

## Hybrid Systems: Discrete and continuous behaviors ... Many challenges

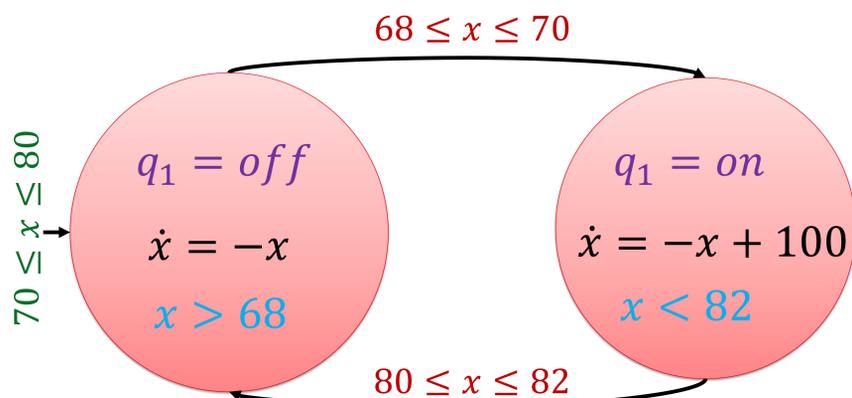


Fig.1: Hybrid automaton modeling a thermostat

## Reachability Problem

Undecidable for Hybrid Systems except some subclasses, implying restrictive constraints over the hybrid automata.

For very simple classes of hybrid systems, reachability is undecidable  $\rightarrow$  Developing tools for analyzing hybrid automata is complex.

Some identified classes are decidable, but their expressive power is too weak to represent practical hybrid systems.

## Qualitative Reasoning and Simulation

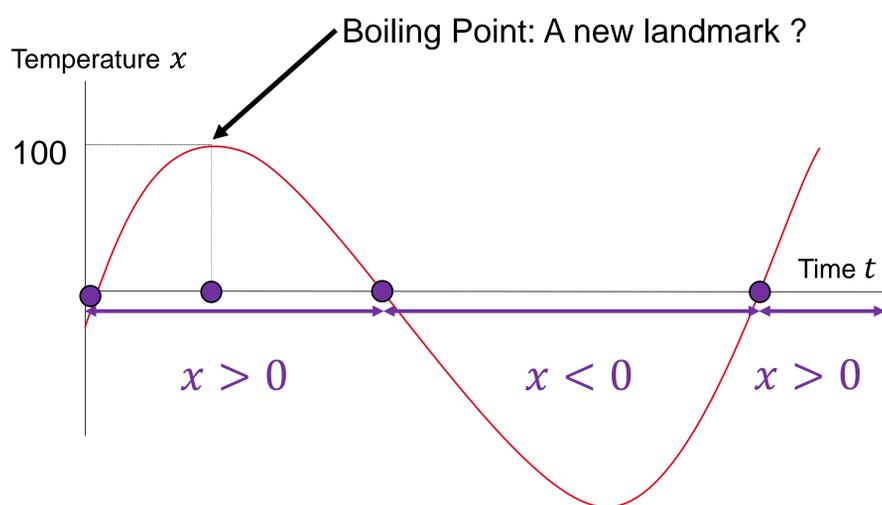
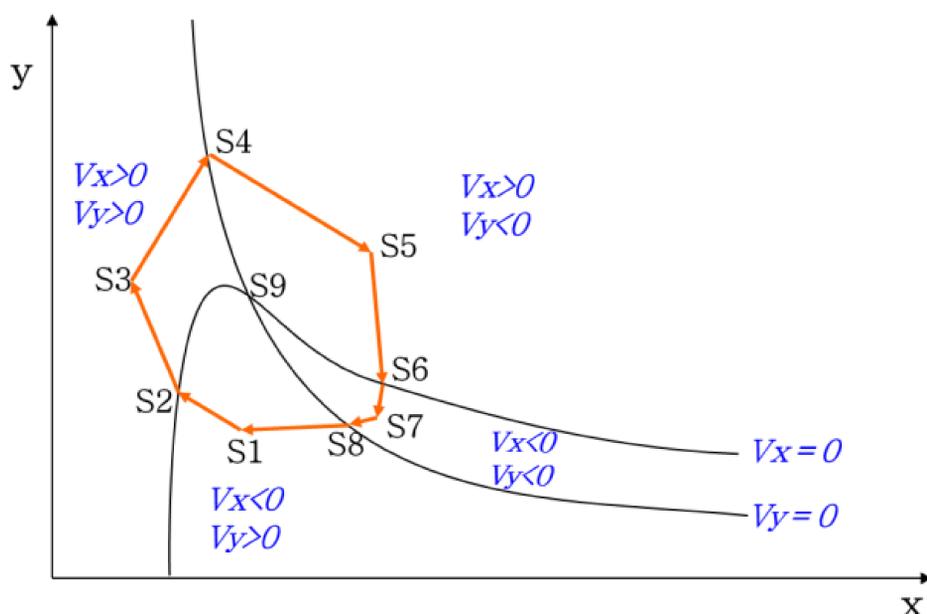


Fig.2: Partitioning with respect to the sign of a variable representing temperature and perhaps its derivative if it is of interest

## For modeling complex systems this means...

Numerical Simulation is an exhaustive process, however qualitative simulation can preserve the important behaviors of the system while still being able to verify properties.

Fig.3: Qualitative Simulation of "The Brusselator" shows 9 states [1]:  
 $X$  and  $Y$  are the concentration of each reagent and  $V_x, V_y$  their respective growth

## Qualitative Reasoning

Reducing the number of numerical values by assigning key values. Such that saying that an object is "heavy" instead of giving it's exact mass.

## Qualitative Simulation

Discretization by partitioning with respect to the domain of variation of the continuous functions.

On domains where the process is continuously differentiable, the derivative cannot change sign without taking a null value, reducing the size of the qualitative behavior graph.

## And as for hybrid systems ?

Discretize the continuous part of a hybrid system. Applying such approaches to hybrid systems, it would then be possible to apply formal methods for verification such as model-checking. Recent state of the art works consist in performing mixed types of abstractions for hybrid automata: Predicate abstraction for the discrete part, and qualitative reasoning for the continuous part

## Thesis Objectives

- Elaborate a complete solution of qualitative simulation of hybrid systems for verification purposes
- Study this solution in DIVERSITY : a multi-purpose and customizable platform for formal analysis based on symbolic execution. DIVERSITY is developed by the CEA
- Extend the solution to be used in DIVERSITY by specifying a user interface and an operative demonstration
- Analyze the results obtained from the qualitative simulation engine then propose these works to industrial partners