Hybrid Systems: mathematical models for discrete reactive systems in a physical (continuous) environment

State-based Models of Hybrid Systems: consist of both discrete and continuous transitions

- on a discrete transition, the values of the variables until some release condition becomes true to change to a new discrete state
- on a discrete transition, a sequence of assignments is executed and determines a new set of differential equations and a new release condition.

Example: Water Tank

The water tank regulates water level \( y \) by filling or emptying the water tank \( x \) is the initial water level, \( \text{in}V \) and \( \text{out}V \) describe the changes of water level, and \( \text{delta}_t \) is a constant value. Since the discretization of continuous transition, each of the filling and emptying procedures is extended by \( \text{delta}_t \) unit-time.

Simulation

\[ \text{ymax} = 10 \text{m}, \ y_{\text{min}} = 5 \text{m}, \ \text{in}V = 2 \text{m/s}, \ \text{out}V = 1 \text{m/s} \]

Verification Condition Generation and Solving Verification Conditions

Formal Verification

- verification condition generation
  Induction-based methods on SCCs and loops of the program
- verification tool evaluation:
  Averest interfaces with various verification tools: iSAT, Z3, etc.
- verification strategies to solve verification conditions
  - modular/compositional verification techniques
  - integration and processing of counterexamples

Modeling and Simulation

- modeling language:
  Quartz language and its extension to hybrid systems
- simulation
- symbolic simulation algorithms
- Zeno behavior detection