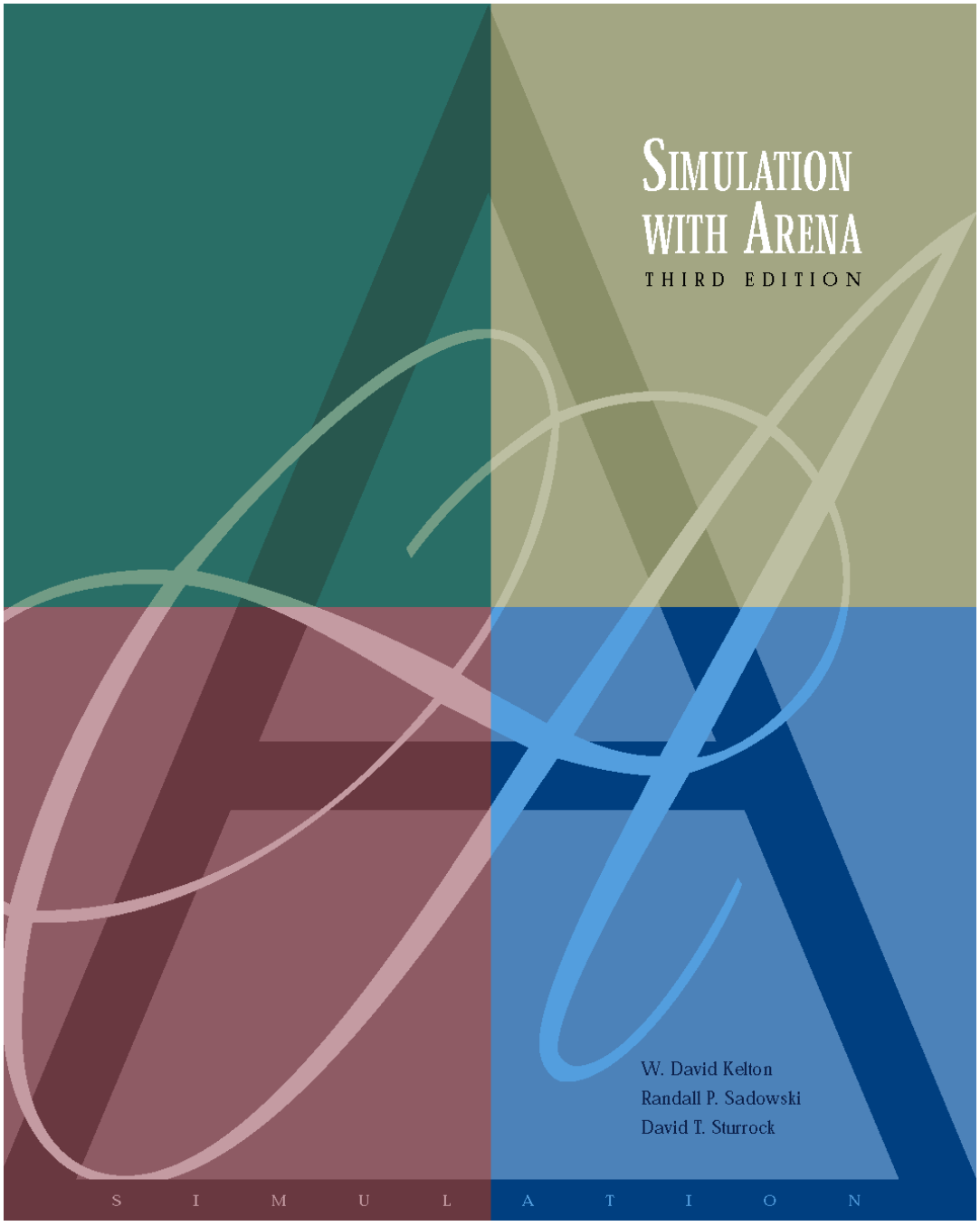


Continuous and Combined Discrete/ Continuous Models

Chapter 11

Last revision July 21, 2003

What We'll Do ...

- What is a continuous system?
- Simple linear continuous systems
- Combined discrete/continuous systems
- Non-linear and complex systems

Continuous Systems

- **Discrete systems – State changes occur at isolated points in time called events**
- **Continuous systems – State changes may occur continuously over time**
  - Flow of fluids and fluid-like materials
  - Temperature changes
  - Chemical operations
  - Biological processes

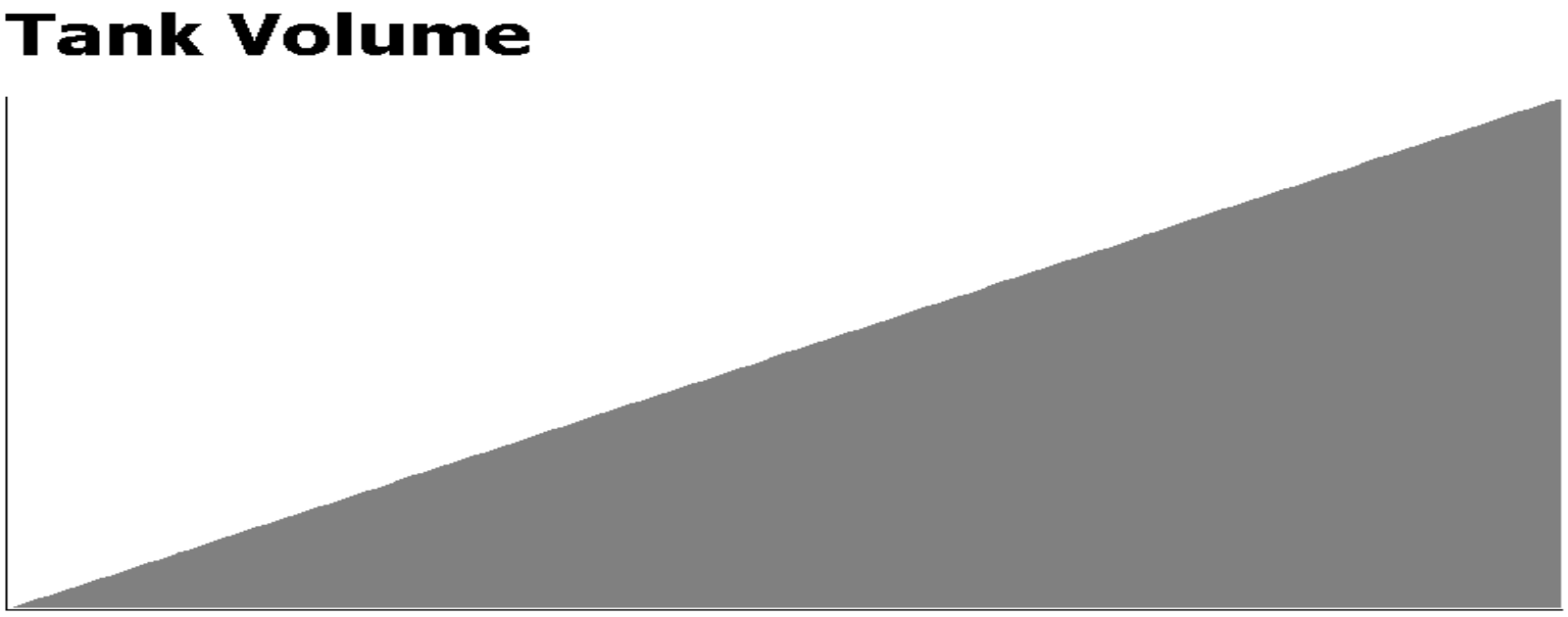
Continuous Systems

- **Simple systems (linear)**
  - Rate of change is constant between events
  - Future value can be calculated from starting value and rate
  - Can step directly to calculated event
- **Complex systems (non-linear)**
  - Rate of change may depend on other continuous processes
  - Specialized approaches used to capture change
  - Approximates continuous change by making a series of small steps between the usual discrete events

Continuous Systems

- **Example of simple continuous system filling a tank smoothly over time**

Levels	Rates	Continuous
Tank Volume	Tank Input Rate	



Continuous Systems

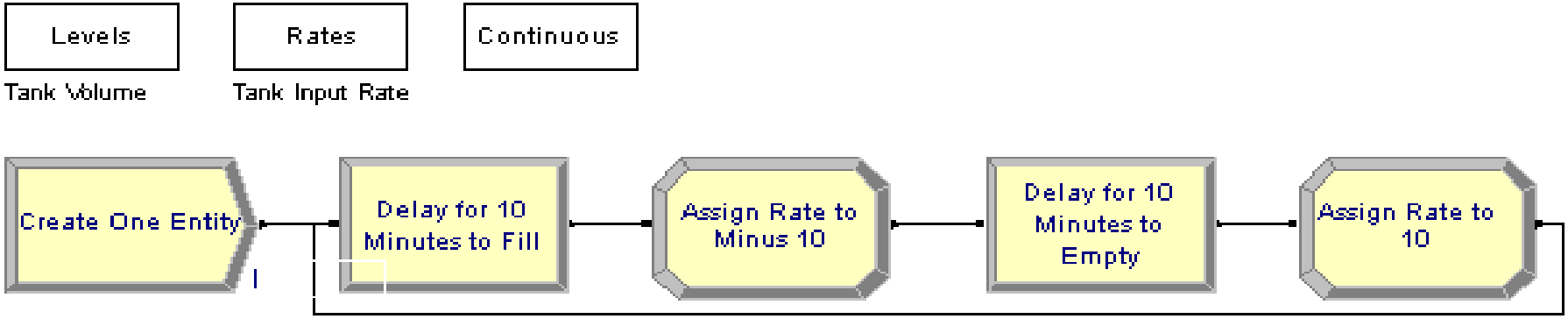
- **Basic constructs:**
  Levels & Rates from Elements Panel
- **A Level is the value that is changing over time**
- **A Rate determines the rate of change of the level**
- **Both are similar to Variables in that they can be assigned a new value at any time.**
- **Levels may also change as time advances if the value of the associated Rate is non-zero.**
- **A Level and a Rate should be used as a pair**
  (e.g. If you have 4 Levels you should have 4 Rates)

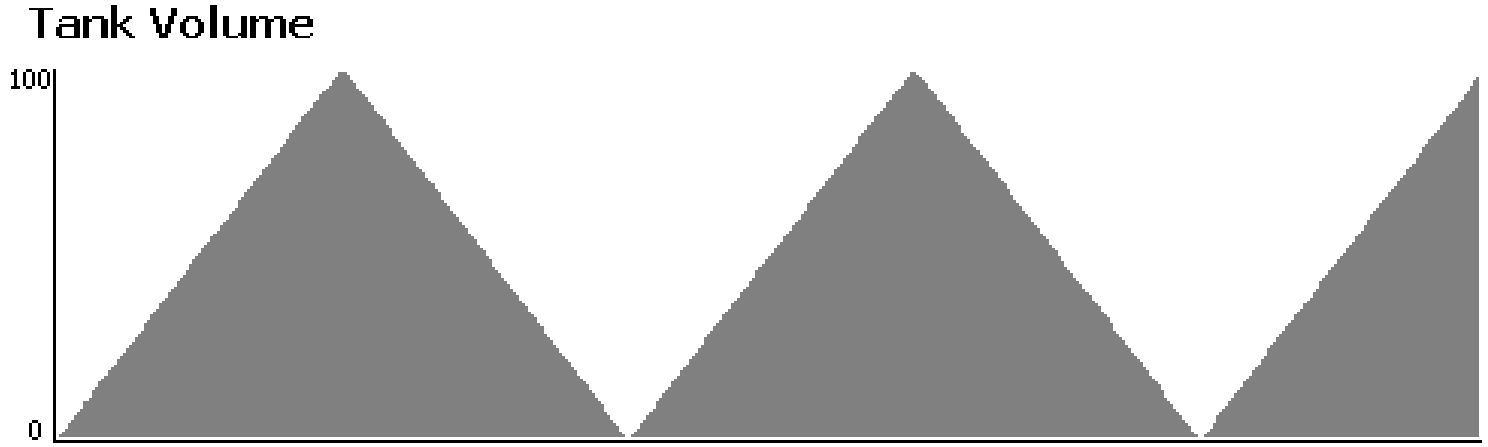
Simple Continuous Systems

- **Continuous Element specifies integration parameters:**
  - Number of Dif Equations – In simple systems, leave at default of number of Rate/Level pairs.
  - Number of State Equations – Ignore in simple systems.
  - Minimum step size – The minimum time advance between integration steps. Use 0.0 in simple systems.
  - Maximum step size – The maximum time advance between integration steps. Use a high value (100) in simple systems.
  - Save Point Interval – The maximum time between save points for recording continuous statistics (CSTATS).
  - Method – Use Euler linear algorithm for simple systems.

Simple Continuous Systems

- **Discrete control loop to empty and refill a tank**



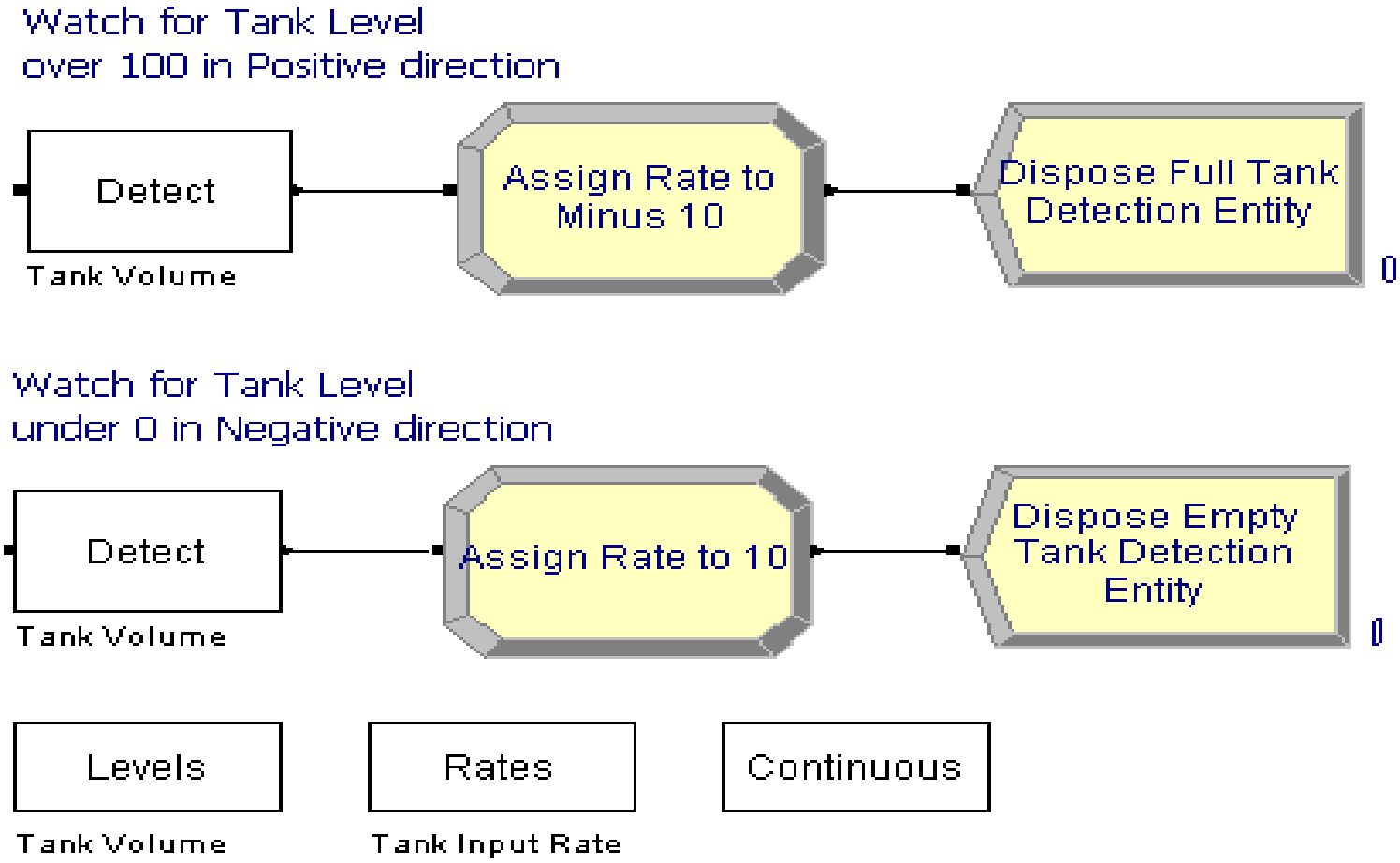


Combined Discrete/Continuous

- **Detect Module from Blocks panel "watches" for and helps predict events.**
- **Watches for value of a variable to cross a threshold value (e.g. a tank level reaching its maximum value)**
- **Similar to Create Module in that an entity is created when crossing occurs.**

Combined Discrete/Continuous

- **Fill and empty logic using Detect modules**



Complex Systems

- Non-linear systems require special algorithms like Runge-Kutta-Fehlberg (RKF).
- Step sizes must be set carefully.
- Smaller step size will generate more accurate results because Arena will calculate continuous-change variables more often.
- Larger step size will run faster, but your error tolerances will need to be set higher.
- Many situations (like a gravity fed tank) are actually non-linear, but can be accurately approximated with faster, linear methods.