

In Situ Adaptive Tabulation for Non-linear MPC

J. D. Hedengren
T. F. Edgar

The University of Texas at Austin
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Model vs. Computational Reduction

- Model Reduction
 - Objective: Reduce the number of states while preserving the most important system dynamics
- Computational Reduction
 - Objective: Reduce the computational time to integrate a model while preserving all of the system dynamics

Current Industrial Implementation of NMPC

- Linear model MPC with non-linear bias modeled with an artificial neural network

$$\dot{x} = Ax + Bu$$

$$y = Cx + \text{NeuralNet}$$

Proposed Implementation of NMPC

- Non-linear model (ODE or DAE) MPC

$$\dot{x} = f_1(x, u)$$

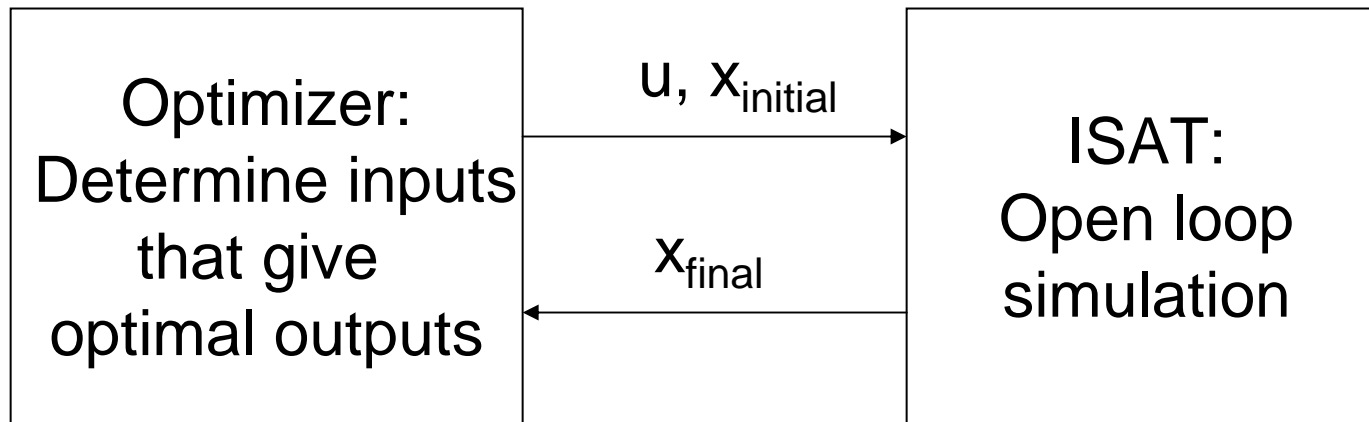
$$0 = f_2(x, u)$$

$$y = h(x, u)$$

- *In Situ* Adaptive Tabulation (ISAT)
 - Adaptable to process shifts / grade changes
 - Reliable error control
 - *In situ* training – It learns as it goes
 - No restrictions on the model

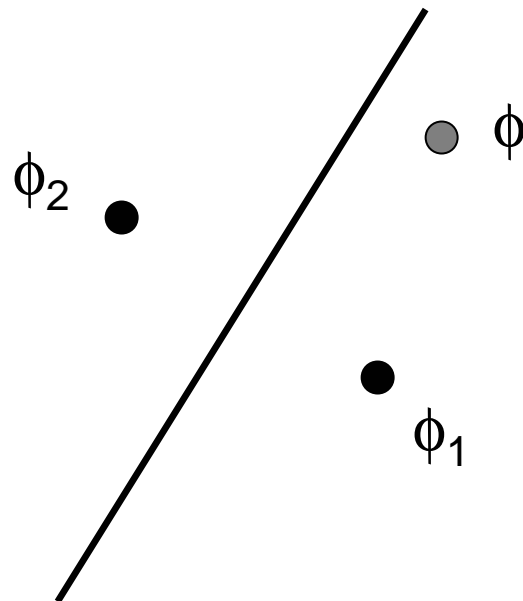
ISAT with NMPC

- ISAT replaces the open loop integrator



ISAT Search

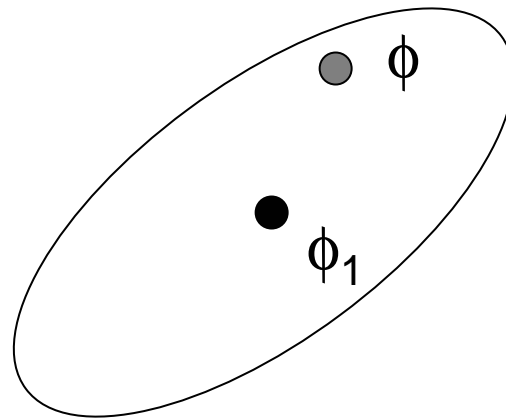
- Binary Tree Architecture
 - Search times are $O(\log_2(N))$ compared with $O(N)$ for a sequential search



$$\phi = \begin{bmatrix} u \\ x_0 \end{bmatrix}$$

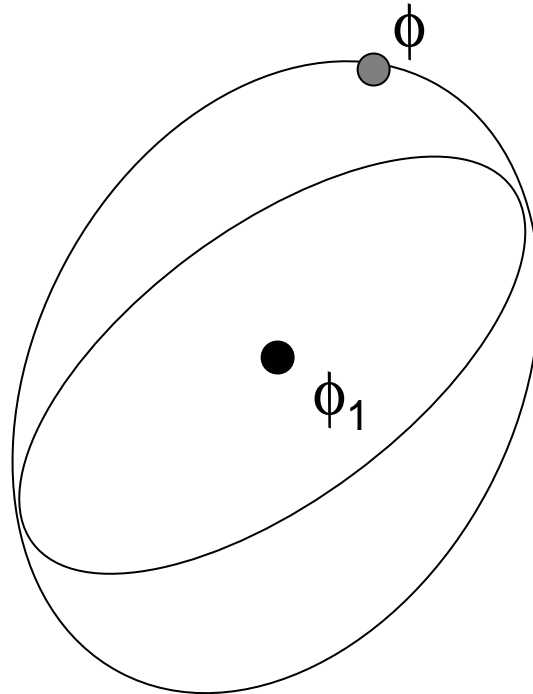
ISAT Integration

- Scenario #1: Inside the region of accuracy



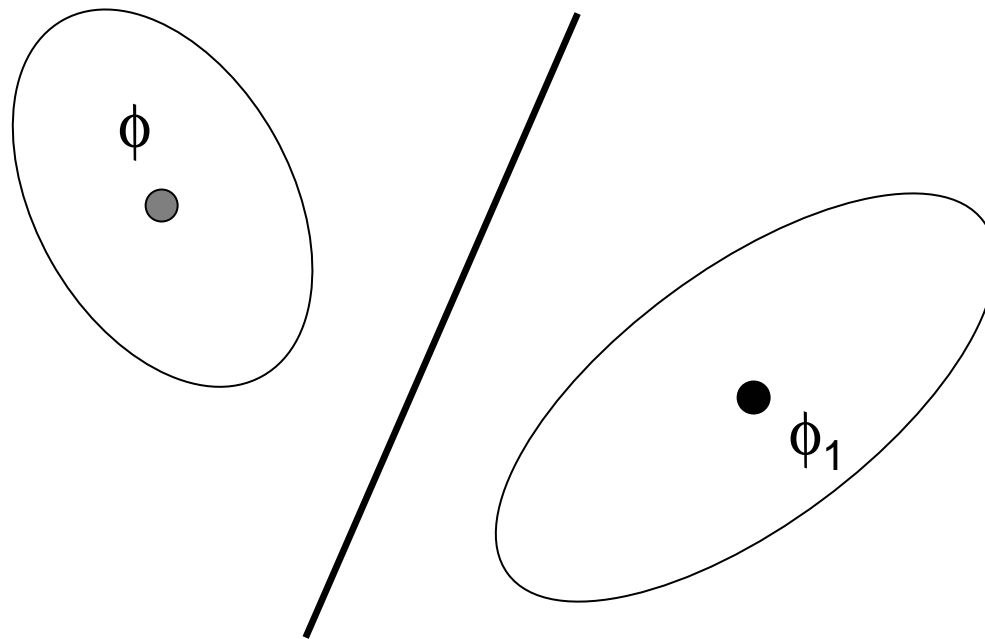
ISAT Integration

- Scenario #2: Outside the region of accuracy but within the error tolerance



ISAT Integration

- Scenario #3: Outside the region of accuracy and outside the error tolerance



ISAT Performance

- Successfully implemented with ODE and DAE models
- Computational speedup generally in the range of 20 – 500 times
- Storage <100MB for 96 state DAE model with a 10^{-3} tolerance on all states
- Constraints

Future Directions

- Fault detection
- Bottleneck: Reliable non-linear models
 - Model database
 - Chemical Systems
 - Distillation Columns
 - Reactors
 - Mechanical Systems
 - Contribute your non-linear models
 - Contact: john_hedengren@hotmail.com
 - Web-site: <http://www.che.utexas.edu/~john/research/>