
# A Practical Demonstration of StocHy

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AIMS: Systems verification

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HOME CONTROL
online
energy
light
20°C
water
other

# Complex continuous dynamics


Complex continuous dynamics


Discrete modes

Complex continuous dynamics


Discrete modes

Noise

Complex continuous dynamics


Discrete modes

Noise

**Stochastic hybrid systems + StocHy**

# What is StocHy

**StocHy** is a new tool for automatic:

- verification,
- synthesis,
- simulation

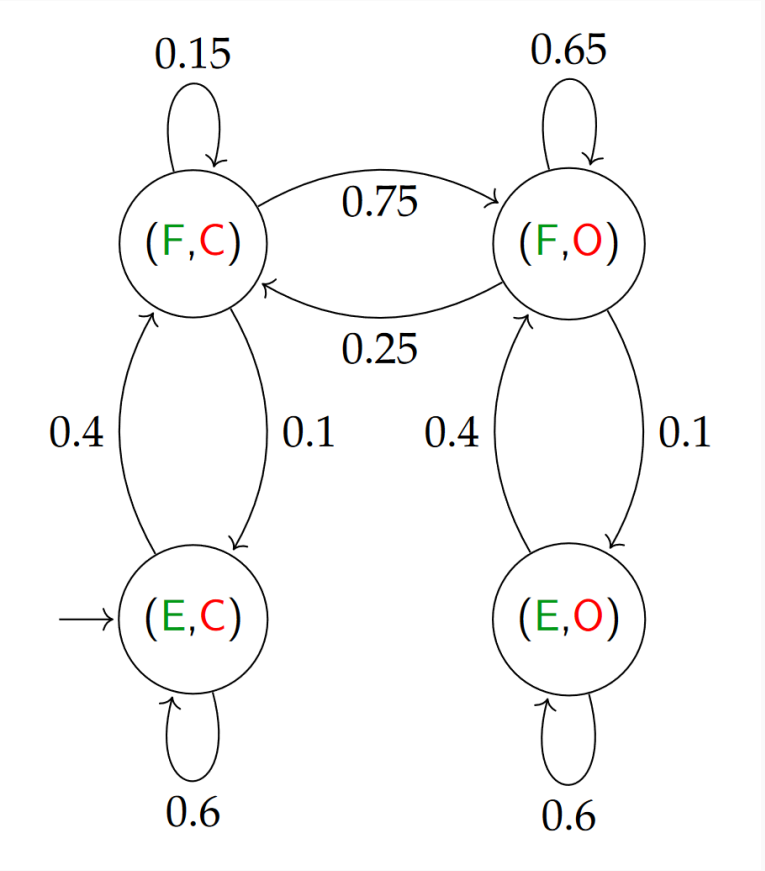
of stochastic processes.
It has been applied to:

- benchmarks for building automation systems
- policy synthesis for robotic application

StocHy repository

# Stochastic Hybrid Systems

- discrete-time stochastic hybrid systems (SHS)
- probabilistic evolution between modes
- stochastic difference equations describe continuous evolution in each mode
- can have actions on discrete modes
- exogenous control inputs effecting continuous dyanmics

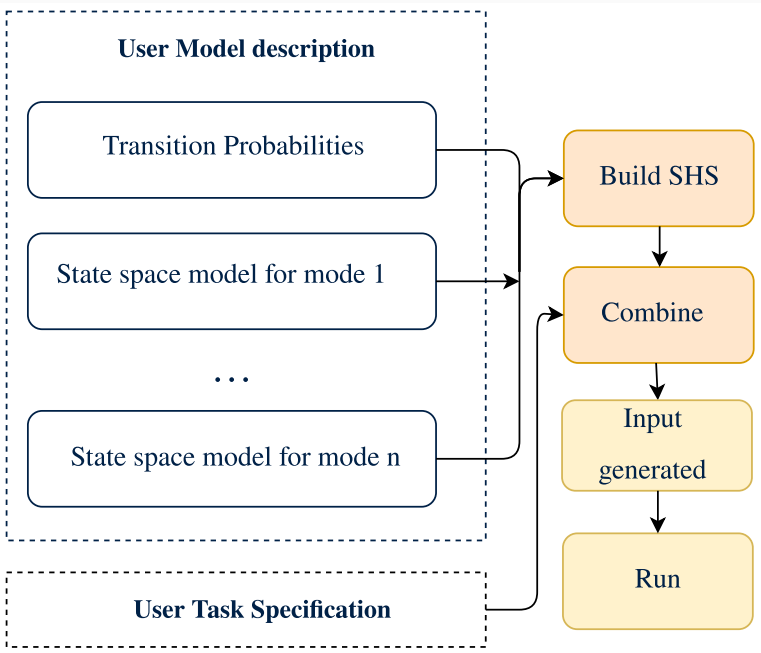


# Stochastic Hybrid Systems + StocHy

- discrete modes: transition probability matrix
- state-space model input for continuous dynamics

$$x_{k+1} = A_q x_k + B_q u + x \sum_{i=1}^{v} N_{q,i} u_{i,k} + F_q + G_q w_k.$$

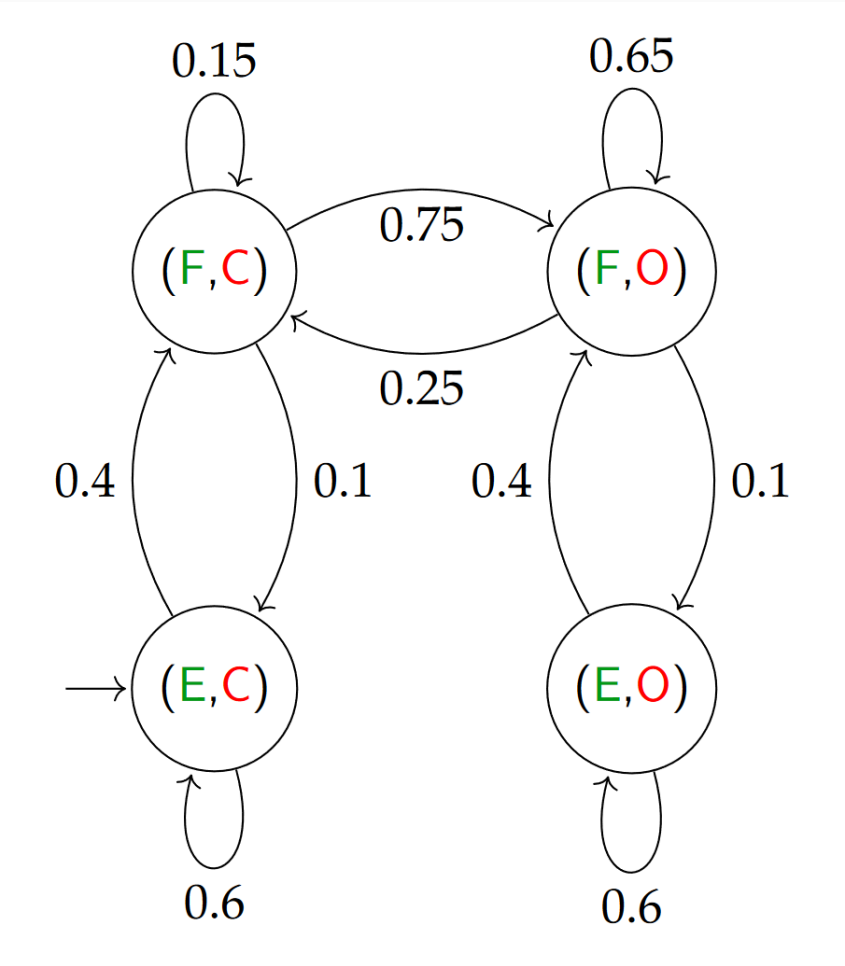
- task selection: verification, synthesis or simulation



# Case study

stochastic hybrid system case study from smart buildings lab:

- coupling of $CO_2$ and temperature dynamics
- switching ON/OFF fan or
- opening or closing windows
- mass air flow controlled externally



# Case study: Example

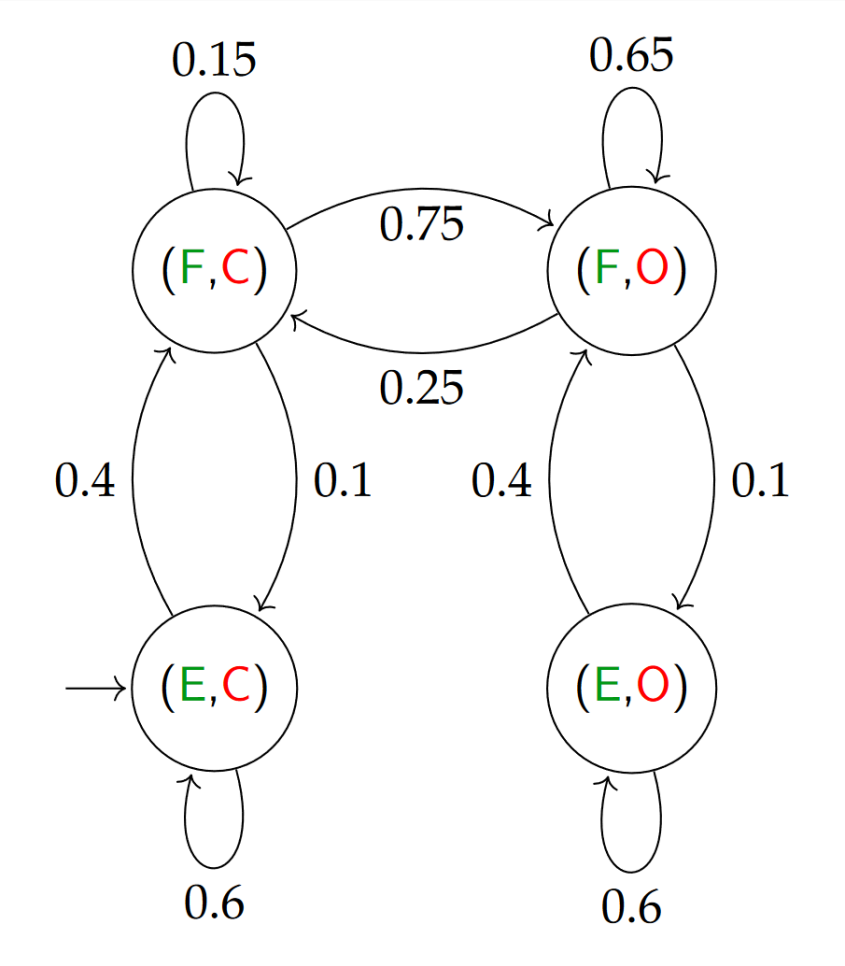
$$
\begin{aligned}
x_{k+1} &= x_k + \frac{\Delta}{V}((-\mathbb{1}_{ON} m x_k + \mu_{\{O,C\}}(C_{out} - x_k)) + \mathbb{1}_F C_{occ} + \sigma_x w_k \\
y_{k+1} &= y_k + \frac{\Delta}{C}(\mathbb{1}_{ON} m(T_{set} - y_k) + \mu_{\{O,C\}} \frac{1}{R}(T_{out} - y_k)) \\
&\quad + \mathbb{1}_F T_{occ,k} + \sigma_y w_k \\
T_{occ,k} &= v x_k + \zeta
\end{aligned}
$$

- $x$ is zone $CO_2$ level, $y$ is zone temperature, $T_{set}$ is the set temperature, $\Delta$ is the sampling time, $T_{out}$ is outside temperature, $T_{occ}$ is the generate heat
- $m$ is the mass air flow
- $\sigma$ is the variance of noise $w_k \sim \mathcal{N}(0, I)$

# Case study: Monte-Carlo Simulation

Steps to perform simulation:

1. Instantiate model
2. Define initial conditions
3. Read input control signal
4. Select simulation task



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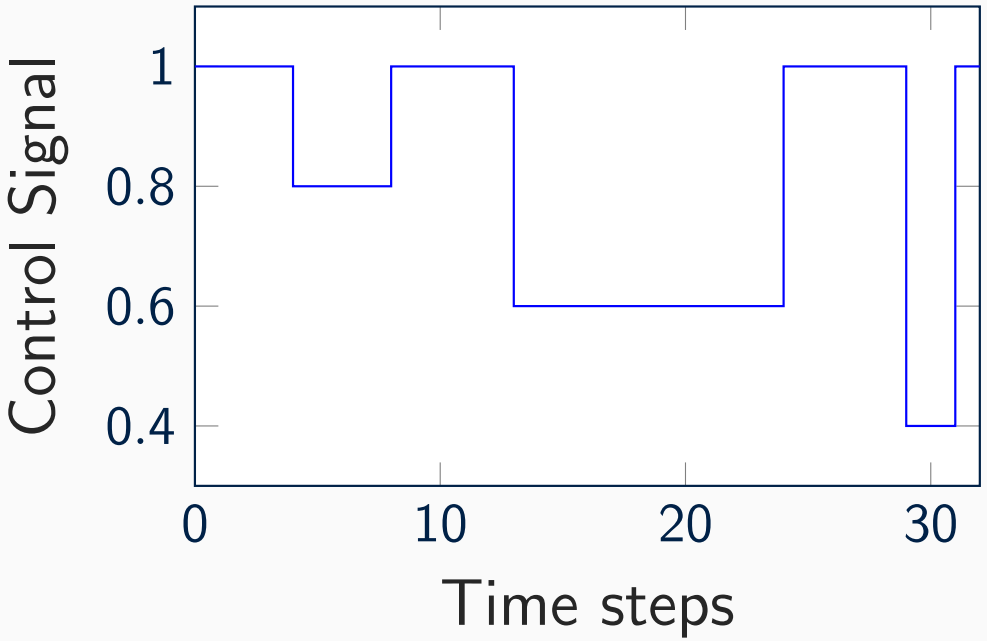


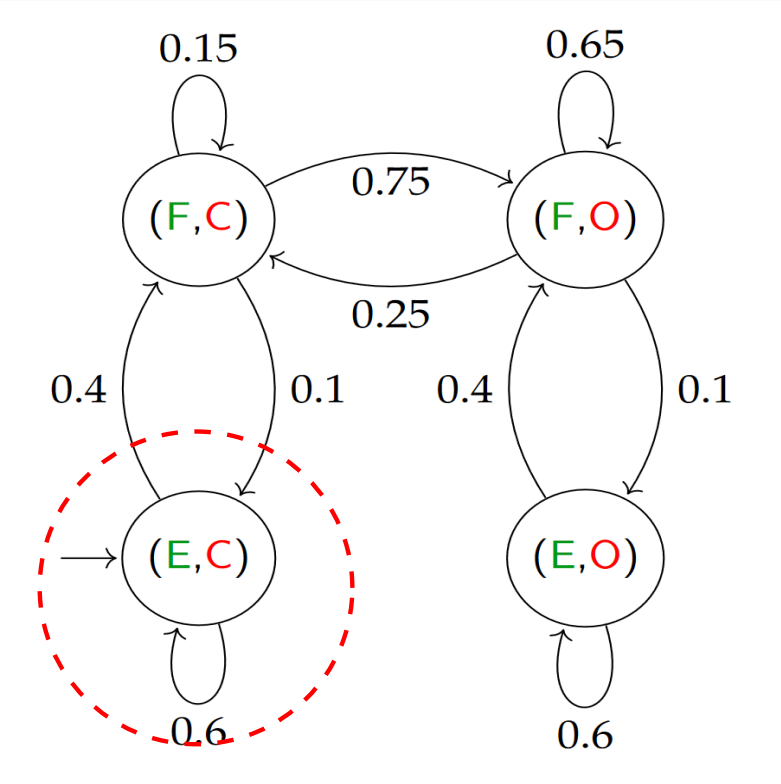
# Case study: Monte-Carlo Simulation

## DEMO 1

# Case study: Verification

Steps to perform verification:

1. Instantiate model
2. Define safe set
3. Define time horizon
4. Define maximum abstraction error
5. Select verification method



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Steps to perform verification:

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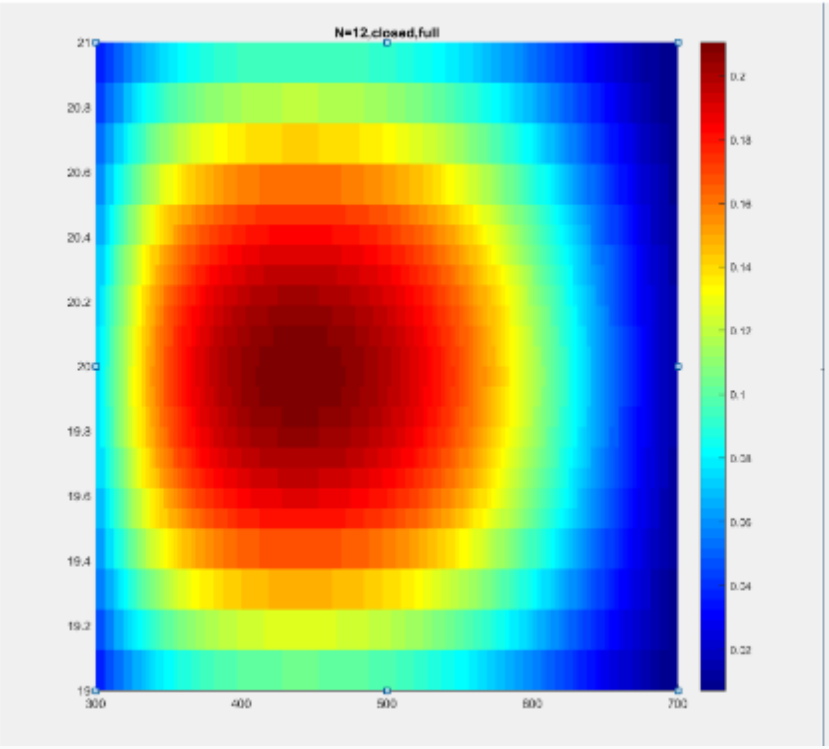
Property of interest:

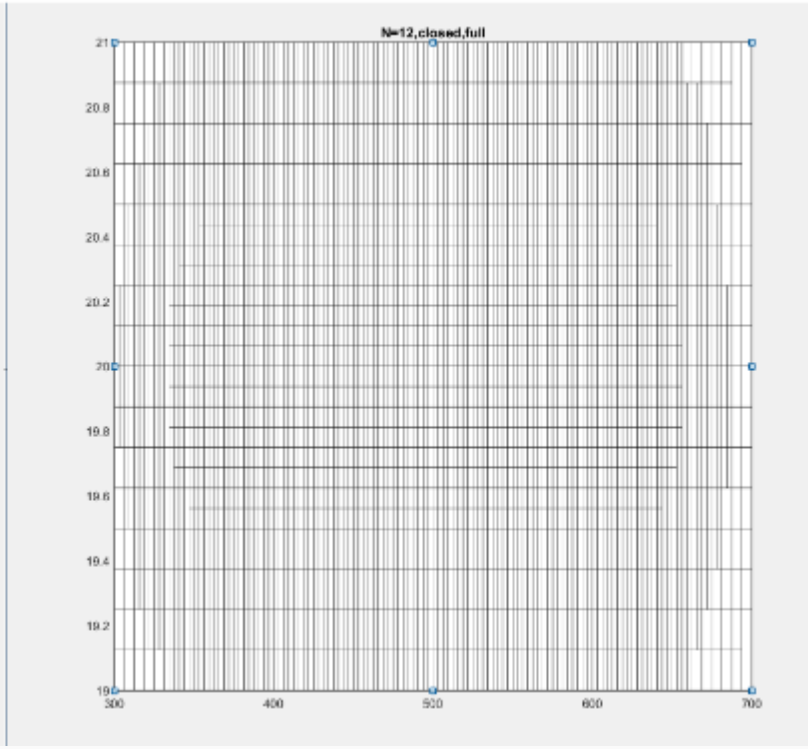
$$\phi_1 := \Box^{\leq K} X_{safe}$$

# Case study: Verification

## DEMO 2

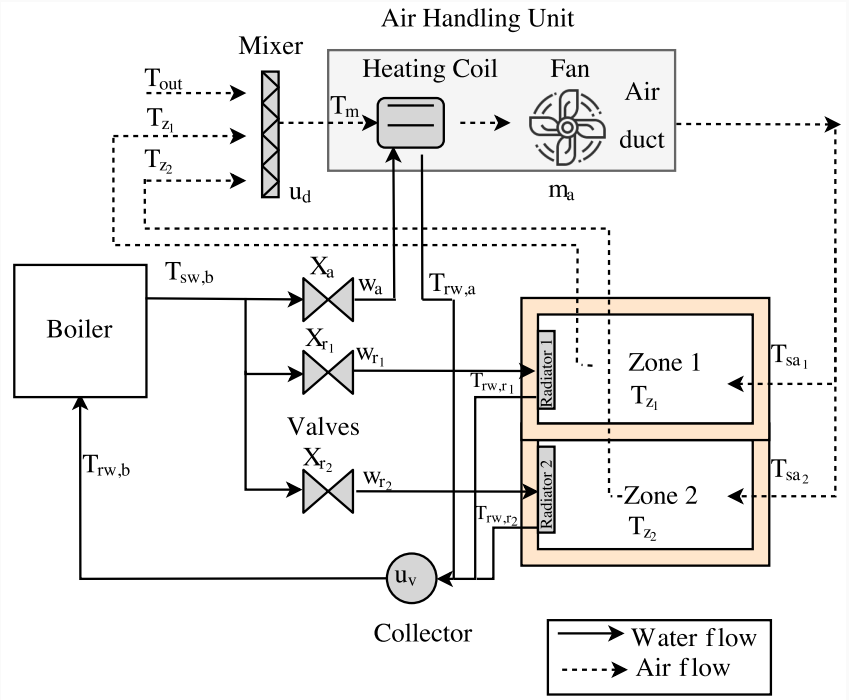
# Case study: Results



# Benchmarks

- provide a set of `benchmarks` for stochastic processes
- library of models for Building automation systems
- can all be run on **StocHy**



# The End

## Thank you!

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StocHy