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Discrete Event Simulation Using AnyLogic

SYS-611: Simulation and Modeling

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Agenda

1. Introduction to AnyLogic
2. Queuing System Model
3. Inventory System Model
4. Factory System Model

Reading: *AnyLogic in Three Days: Modeling and Simulation Textbook*

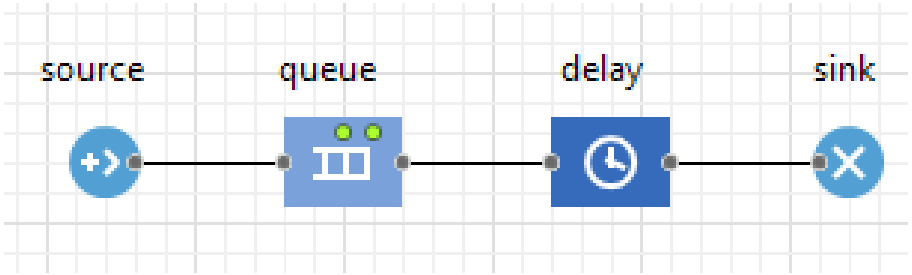
Introduction to AnyLogic

AnyLogic Overview

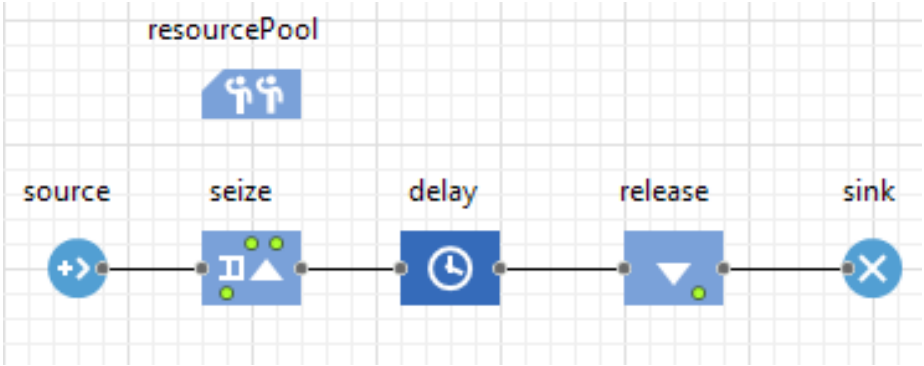
- **AnyLogic** is a multi-method simulation platform for models using any of the following formalisms:
  - Discrete Event Simulation
  - Agent-based Simulation
  - System Dynamics
- Uses Java under the hood and for customization
- Commercially licensed (some limitations apply)
- Free "Personal Learning Edition" available online:
  - https://www.anylogic.com/downloads/personal-learning-edition-download/

AnyLogic Process Modeler

- Click-and-drag common process components:
  - Sources
  - Queues
  - Delays
  - Sinks



- And more complex process components:
  - Resource pools
  - Seizing resources
  - Releasing resources

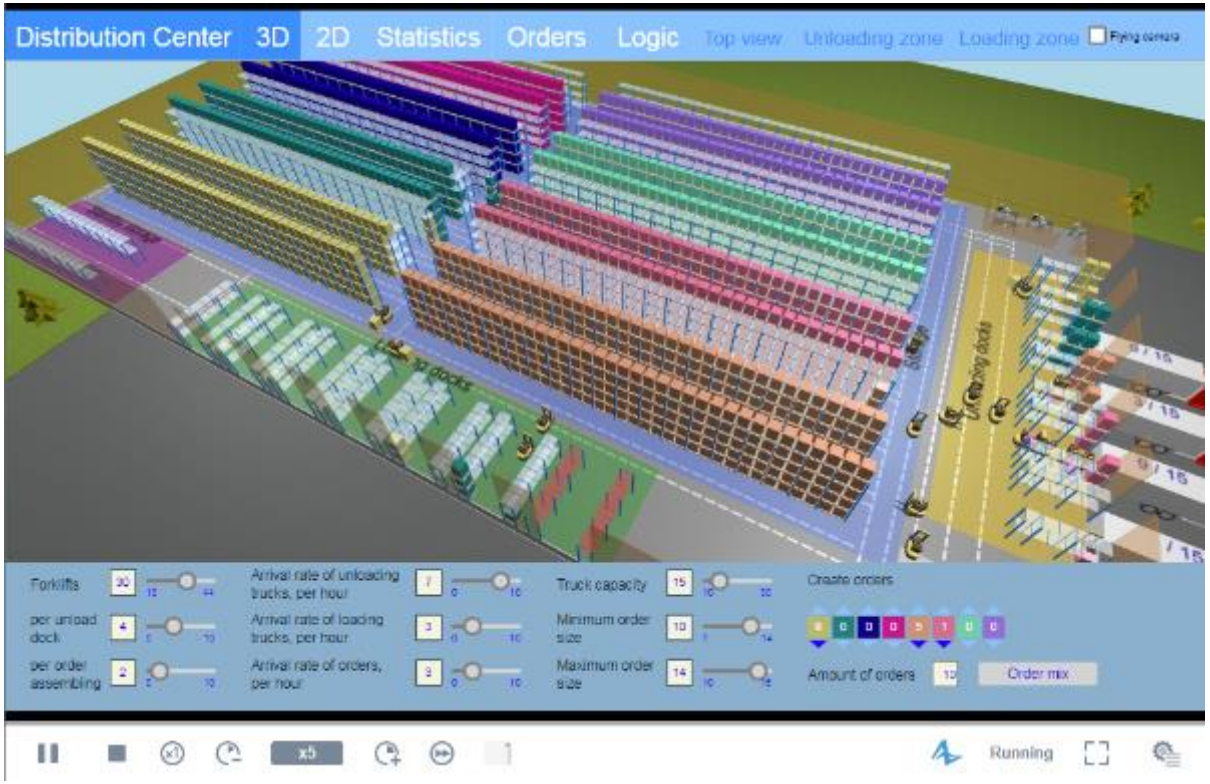


AnyLogic Agent Modeler

- Click-and-drag common “agent” components:
  - **Parameters**: scalar state variables (typically inputs)
  - **Variables**: more flexible state variable (typically outputs)
  - **Functions**: state transitions / updates
    - Note: typically have to program in Java language
  - **Events**: when to trigger functions
    - Automatic on constant timeout schedule or manually scheduled

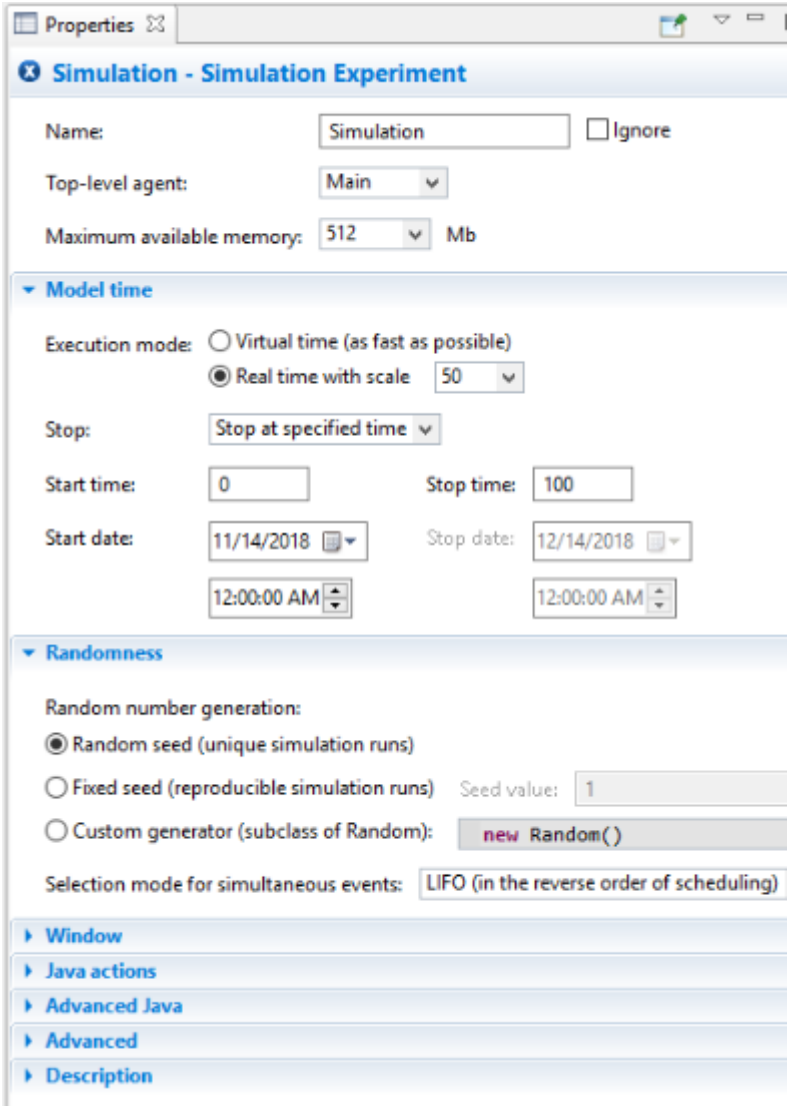
AnyLogic Graphical Interface

- Quickly add charts/plots/datasets to record data
- Capabilities for 2D/3D visualization



Simulation Experiment

- Control simulation settings
- Model time
  - Virtual or scaled real time
  - Terminal condition
- Randomness
  - Random seed
  - Fixed seed



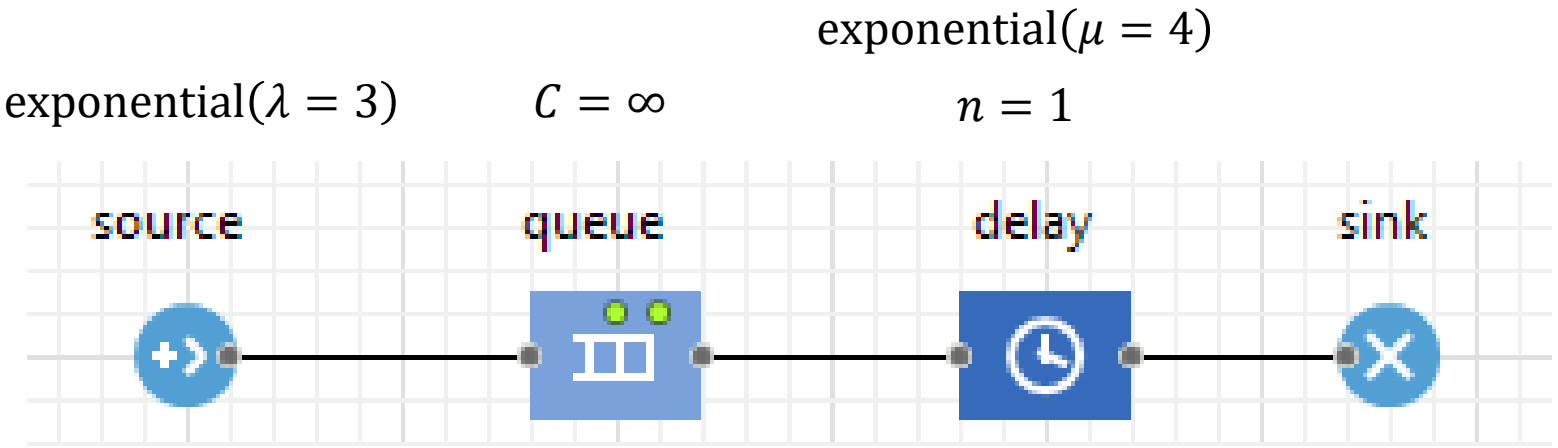
AnyLogic Caveats

- Very comprehensive/complex software package
- Java programming is required for custom models
- Personal Learning Edition (PLE) is limited
  - No Monte Carlo / optimization / sensitivity analysis
  - Limitations on size/scope of simulation models
- Commercially licensed, proprietary
  - All modeling must be done within AnyLogic environment
  - Cannot export models without special license ($$$)

AnyLogic Example: Queuing Model

Queuing System "Process"

- Queuing system specification:
  - $n = 1$ server, $C = \infty$ queue capacity
  - Customer inter-arrival period $x \sim \text{exponential}(\lambda = 3)$
  - Service time $y \sim \text{exponential}(\mu = 4)$

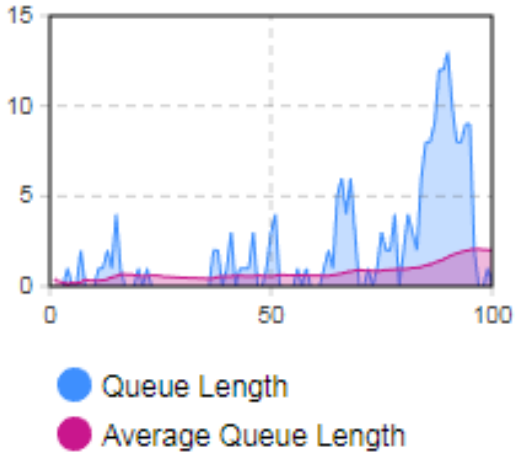


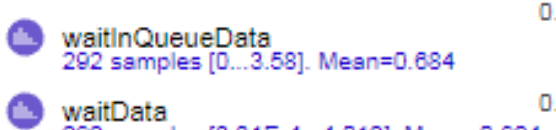
Queuing System Visualization

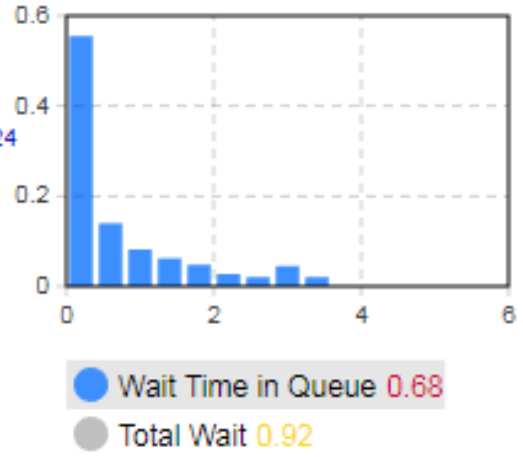
- Plots: **`queue.size(), queue.statsSize.mean()`**
- Histograms: **`waitInQueueData, waitData`**
  - Add agent parameter **`enterSystem`**
  - Log data using event actions:
    - Source on exit: **`agent.enterSystem = time();`**
    - Queue on exit:
      `waitInQueueData.add(time() - agent.enterSystem)`
    - Sink on enter:
      `waitData.add(time() - agent.enterSystem)`

Queuing System Outputs

Counts of enter/exit from each block







Time Series Plots

Histograms

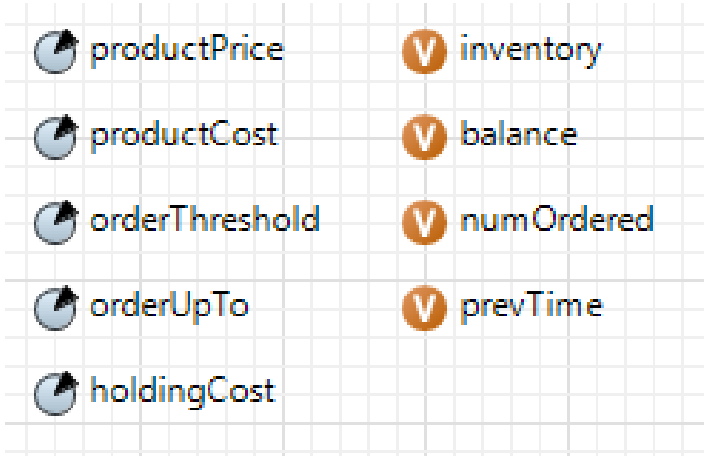
AnyLogic Example: Inventory Model

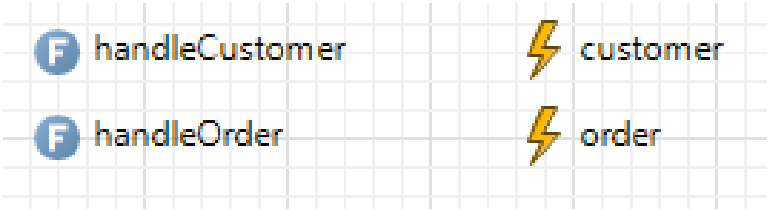
Inventory System Model

- Inventory system specification:
  - Sell products for $r = 100$ (can only sell those in stock)
  - Customer inter-arrival period $d \sim \text{exponential}(\lambda = 5)$
  - Each customer demands $D \sim \text{uniform}(1,4)$ products
  - Order policy (Q, S): if inventory is $x < Q$, order $y = S - x$
  - Costs $c(y) = 50y$ to order y units
  - Delay of $L = 2$ days until delivery
  - Holding cost of $h = 2$ per item per day

Inventory System "Agent"

- Model state:
  - **Parameters**: product price, product cost, holding cost, order threshold (Q), order up to quantity (S)
  - **Variables**: Inventory, balance, number ordered, previous time
- Model behavior:
  - **Functions**: handle customer, handle order
  - **Events**: customer, order (both manually triggered)





Handle Customer Function

```
balance -= holdingCost*inventory*(time() - prevTime);
prevTime = time();
int demand = uniform_discr(1,4);
int numSold = 0;
if(inventory > demand) {
  numSold = demand;
} else {
  numSold = inventory;
}
balance += productPrice*numSold;
inventory -= numSold;
if(inventory < orderThreshold && numOrdered == 0) {
  numOrdered = orderUpTo - inventory;
  balance -= productCost*numOrdered;
  order.restart();
}
customer.restart(exponential(5));
```

Inventory System Outputs

productPrice
100

productCost
50

orderThreshold
10

orderUpTo
30

holdingCost
2

inventory
16

balance
34,829.512

numOrdered
0

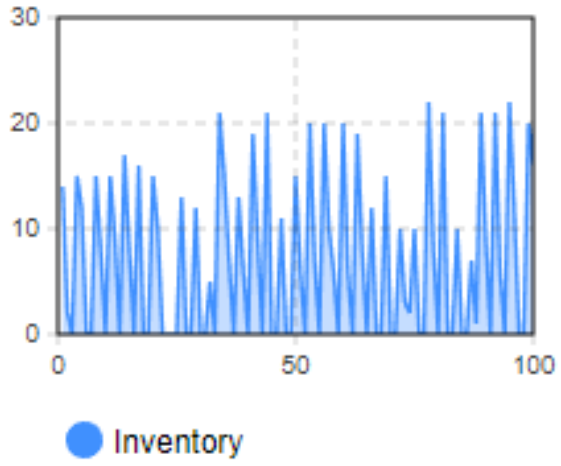
prevTime
99.684

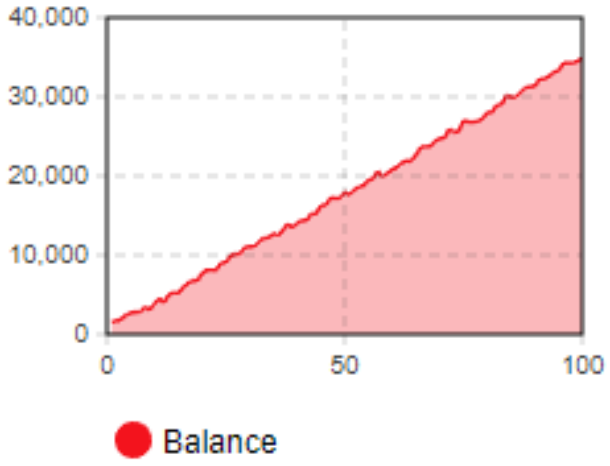
handleCustomer

handleOrder

customer
0.223

order





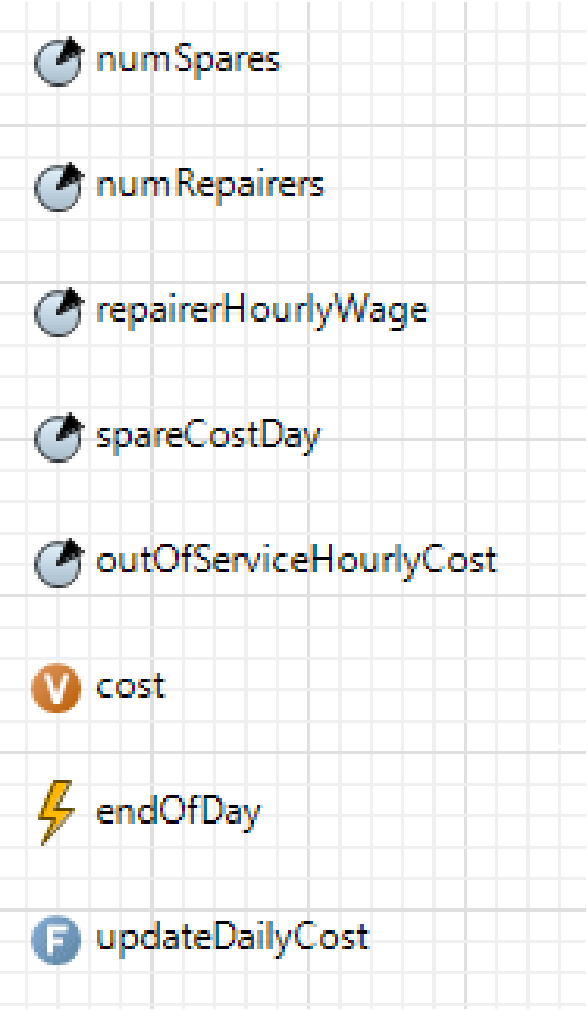
AnyLogic Example: Factory Model

Factory System Model

- Factory system specification:
  - $n = 50$ machines working 8 hours/day, 5 days/week
  - Each fails randomly after $d \sim \text{uniform}(132,182)$ hours
  - Immediately replace with spare when available
  - Repairer fixes failed machine in $r \sim \text{uniform}(4,10)$ hours, returns to spares
  - Hire R repairers at $3.75/hour
  - Purchase S spares at $30/day
  - Costs $20/hour/machine if out-of-service (no spares)

Factory System "Agent"

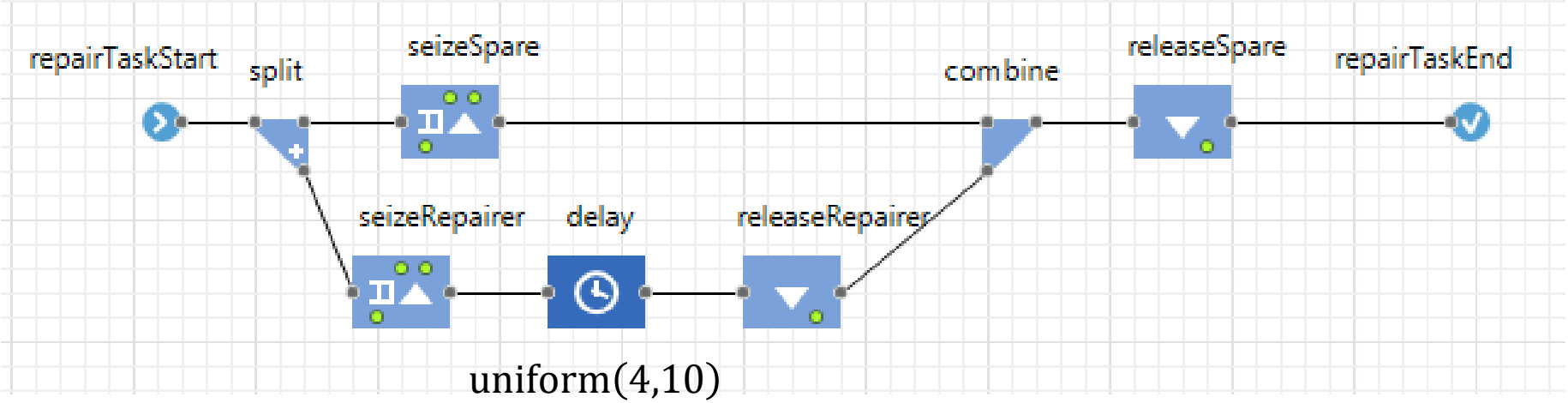
- Model state:
  - **Parameters**: number spares (S), number repairers (R), hourly wage, spares cost, out-of-service cost
  - **Variables**: total cost
- Model behavior:
  - **Function**: update daily cost
  - **Event**: end of day, triggers every 8 hours



Factory System "Process"

uniform(132,182)

- Resource pools:
  - Machines, spares, repairers
  - Machines have failure process with time between failures
- Machine pool failure flowchart
  - Tabulate cost of spare on "seizeSpare" process



Factory System Outputs