Merged Environment for Simulation and Analysis (MESA)

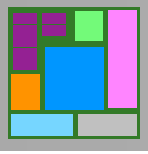
Project Investigator:	Dr. Mark Bryden
Date:	03/21/2017
DOE Award Number	DE-AC02-07CH11358
Period of Performance	FY2016

Objective

- Testing and Demonstrating a Stigmergic Control Strategy

Milestones

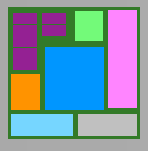
- Characterization of Stigmergic Control Algorithm (Hyper facility)
- Characterization of Multivariable Control Strategies (Hyper facility)



Project Goals and Objectives

1. Model based statistic approach - Multi model adaptive control

2. Model-free statistic approach - Multi-agents (Stigmergic)



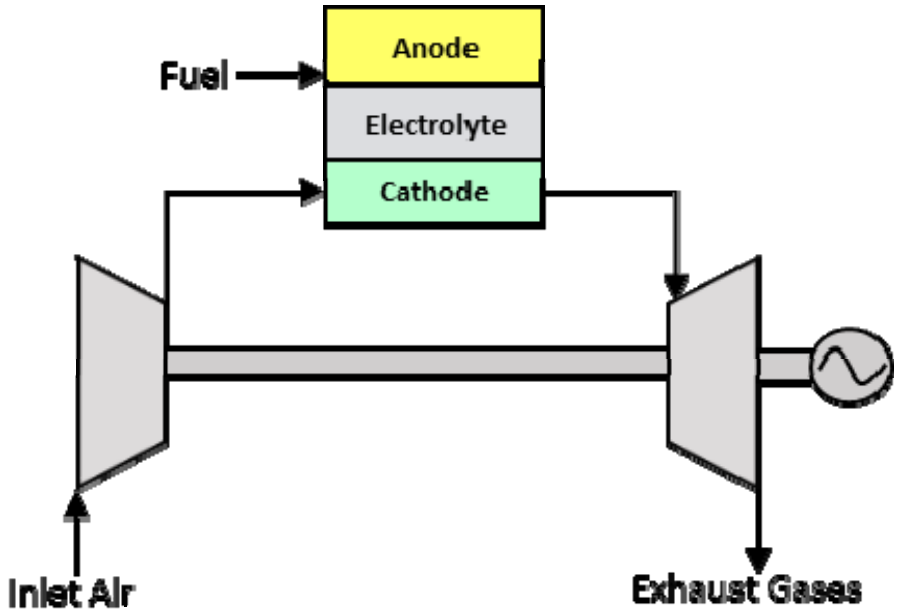
Presentation Outline

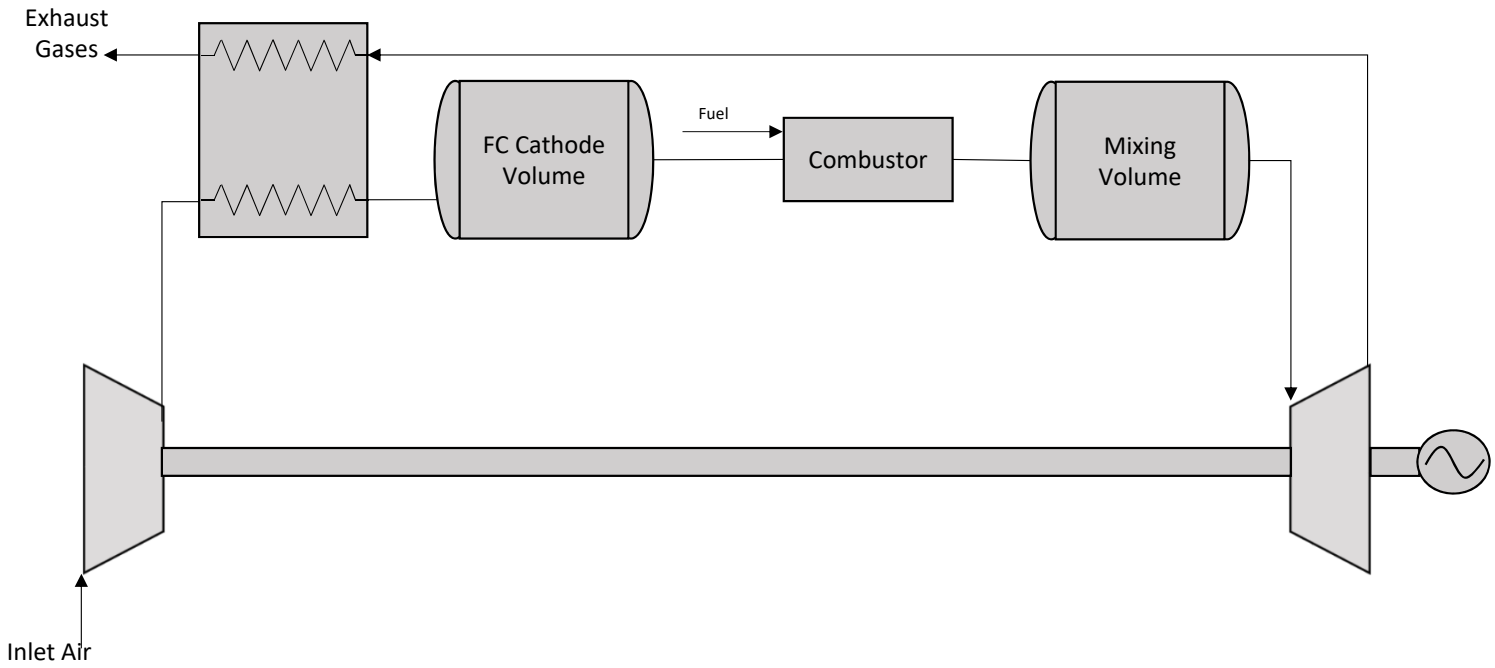
Hybrid systems

- High efficiency
- Low emissions

Innovative control solutions

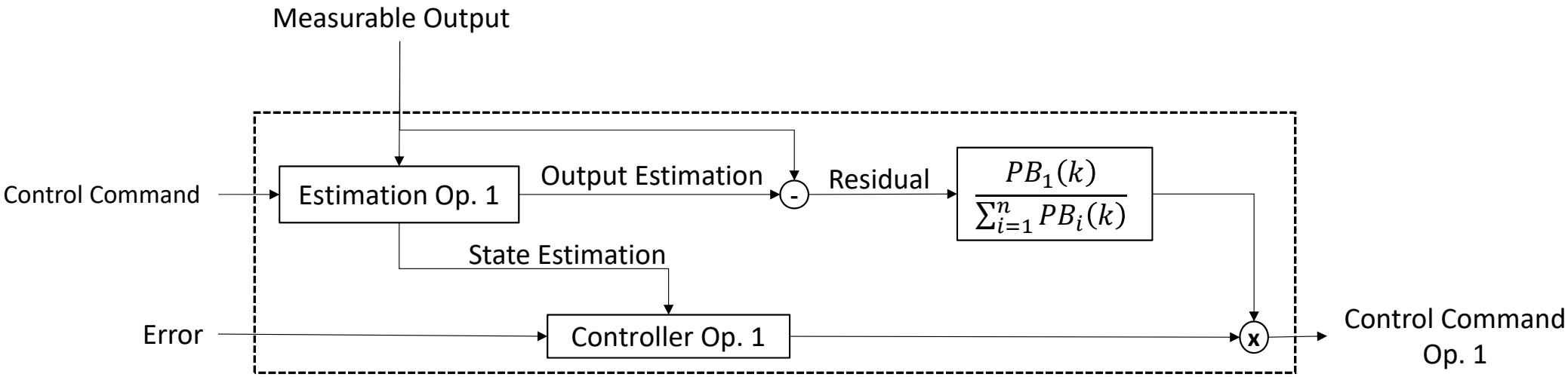
- Coupling between energy devices
- Different time scale



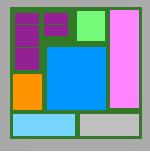


Hyper configuration

- Identification of each operating point using an estimation
- Probability calculation based on the residual between real system output and output estimation

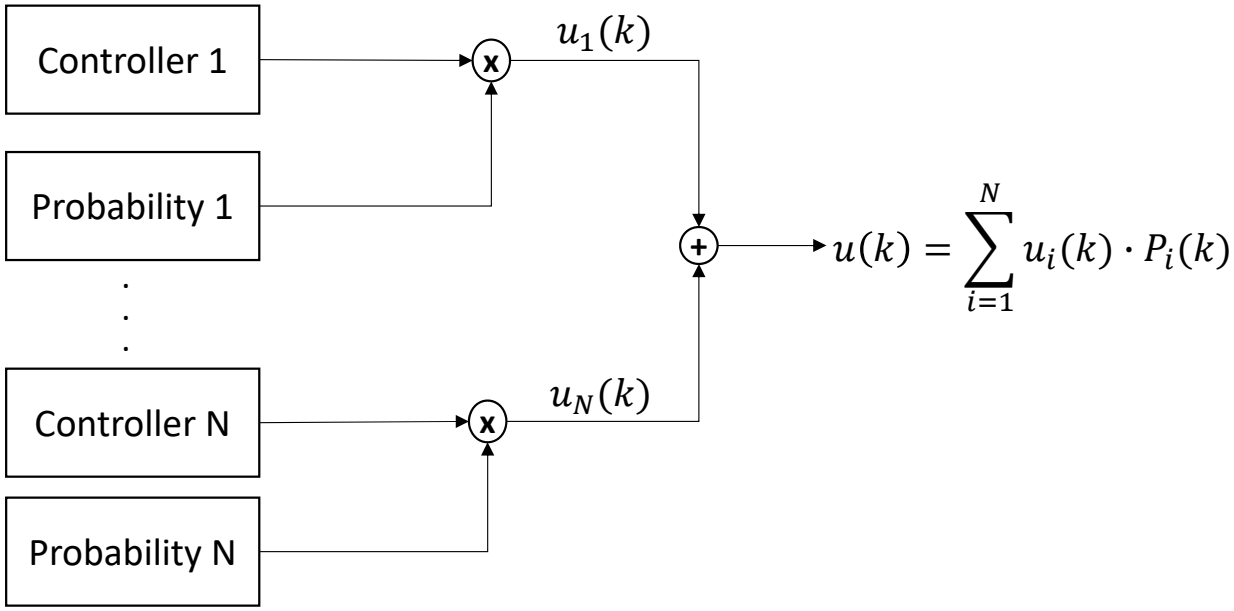


Control Diagram for each Operating Point

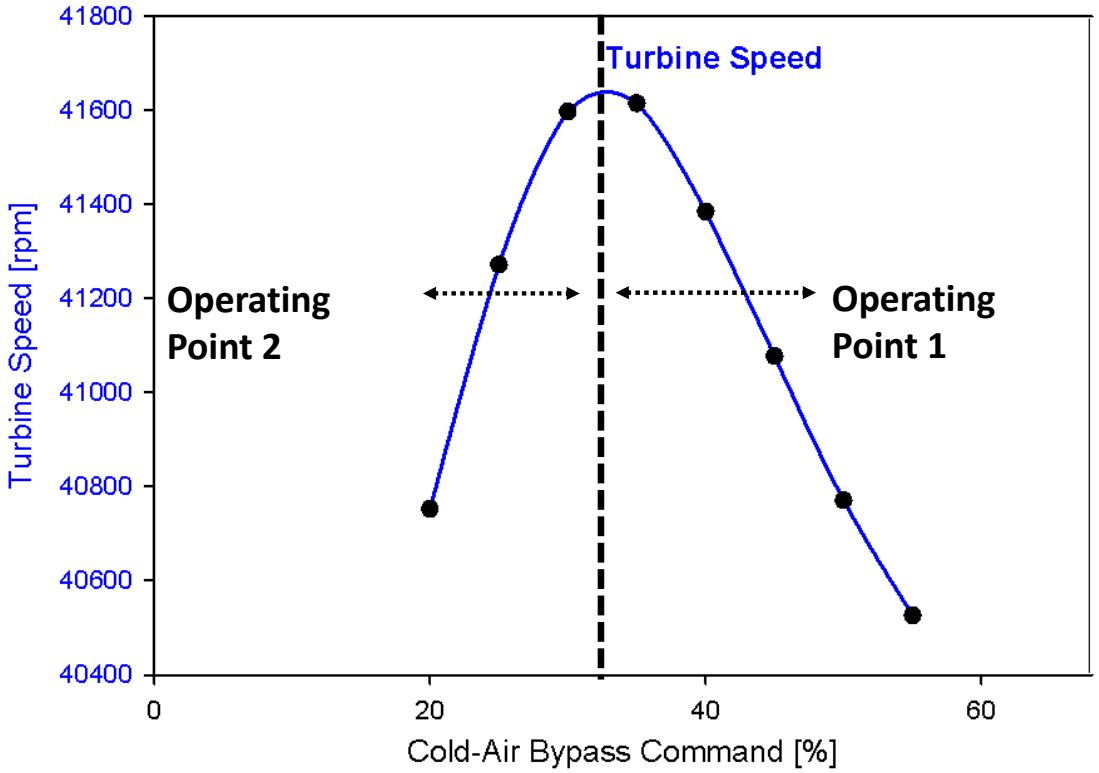


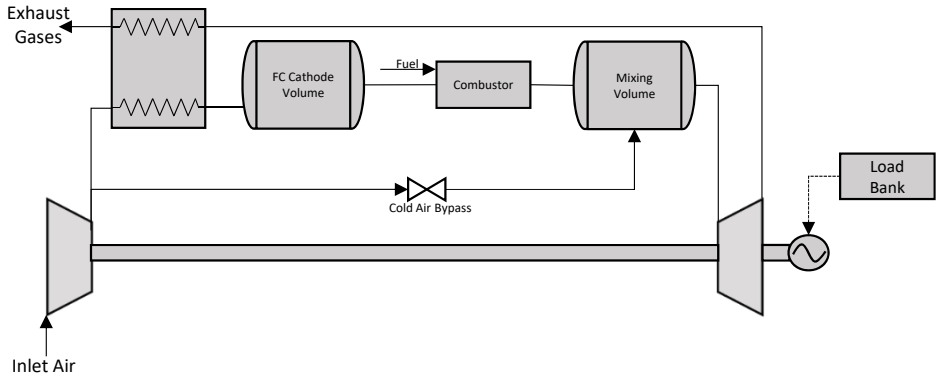
Multi model adaptive control

- Probability weights for each controller
- All the control signals are merged into one control action

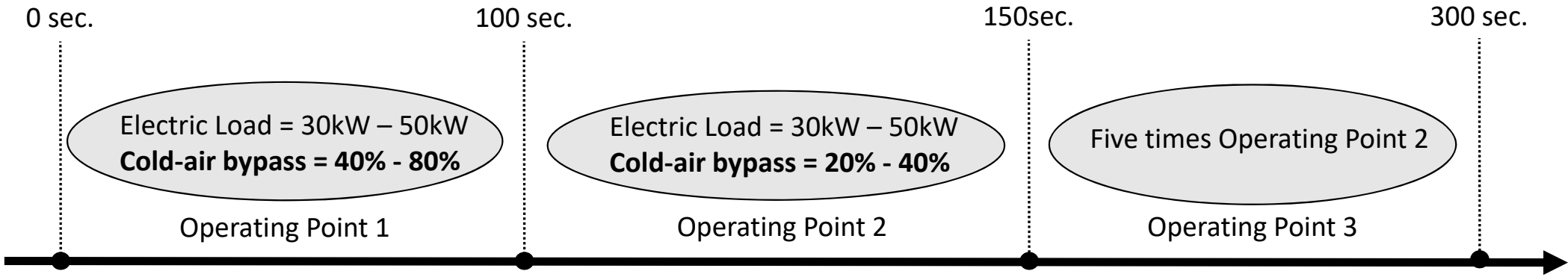


Multi model adaptive control signal

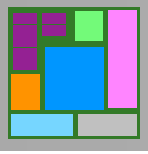




Nonlinear Response

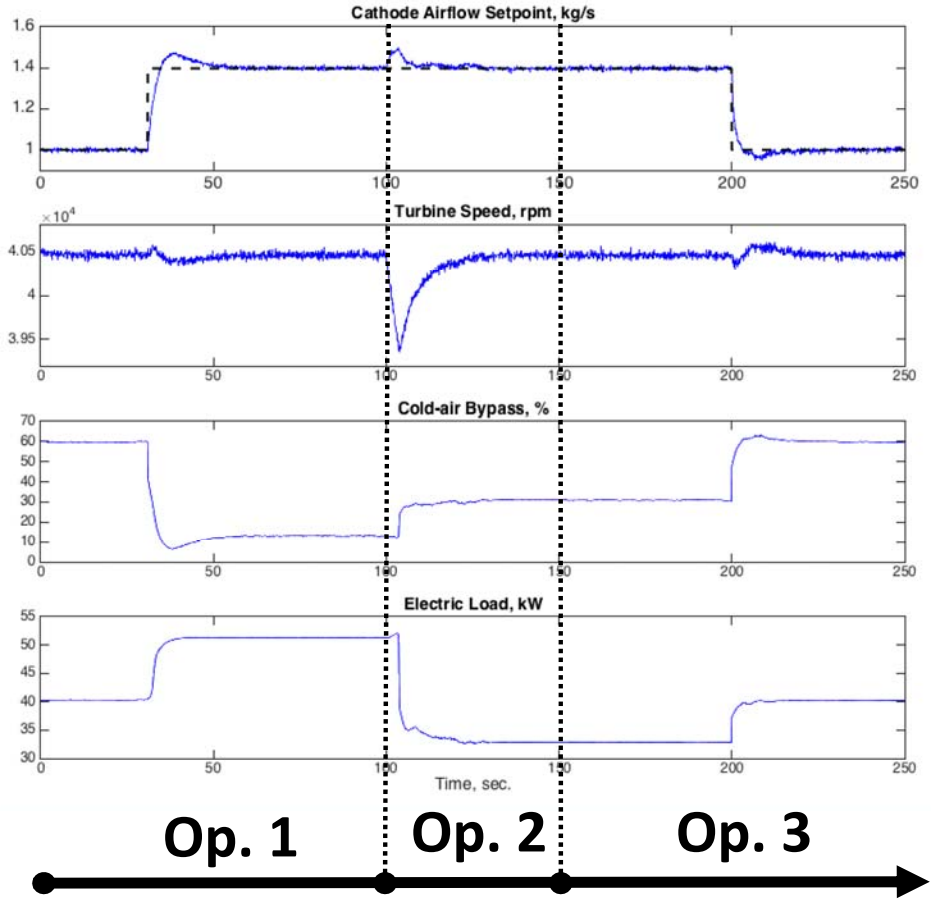


Operating point switching, as a sort of perturbation

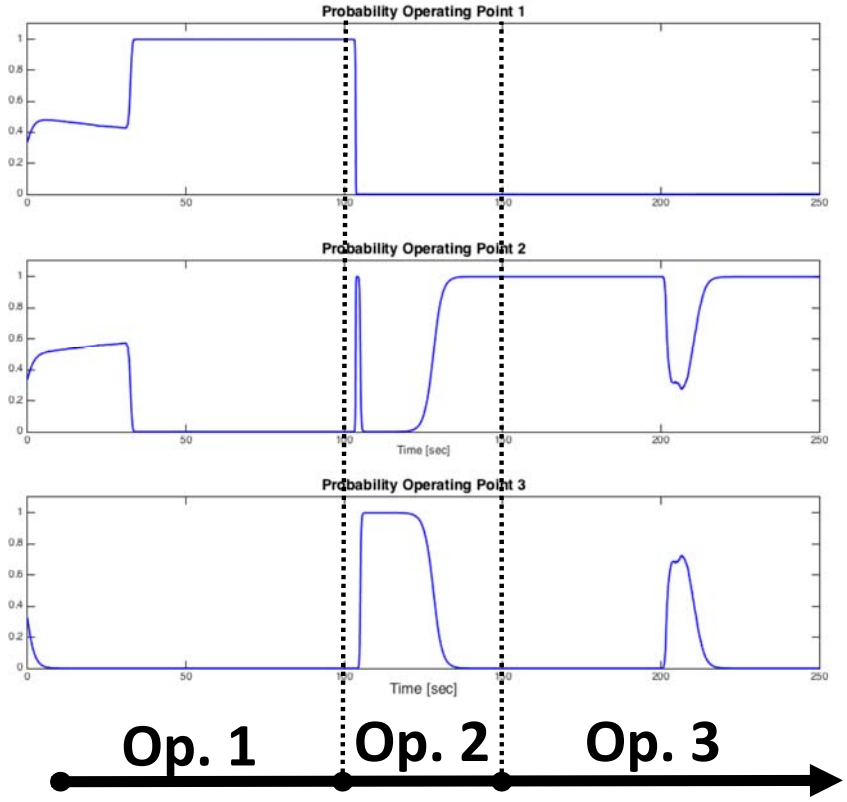


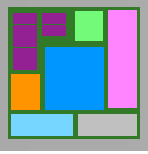
Plant model switching simulation

Cathode airflow Perturbation: 0.4 kg/s (40%)



Probability response





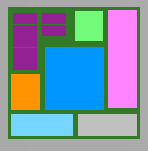
Simulation Results

Advantages

- Adaptability proven on simulation tests

Disadvantages

- System Modeling at each operating point
- Real-time model matching at each operating point

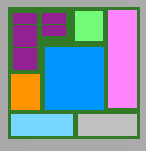


Statistic control strategies

Construction behavior from social insects

Insects accomplish tasks without centralized authority

Insects make adaptable changes based on modifications to the environment

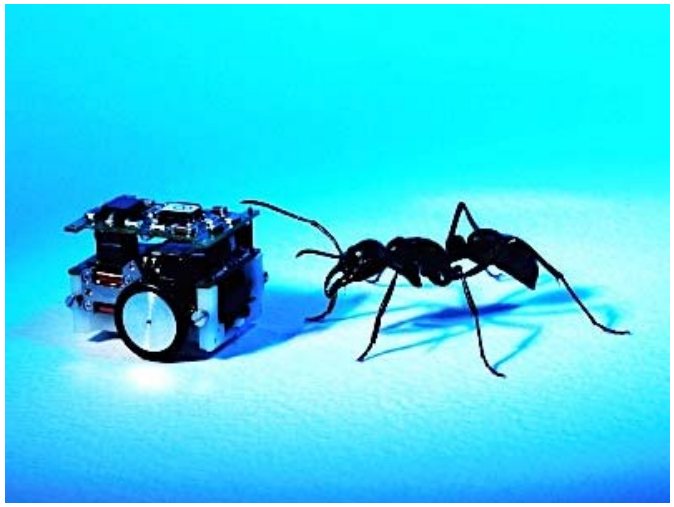


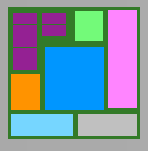
Distributed construction - Stigmergic

Computational agents represent insects

Agents imitates the construction behavior of social insects

Each agent takes independent decisions





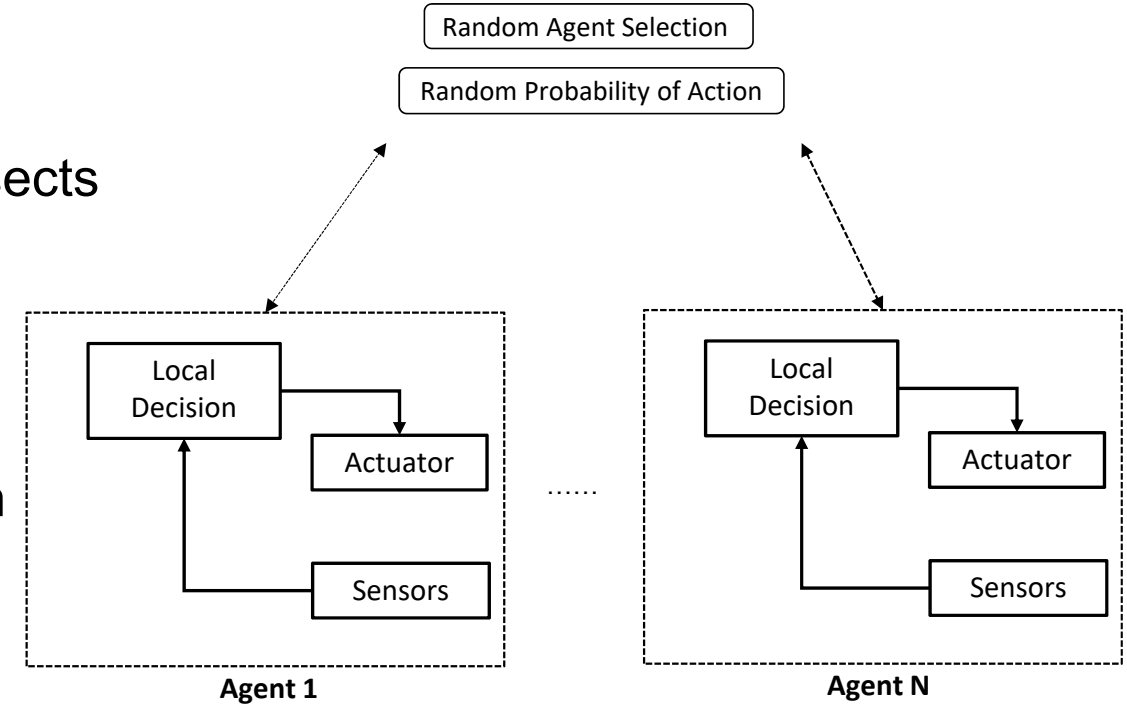
Stigmergic

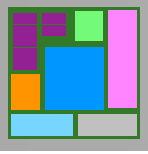
Random Agent Selection

- Emergent behavior found in social insects
- Avoids simultaneously actions

Random Probability of action

- Determines frequency of action taken





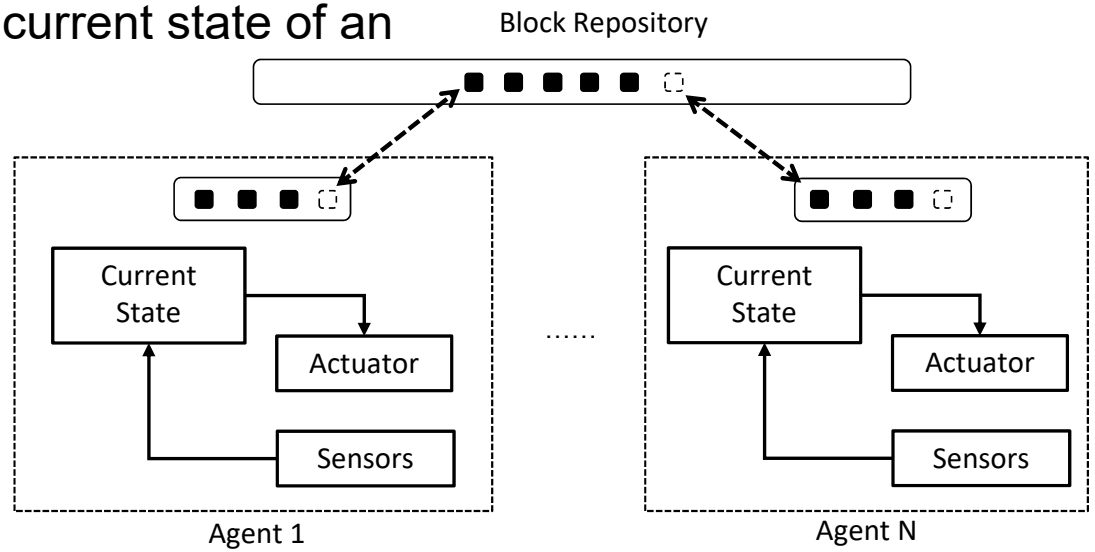
Grouping sensors and actuators in computational agents

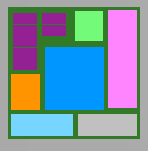
Shared Resource (Blocks)

- Establishes cooperation and sharing

- Blocks are a discrete unit of change to an actuator

- An exchange of blocks occurs when the current state of an agent is outside a tolerance

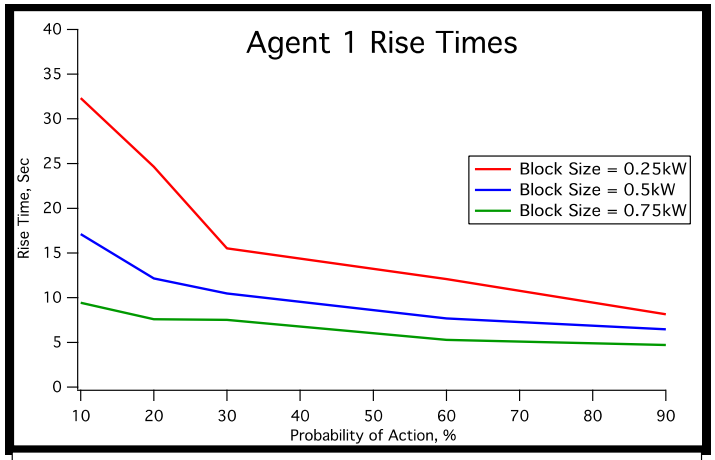


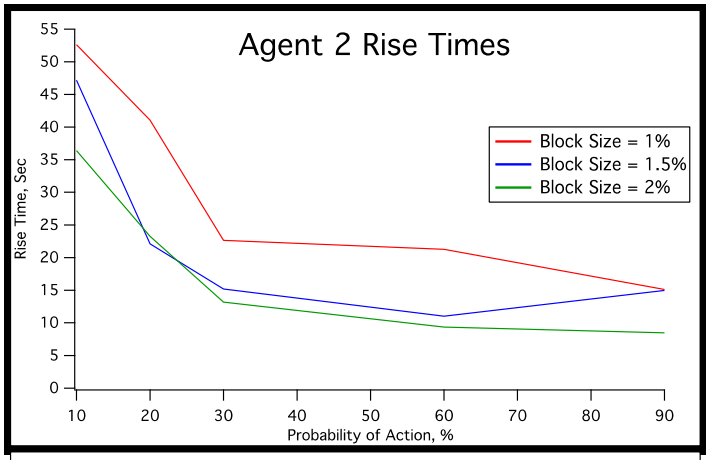


Resource sharing algorithm

Validation on a Physical system (Hyper)

- Different values of block size
- Different values of probability of action threshold
- Tolerance



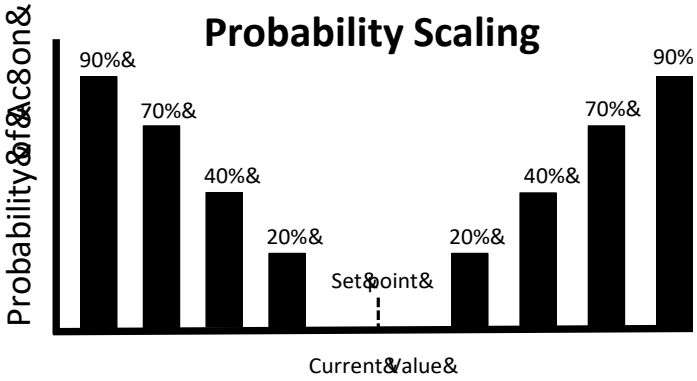


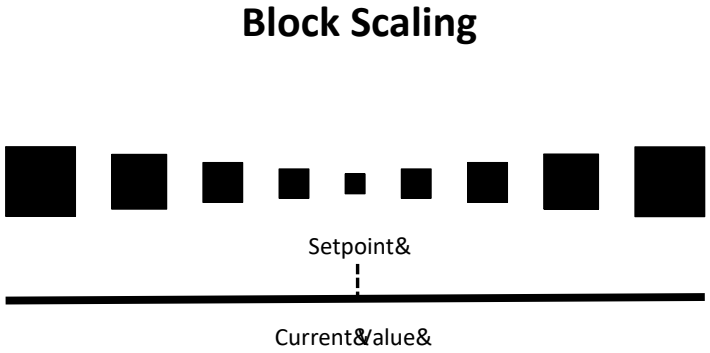
Automatically scaling Block Size/Probability of Actions

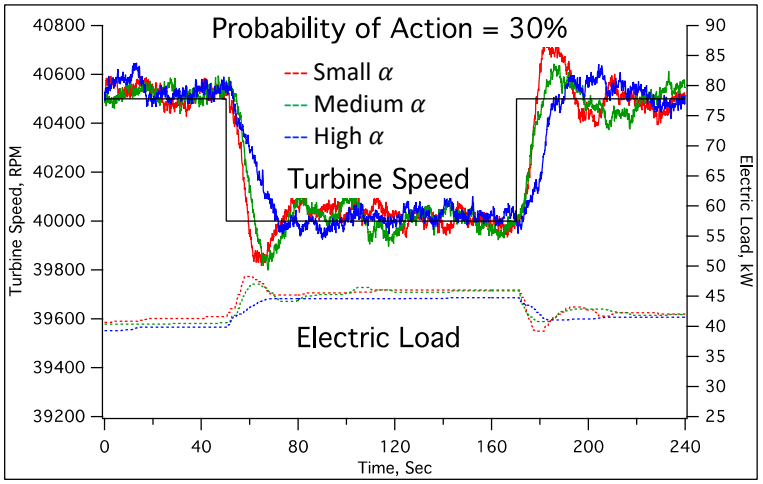
- Small α produce a high scaling factor, high block size or probability of action
- Initial block size a priori definition (1kW and 3%)

$$e = |current\ value - setpoint|$$

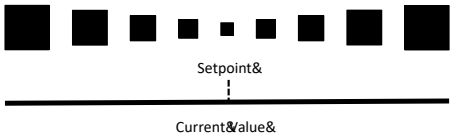
$$Scaling\ Factor = \frac{e^2}{(e+\alpha)^2}$$





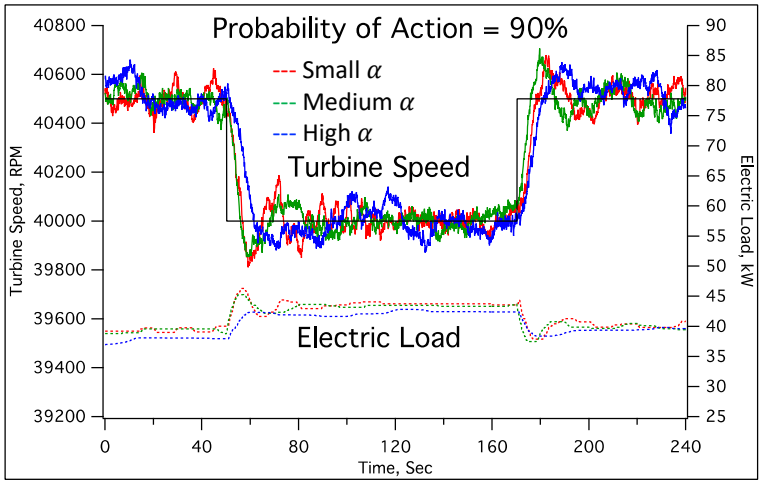


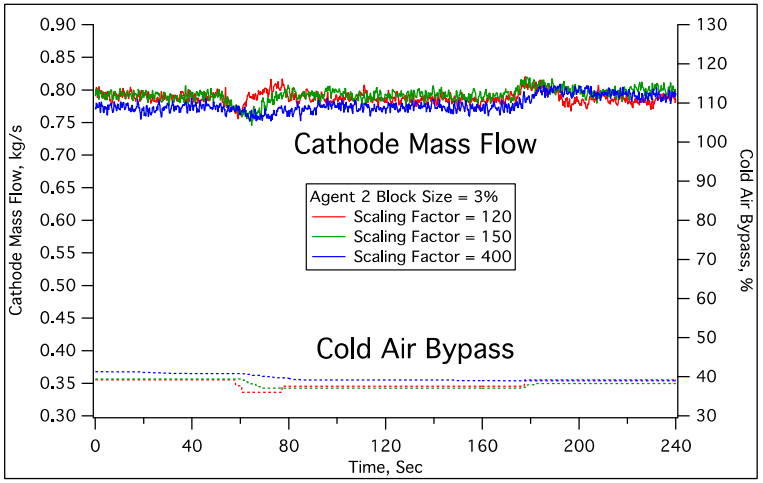
Block Scaling

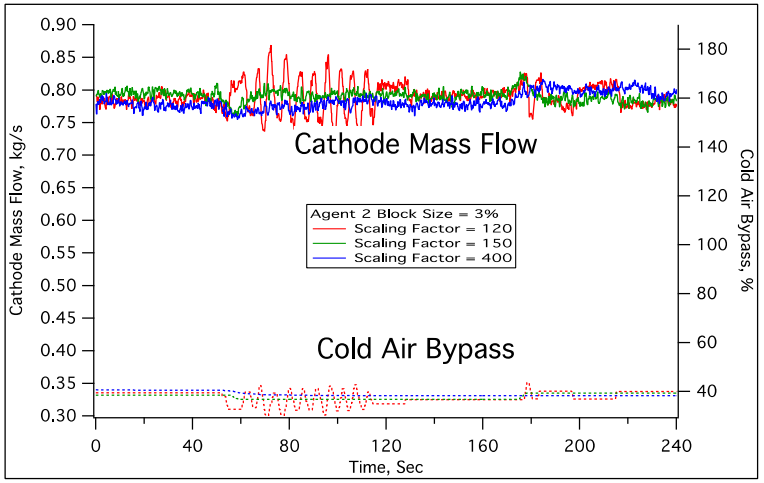


$$e = |current\ value - setpoint|$$

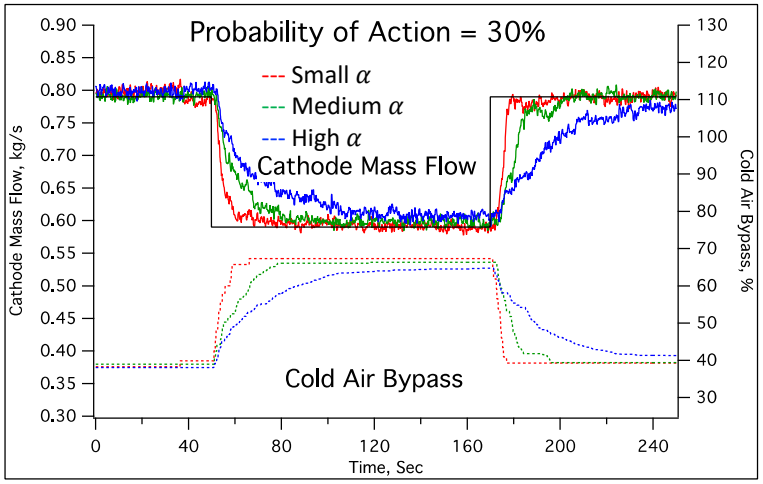
$$Scaling\ Factor = \frac{e^2}{(e+\alpha)^2}$$



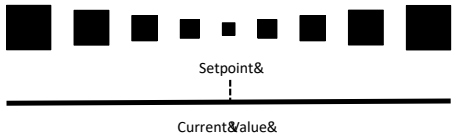




Agent 1 - Block Scaling Results

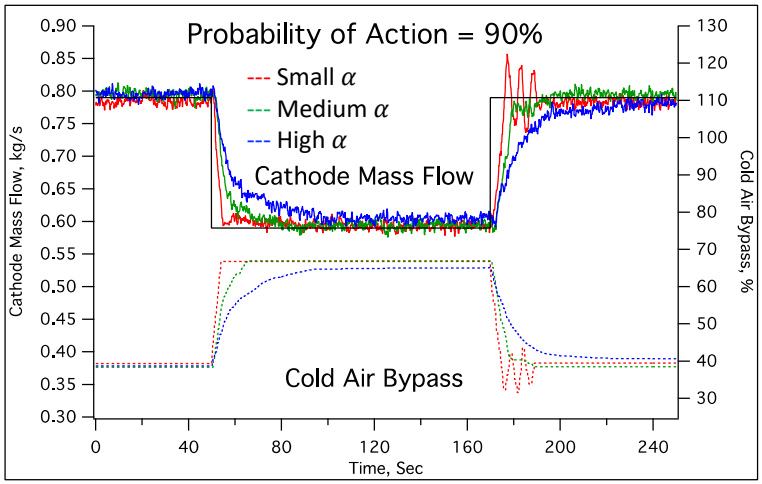


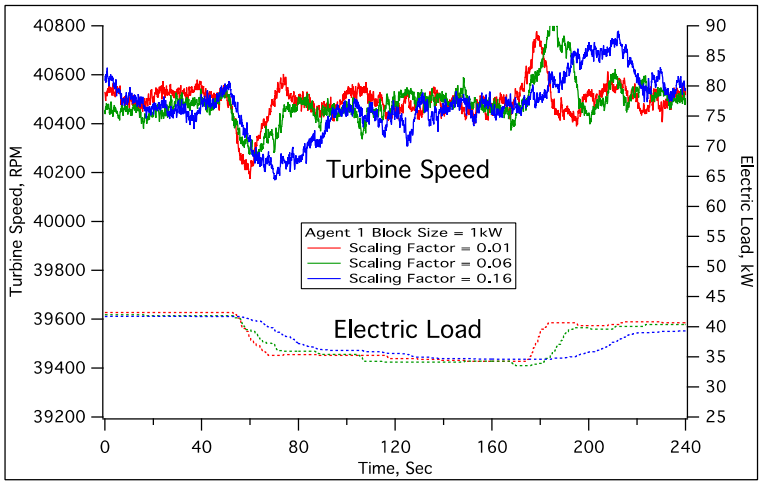
Block Scaling

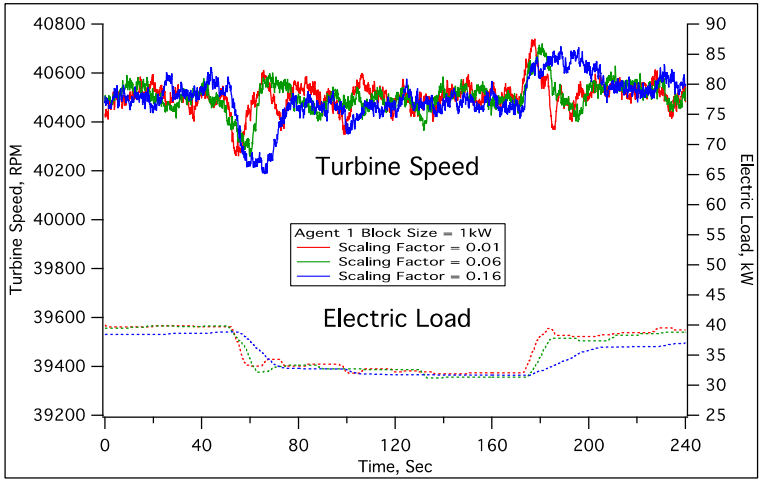


$$e = |current\ value - setpoint|$$

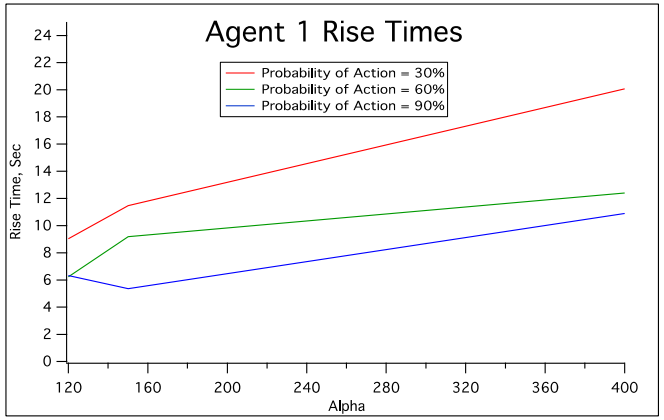
$$Scaling\ Factor = \frac{e^2}{(e+\alpha)^2}$$



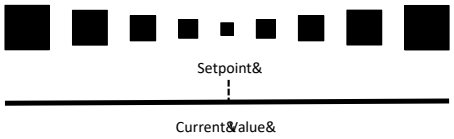




Agent 2 - Block Scaling Results

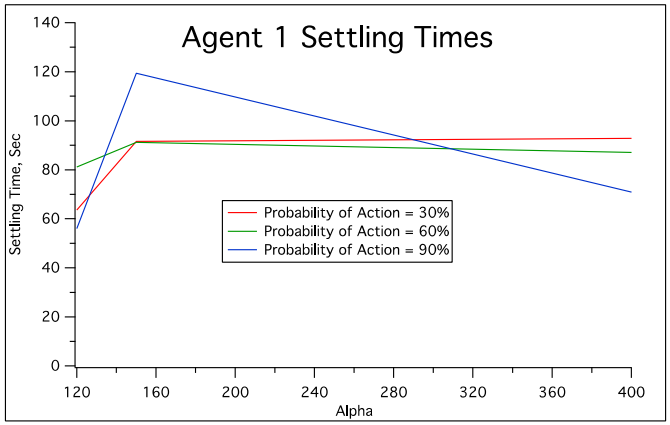


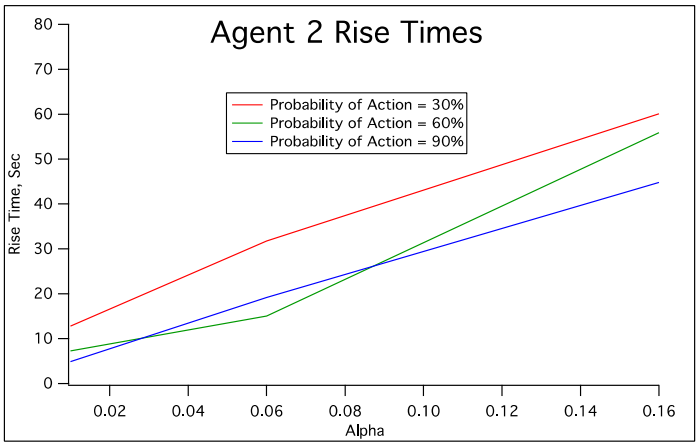
Block Scaling

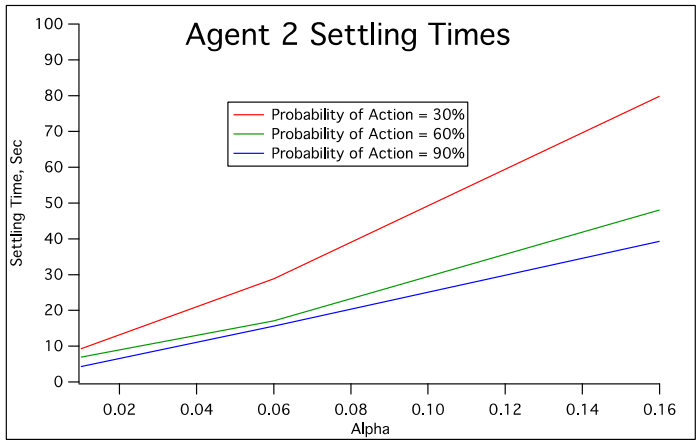


$$e = |current\ value - setpoint|$$

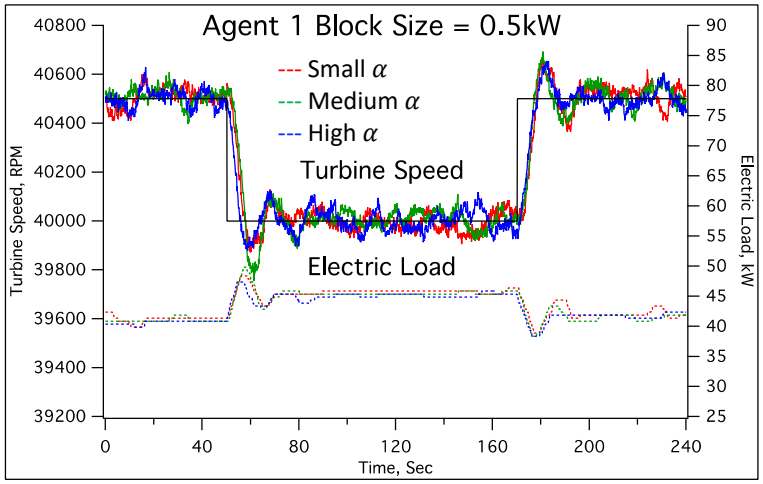
$$Scaling\ Factor = \frac{e^2}{(e+\alpha)^2}$$

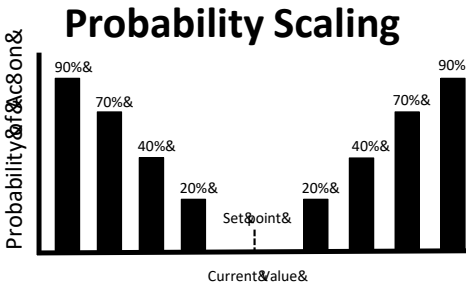






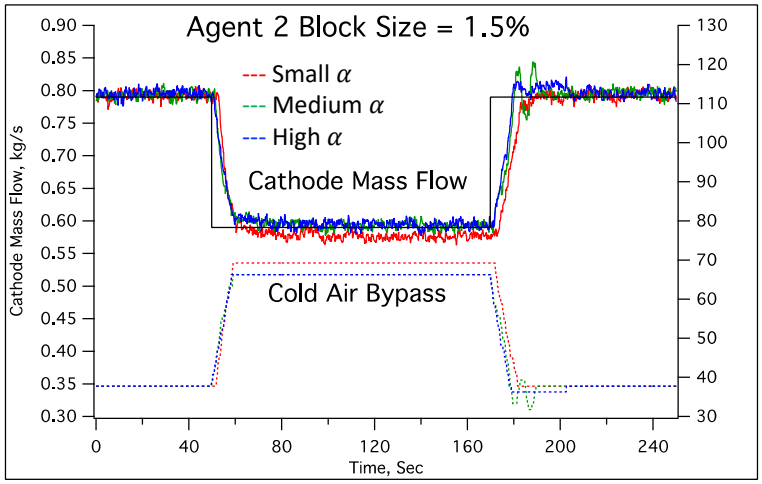
Stigmergic – Tuning Parameter Results

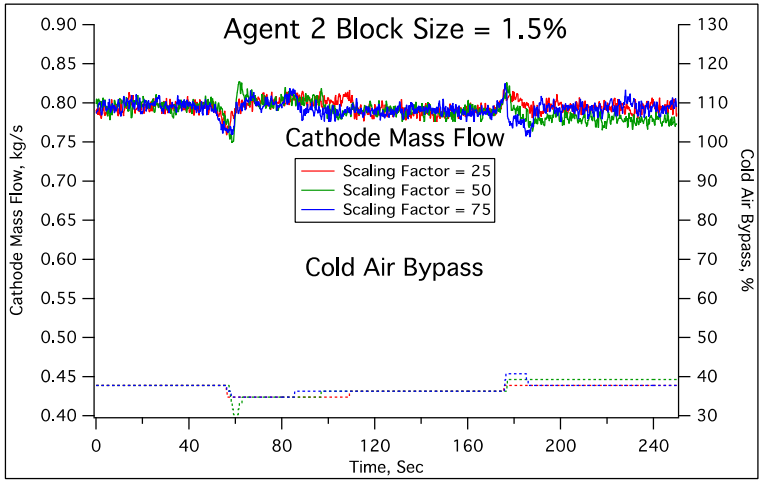


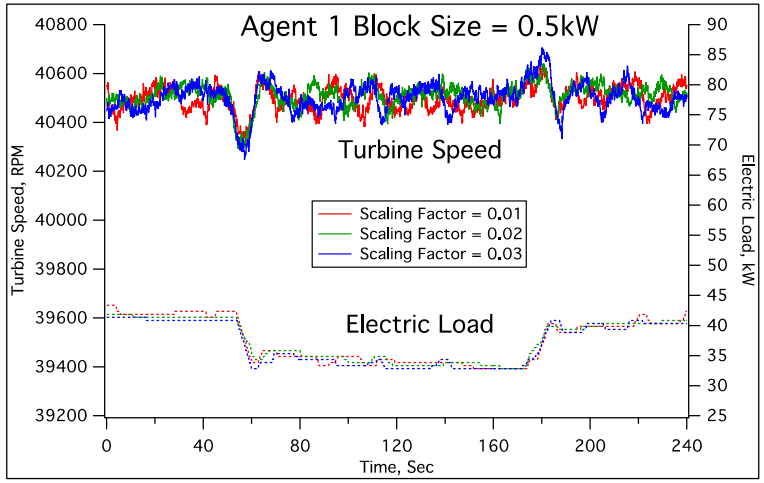


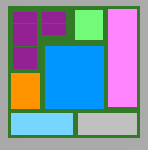
$$e = |current\ value - setpoint|$$

$$Scaling\ Factor = \frac{e^2}{(e+\alpha)^2}$$









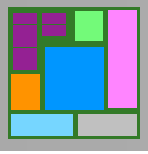
Agent 1 and Agent 2 Probability Scaling Results

Stigmergic Control Schema

- No modeling of the system is required
- Automatic block scaling – Improvements in the algorithm response
- Automatic probability scaling – No significant improvements

Multi Model Adaptive Control Architecture

- Modeling of the system at each operating point
- Real-time model matching at each operating point



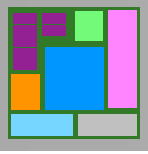
Summary

Co-worker/Homogenous agents

- Adding cooperation through multiple agents on each actuator

Multiple sensors on each agent

- A control decision will be made on overlap, duplication, and reuse of sensors



Future work

MESA Team in Ames

Dr. Peter Finzell

Dan Bell (PhD grad, Iowa State U)

Zach Reinhard (PhD grad, Iowa State U)

Tina Akinyi (PhD grad, Iowa State U)

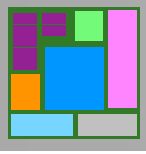
Hyper Team in NETL

Dr. David Tucker

Dr. Larry Shadle

Dr. Farida Nor Harun

Valentina Zaccaria (PhD grad, U of Genoa)



Acknowledgements