediction time

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- **Applications:**
  - Fuel mix uncertainty
  - Combustion nozzle geometry
  - Problems with discontinuities