Comp-763

Hybrid (Differential Equations - Statecharts) modeling in Anylogic

McGill University

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Overview

- AnyLogic
- Agent-Based Modeling
- Discrete Event Modeling
- Continuous Time Modeling
- Hybrid (or Mixed) Discrete/Continuous Modeling
- Wandering Elephant Demo

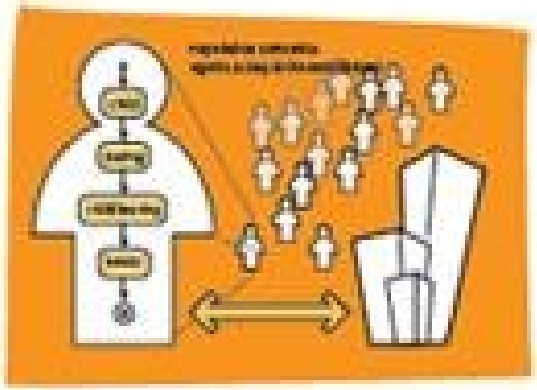
It's not the tool, it's the idea!

What is AnyLogic?

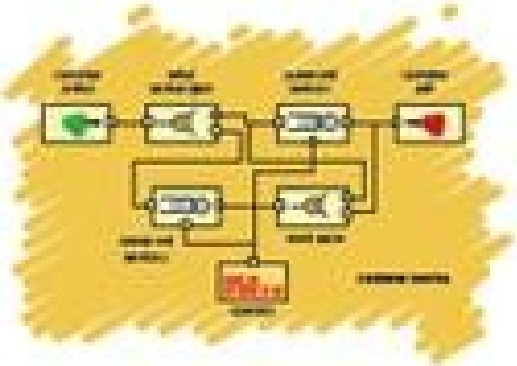
"AnyLogic is the first and only dynamic simulation tool that brings together System Dynamics, Process-centric (AKA Discrete Event), and Agent Based approaches within one modeling language and one model development environment."

-- http://www.xjtek.com/anylogic/

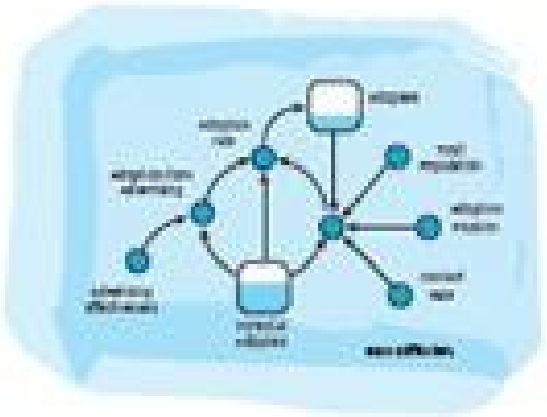
AGENT BASED APPROACH



DISCRETE EVENT



SYSTEM DYNAMICS



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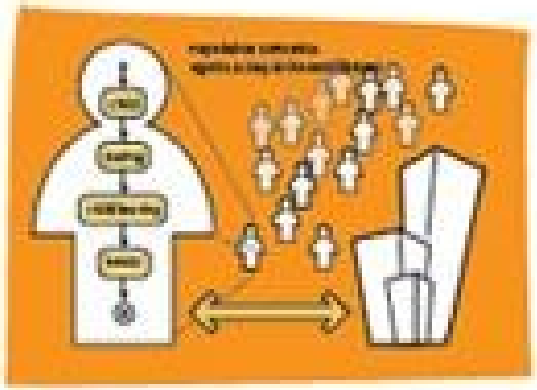

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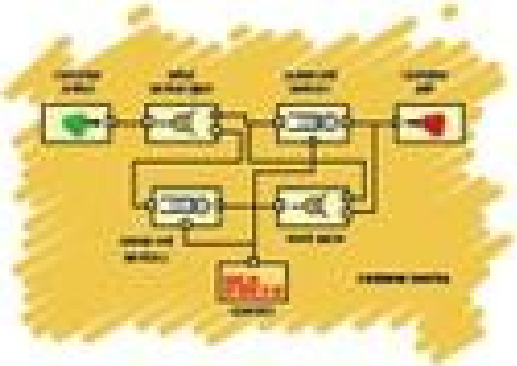

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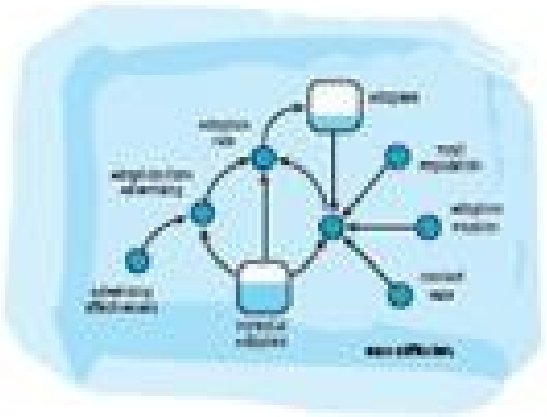


Agent-based Modeling

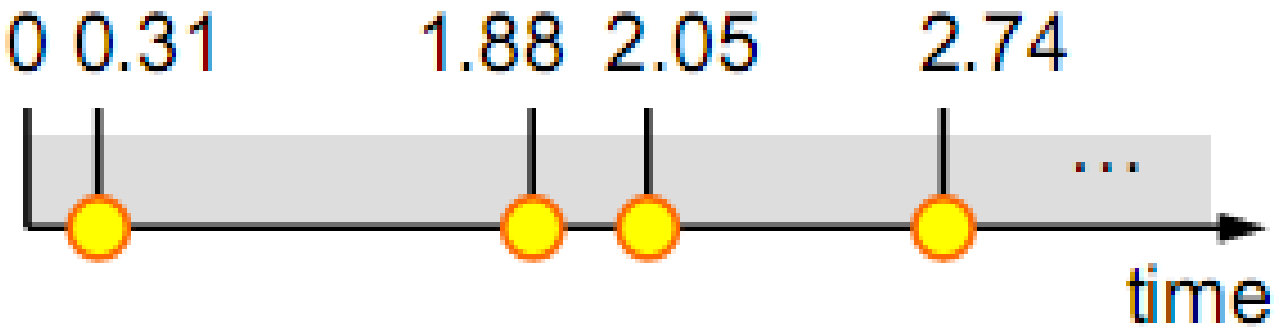
- Can be considered decentralized, individual-centric approach to modeling.
- Individual participants each have their own behavior and are known as agent.
- The agents are store inside an environment, where they may or may not communicate with each other.
- The combined behavior of the agents create a system level behavior.

Discrete Event Modeling

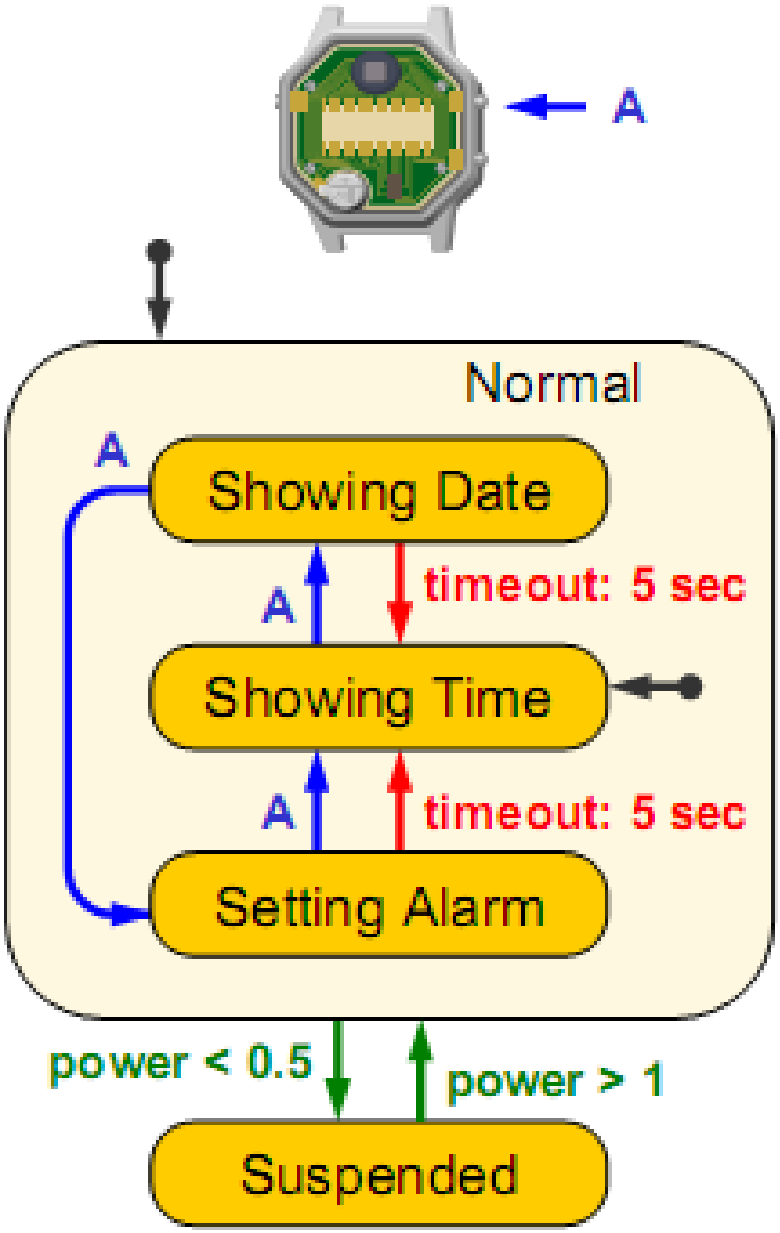
- In AnyLogic, discrete event modeling is achieved through a combination of :
  - Statecharts: Defines how a model changes from one state to another when receiving an event.
  - Timers: Generates events at a specific (random, statistical distribution, etc)
  - Plain variable: Stores values, can be changed by events or transitions in statecharts.

Events

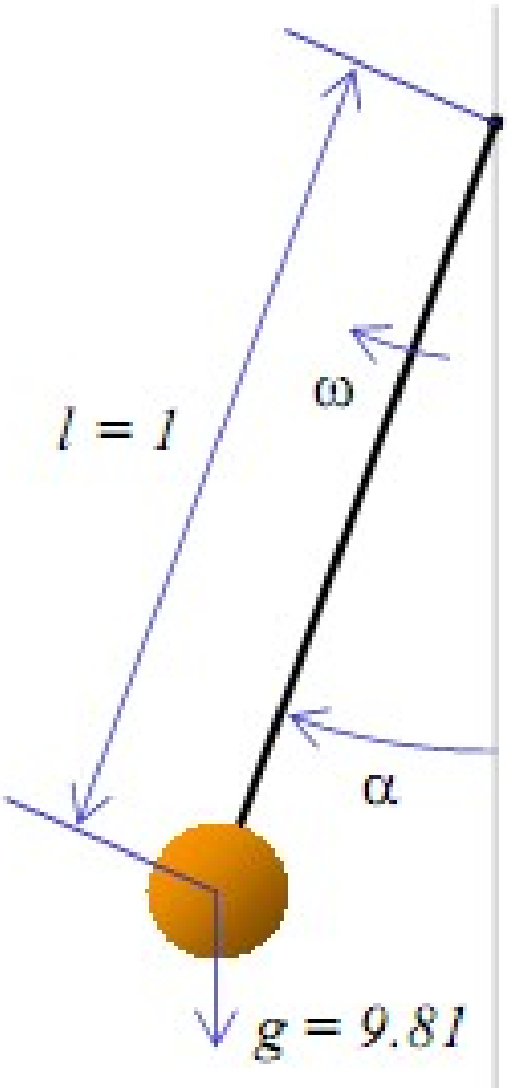
- Events are “important” moments in our system.
- Execution of events
  - requires zero time to complete
  - is atomic and cannot be interrupted
- They may cause other events to be scheduled in the future.
- AnyLogic models a series of events as an event queue.



Our friends, Statecharts

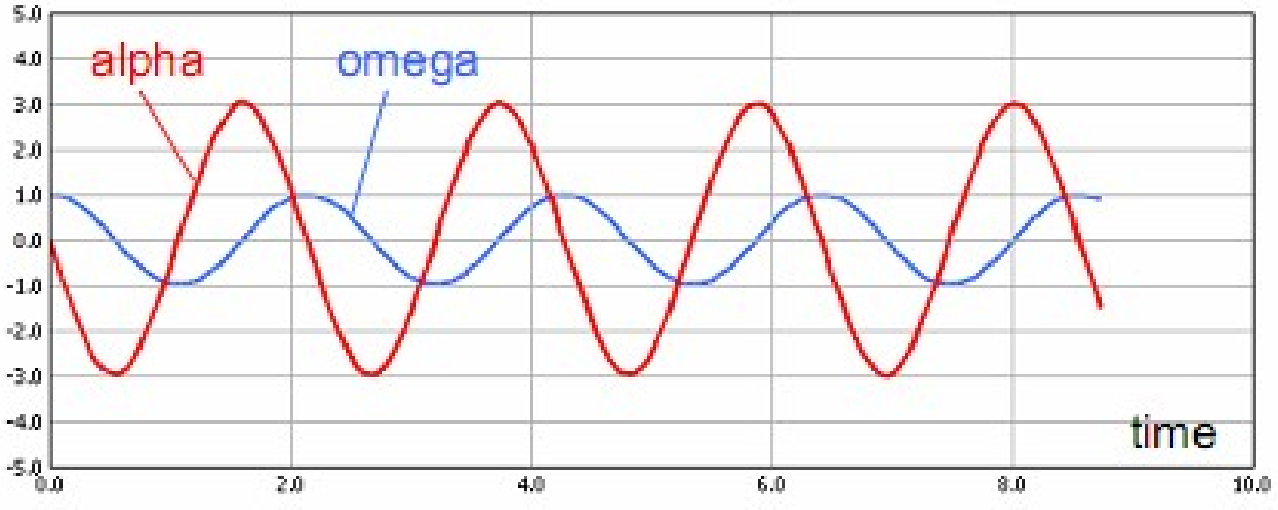


Continuous Time System



$$\frac{d\alpha}{dt} = \omega$$

$$\frac{d\omega}{dt} = -\frac{g}{l}\sin\alpha$$



Variables and Equations

- Continuous time systems are achieved through the use of various types variables and equations.
- The variables define the state of the system ...
  - Stock variables (or state variables) : Change their value over time.
  - Flow variables (or rates) : Changes the values of stock variables.
  - Note: stock = inflow1 + inflow2 ... - outflow1 - outflow2

Variables and Equations (cont.)

- The equations define the value of variables ...
  - Mathematical functions : $y = f(x,z,t,\ldots)$
  - Table functions : $y = f(x)$ mix in with some interpolation techniques
  - Algorithmic functions : defined using the Java program languages.

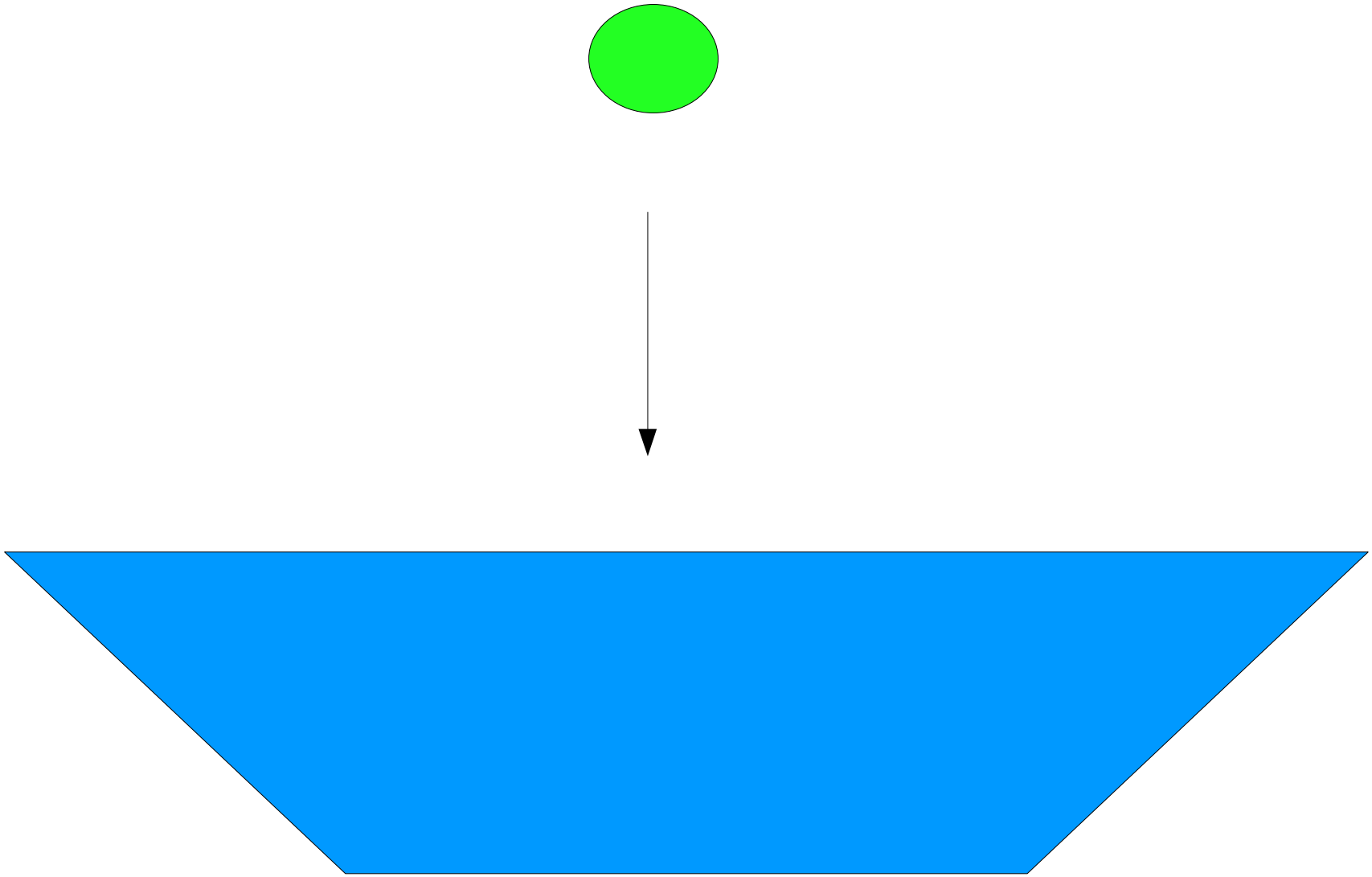
Equation System

- Differential
  - d(X)/dt = V
  - d(V)/dt = A
- Algebraic
  - 0 = X – sin(t)
  - 0 = Z – 2 * Y
  - 0 = X + Y + Z
  - find(X,Y,Z)
- Mixed
  - d(X)/dt = -sin(t)
  - 0 = Z – 2 * Y
  - 0 = X + Y + Z
  - find(Y,Z)

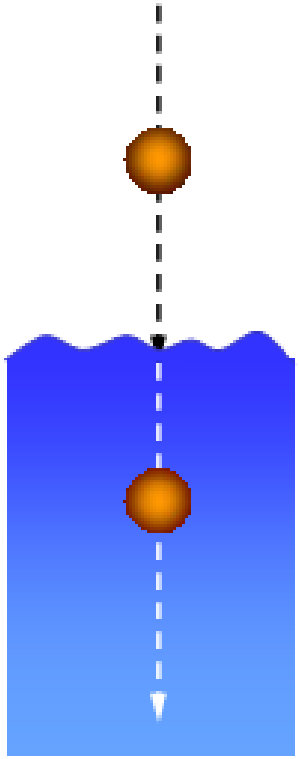
Solving Equations

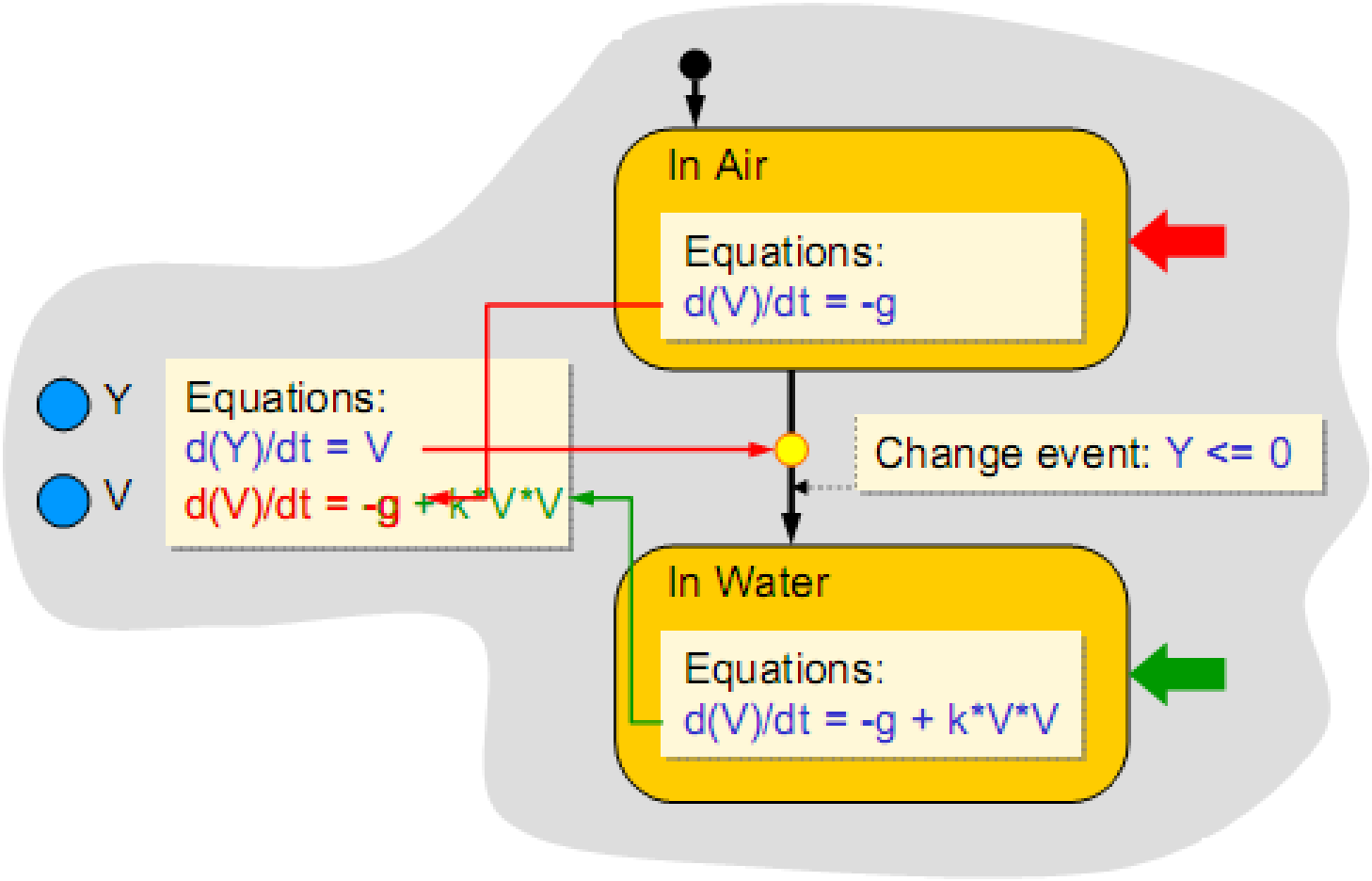
- Equations are solved numerically.
  - It would be unfeasible and unpractical to solve them analytically
- Continuous trajectories are obtained in discrete time steps.
- This works within a certain tolerance (threshold).

Hybrid Models

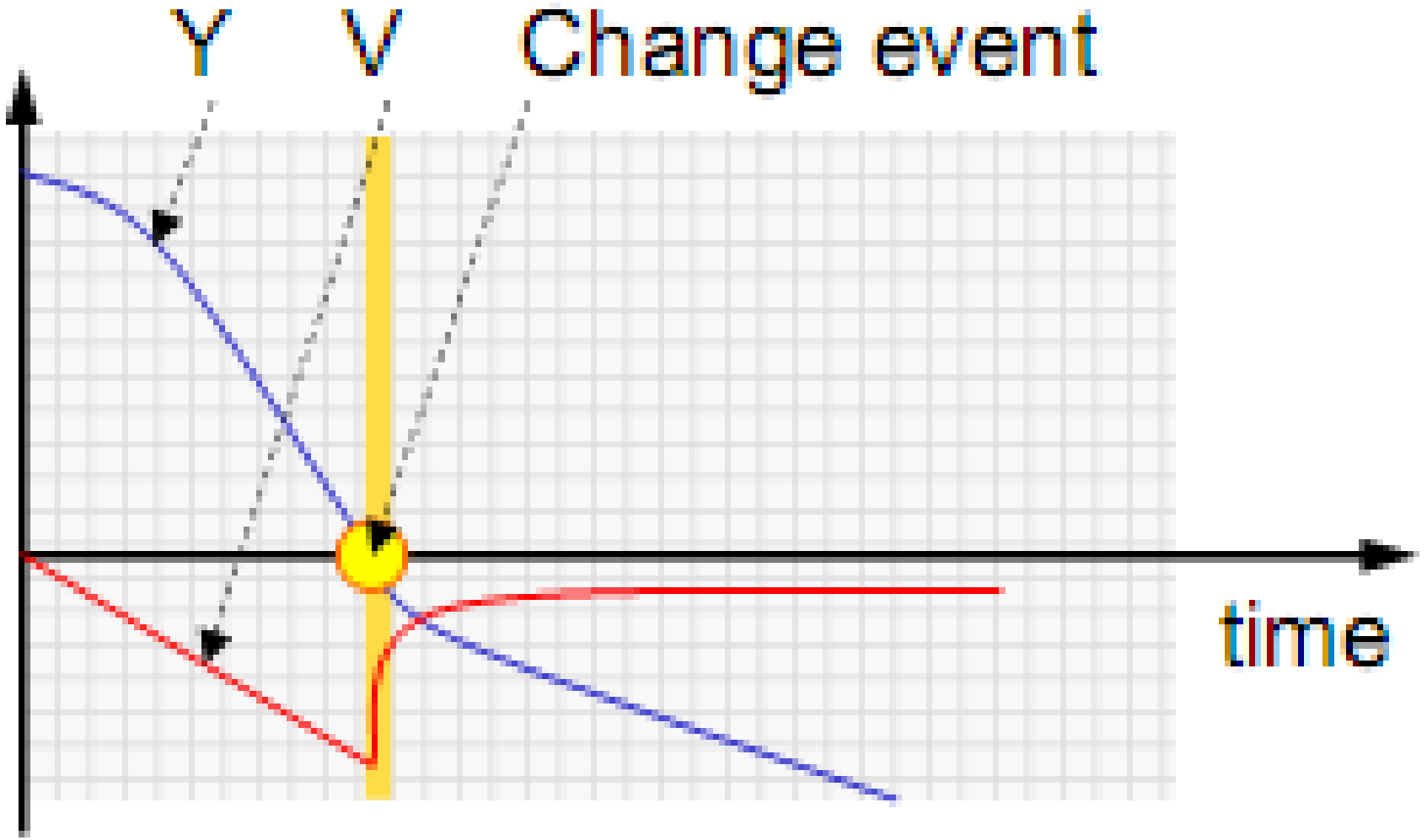


Hybrid Models

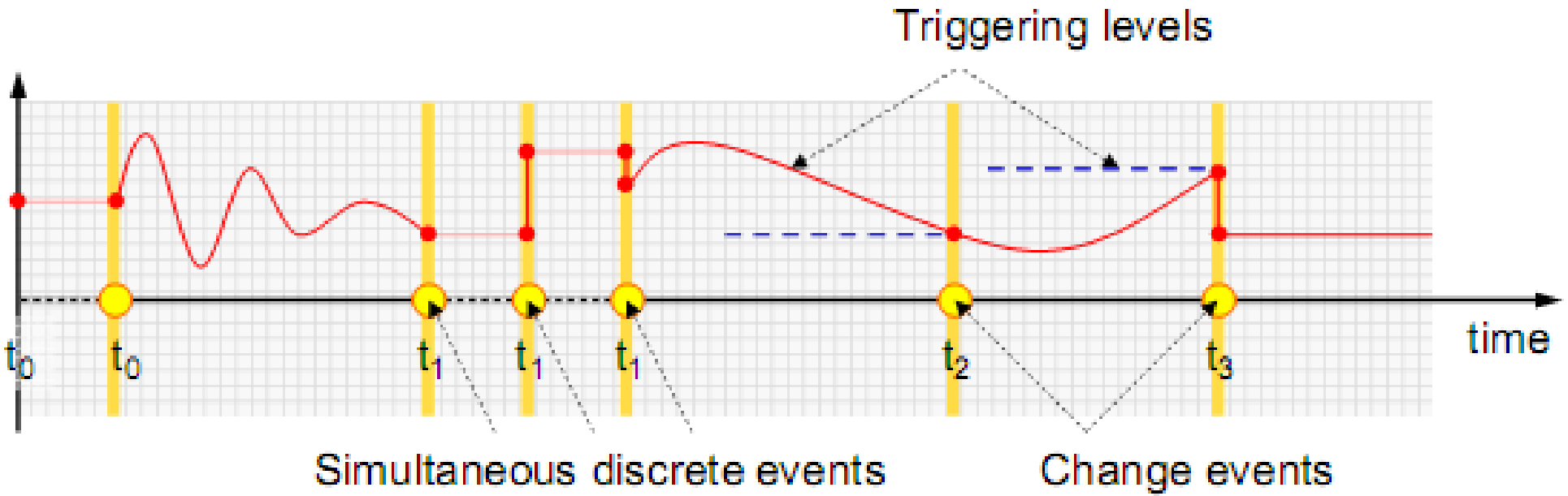




Effect of Events



Changes in State



Doing this in Anylogic

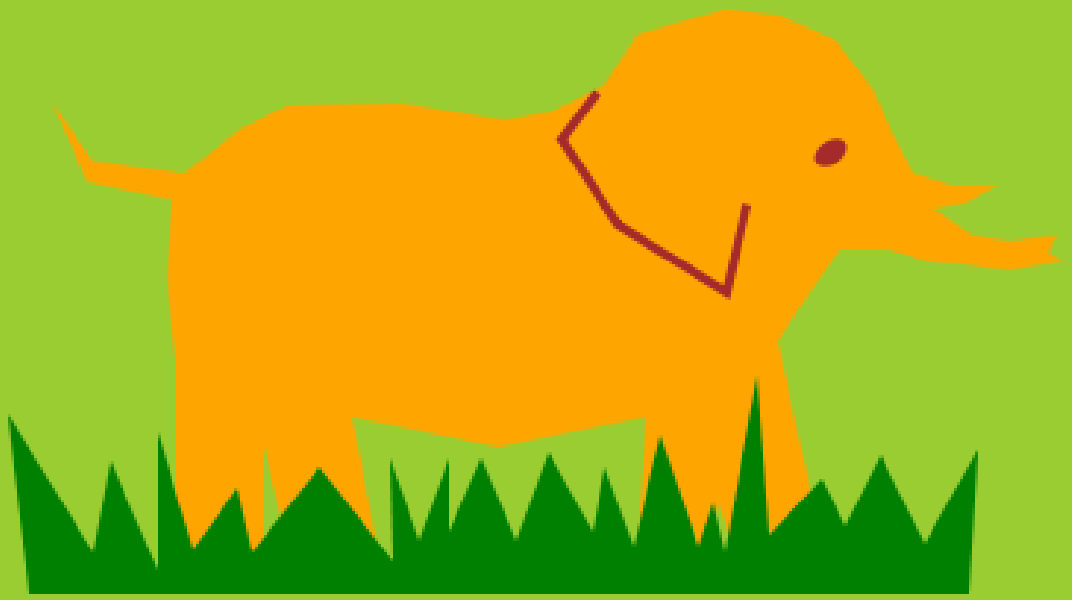
- With Stock and Flow variables.
- With Agent active objects.
  - Synchronized and unsynchronized

Wandering Elephants Demo

Wandering Elephants

A number of elephants live in the area 100 by 100 kilometers. There are two layers of geographical information: altitude and vegetation (you can switch between them). Elephants randomly wander in the area, but every once in a while they get thirsty and go to the nearest lake to drink water. As elephants walk, they demolish vegetation with a certain rate. Vegetation regenerates, but it can never exceed a natural maximum that depends on the altitude. A new landscapes are generated each time you restart the model.

Run the model



This model also demonstrates a very efficient way of displaying large dynamically changing raster or vector maps.

Summary

- Discrete Event Modeling
- Continuous Time Modeling
- Hybrid (or Mixed) Discrete/Continuous Modeling

Questions?