Computer Simulation

Module 5: Arena

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The Joy of Sets

Lesson Overview

Last Lesson: Talked about the Blocks template, which we'll occasionally use to help with specialized little issues.

This Lesson: What are sets, and how do they enhance our modeling ability?

Idea: We'll especially concentrate on resource sets.

Sets

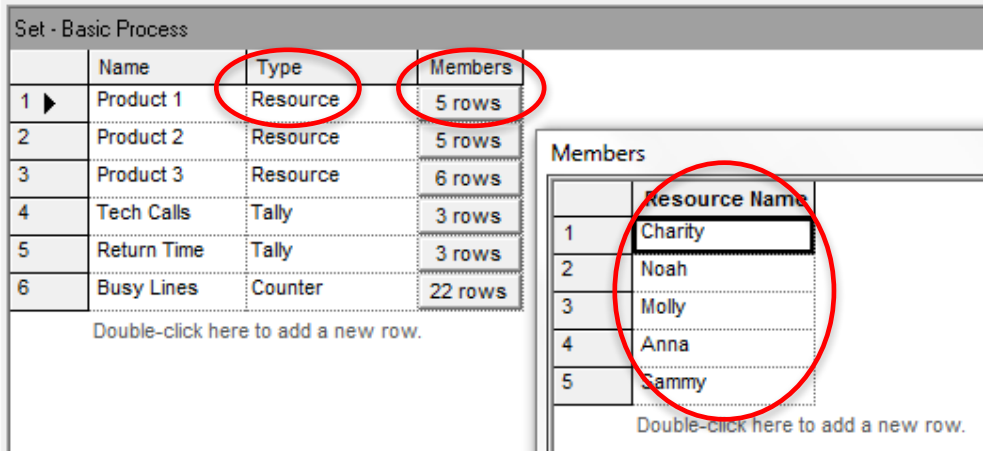
- As in baby math class, a set is just a group of elements. Elements are allowed to belong to more than 1 set.
- “Elements” can mean a lot of things in Arena, and so there are various types of sets:
  - Resource (e.g., a set of servers)
  - Counter
  - Tally
  - Entity Type
  - Entity Picture
  - …and tougher stuff later

Resource Sets

- Use the Set spreadsheet in the Basic Process template to define sets.
- We'll just study resource sets for now.
- A "vanilla" resource has identical, interchangeable servers. But a resource set can have distinct servers, with different schedules, service speeds, service specialties, etc.
- Call Center Example: Three products with the following resources
  - Product 1: Charity, Noah, Molly, Anna, Sammy
  - Product 2: Tierney, Sean, Emma, Anna, Sammy
  - Product 3: Shelley, Jenny, Christie, Molly, Anna, Sammy
  - Molly, Anna, and Sammy all have degree of cross-functionality.
  - All 11 servers turn out to have different schedules (more on that later)

Resource Sets

- To define the resource set Product 1, choose Type = Resource, click in Members, then enter Product 1's servers under Resource Name.



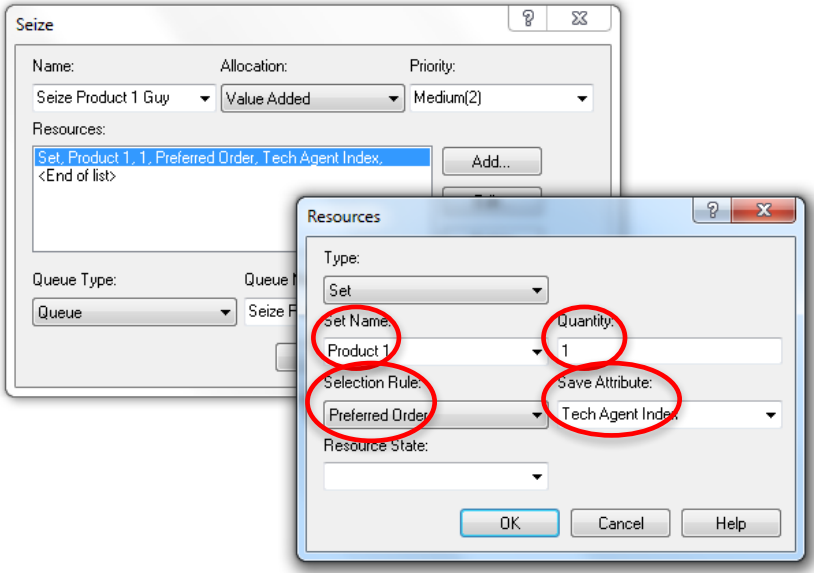
- Product 1's "Preferred Order" is to try Charity first. If she's not available, try Noah. Save Sammy for last because he's cross-functional. Other orders are possible.

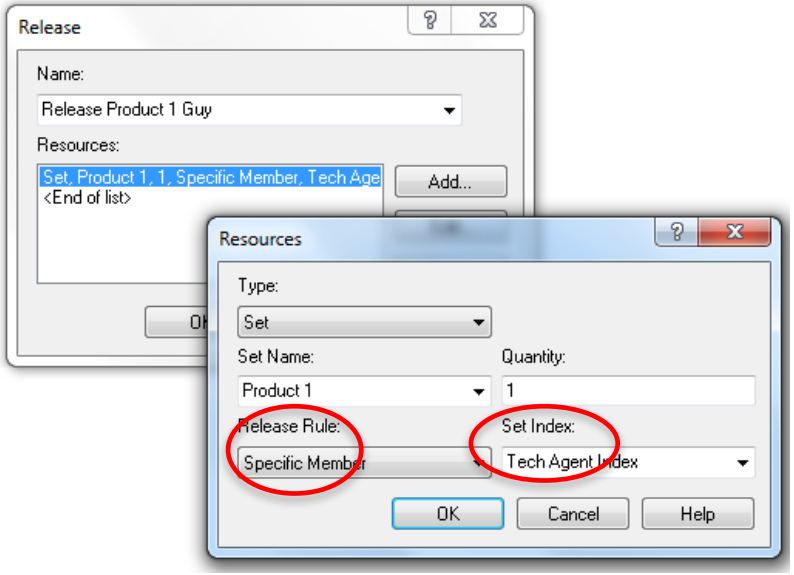
Seize-Delay-Release

- Have to be a little careful with Seize-Delay-Release for a resource set.
- The problem is that you have to make sure that you Release the same guy that you originally Seize'd. (If you release a random server, some other customer may lose his server!)

- Let's Seize a server from the set Product 1 in Preferred Order. Make sure we remember who it is. Then when we're done, Release that same guy.

Seize-Delay-Release (cont'd)





- Seize Quantity = 1 guy from the set Product 1 in the Preferred Order. Save the "name" of that server in the customer's Save Attribute called Tech Agent Index.
- Later, Release that Specific Member stored in Tech Agent Index.

Remarks

- Various Seize Selection Rules are possible:
  - Cyclical
  - Random
  - Preferred Order
  - Specific Member
  - Largest Remaining Capacity
  - Smallest Number Busy
- This stuff will be very useful when we do our Call Center example.
- Demo Time! A simple model with 4 servers.

Summary

This Time: How joyful! We introduced sets, especially resource sets. Then we showed how to use Seize-Delay-Release with such sets.

Next Time: We'll describe in Plain English the Call Center example that seems to be all the rage these days.

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Description of Call Center Example

Lesson Overview

Last Lesson: Mainly discussed resource sets, and how to use Seize-Delay-Release with them. Have to be a little careful. 

This Lesson: What we've all been waiting for! Let's start describing the Call Center example.

When we're done with this, you can be consultants!

Call Center Description

Program is arranged in submodels.

- Create and Direct Arrivals
  - How often do calls show up and where do they go?
- Tech Support Calls
  - What kind of tech support do you need?
- Returned Tech Calls
  - Sometimes the guy has to get back to you.
- Sales Calls
- Order Status Calls
- Time Period Counter – What ½-hour period of the day is it?

Arrivals

Calls show up according to a nonhomogeneous Poisson process.

- The center accepts calls from 8:00A till 6:00P.
  - The arrival rates change every half hour (see table below from KSZ).
  - Also see Arrival Schedule in the Basic Process Schedule spreadsheet.

Time	Rate	Time	Rate	Time	Rate	Time	Rate
8:00 – 8:30	20	10:30– 11:00	75	1:00– 1:30	110	3:30– 4:00	90
8:30– 9:00	35	11:00– 11:30	75	1:30– 2:00	95	4:00– 4:30	70
9:00– 9:30	45	11:30– 12:00	90	2:00– 2:30	105	4:30– 5:00	65
9:30– 10:00	50	12:00– 12:30	95	2:30– 3:00	90	5:00– 5:30	45
10:00– 10:30	70	12:30– 1:00	105	3:00– 3:30	85	5:30– 6:00	30

← These rates are per hour (even though time intervals are 30 min)

- A few staff actually stay at work until 7:00P, in order to let the calls at the end of the day clear out. (You have to explicitly model 0 arrivals for the last two half-hour segments of the Arrival Schedule.)

Phone Lines

There are 26 phone lines. If you get a busy signal, you balk and get killed off.

- Use a Queue block with capacity 0 to try to Seize a line. If the Seize fails, there's no place to go in the Queue, and out you go.
- The Queue and Seize both come from the Blocks template panel. This is the only place where you can get a Queue block, and it only connects to this kind of Seize. (Recall that you can also use a Seize within a Process module in the Basic Process template, and there's another Seize in the Advanced Process template!)

Types of Calls

There are 3 general types of calls, which we'll handle with an "N-way by Chance" Decide module. Each customer hears a recording for a UNIF(0.1,0.6) amount of time, while he makes his choice of call type.

- 76% go to Tech Support.
- 16% go to Sales.
  - There are 7 identical, faceless Sales guys that we'll need to schedule (but not on an individual basis).
  - Sales calls take TRIA(4,15,45).
- 8% go to Order Status.
  - Most callers can do self-service in a TRIA(2,3,4) amount of time. But…
  - 15% of customers need a Sales guy for TRIA(3,5,10).

Tech Support

There are 3 specific types of Tech Support calls (which we'll again handle via a Decide module):

- 25% are for Product 1.
- 34% are for Product 2.
- 41% are for Product 3.
- Each customer gets another recording for a UNIF(0.1,0.5) amount of time, while he makes his choice.
- All Tech Support calls require staff for a TRIA(3,6,18) duration of time.

Call Backs

4% of Tech Support calls require additional investigation.

- This additional investigation is carried out by another group of staff that we won't worry about. The customer's original server is freed up when he makes the determination that more research is needed.
- The investigation takes an EXPO(60) amount of time.
- At that point, the original Tech Support guy will call the customer back using one of the 26 phone lines (but with high priority).
- That call takes TRIA(2,4,9) time.

Tech Support Info

Tech Support staff have some interesting issues.

- They all have 8 hr days + 30 min for lunch.
- They all have different schedules. We'll need Resource Schedules to model this on an individual basis.
- They all have different product expertise. We'll need Sets to model this. Here are the Preferred Orders for the sets:
  - Product 1: Charity, Noah, Molly, Anna, Sammy
  - Product 2: Tierney, Sean, Emma, Anna, Sammy
  - Product 3: Shelley, Jenny, Christie, Molly, Anna, Sammy

Tech Support Staff Schedules (from KSZ)

		Periods on Duty																					
Name	Products	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Charity	1	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x					
Noah	1						x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Molly	1, 3			x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x			
Anna	1, 2, 3					x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	
Sammy	1, 2, 3				x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		
Tierney	2	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x					
Sean	2						x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Emma	2				x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		
Shelley	3	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x					
Jenny	3						x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Christie	3				x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		

Summary

This Time: Gave a long, tedious verbal description of the Call Center model.

Next Time: Gigantic Demo Time! Now we get to see the Arena program in its full glory!

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Call Center

Lesson Overview

Last Lesson: Plain English description of the Call Center model, along with some Arena details (but no actual demo).

This Lesson: It's Demo Time!

Idea: We're putting together ideas from many of the recent lessons. Everything from fake customers to resource sets.

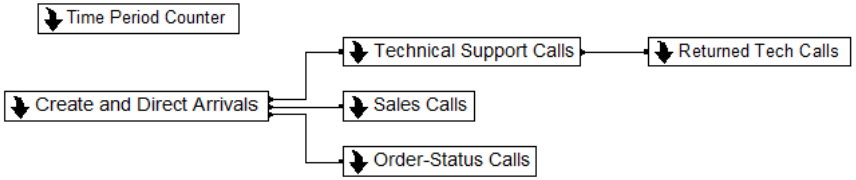
Be On The Lookout

As we go thru the model, keep an eye out for some interesting things…

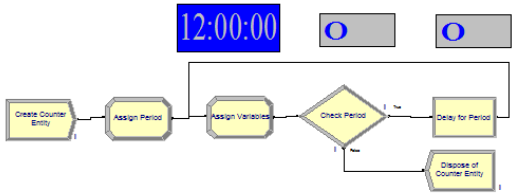
- Submodels
- Fake customers used as timers
- Use Queue with capacity 0 to kick out callers getting busy signal
- NHPP arrivals
- 3 resource sets for Tech Support
- Tricky Seize-Delay-Release
- Quirky callback procedure

Demo Time!

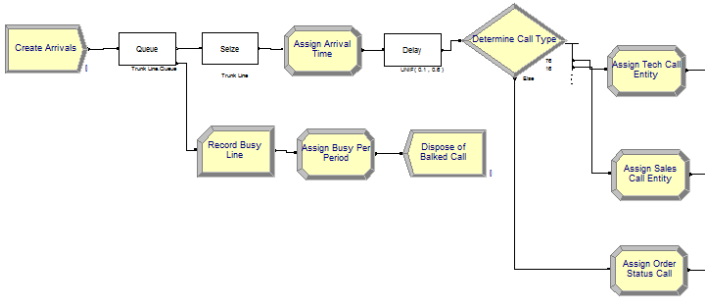
Top-Level View



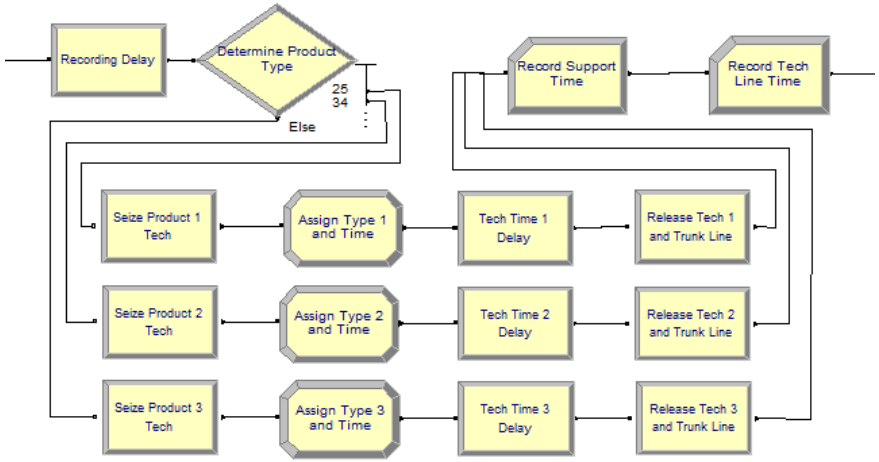
Time Period Counter



Arrivals Submodel



Tech Support Submodel



Summary

This Time: We put together a lot of stuff and finally demo'd the Call Center example in all of its radiant glory.

Next Time: We'll describe an Inventory system in Plain English before doing an analogous demo.

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An Inventory System

Lesson Overview

Last Lesson: Call Center simulation demo.

This Lesson: Plain English description of simple Inventory system and then a demo.

The Next Few Lessons

We'll now look at several demos.

- An Inventory Model ← now
- One Line vs. Two Lines?
- A Re-entrant Queue
- SMARTS files and Rockwell demos
- A Manufacturing System (with transporters, conveyors, …)

Description of (s,S) Policy

- Simulate the widget inventory stock over time.
- Use modules from the Basic and Advanced panels.
- Customer interarrivals are EXPO(0.1).
- Demand size is a DISC function.
- Demand is always “met” (backlogged, if necessary).
- Inventory is “taken” at the start of each day.
- If inventory is below s, we order up to S.
- Delivery lead time is UNIF(0.5,1) before order arrives (pretty quick, but by the time it arrives, other customers will have arrived).
- Order costs (set-up + incremental), holding costs, penalty costs.

Description (cont'd)

- Calculate average total cost per day over 120 days.

- Inventory, unit costs, and all of the other parameters are variables.
- Inventory is decremented by demands, incremented by orders.
- Interarrival times, demands, lead time, are expressions from Advanced Process template.
- Accumulated costs are calculated in the Statistic spreadsheet in the Advanced panel.
- Daily inventory review is conducted by a "fake" customer.

Demo Time!

Summary

This Time: Discussed and demo'd a nice little (s,S) inventory policy.

Next Time: One Line, Two Lines, Red Line, Blue Line?

https://www.youtube.com/watch?v=yauPbZKzChs

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One Line vs. Two Lines?

Lesson Overview

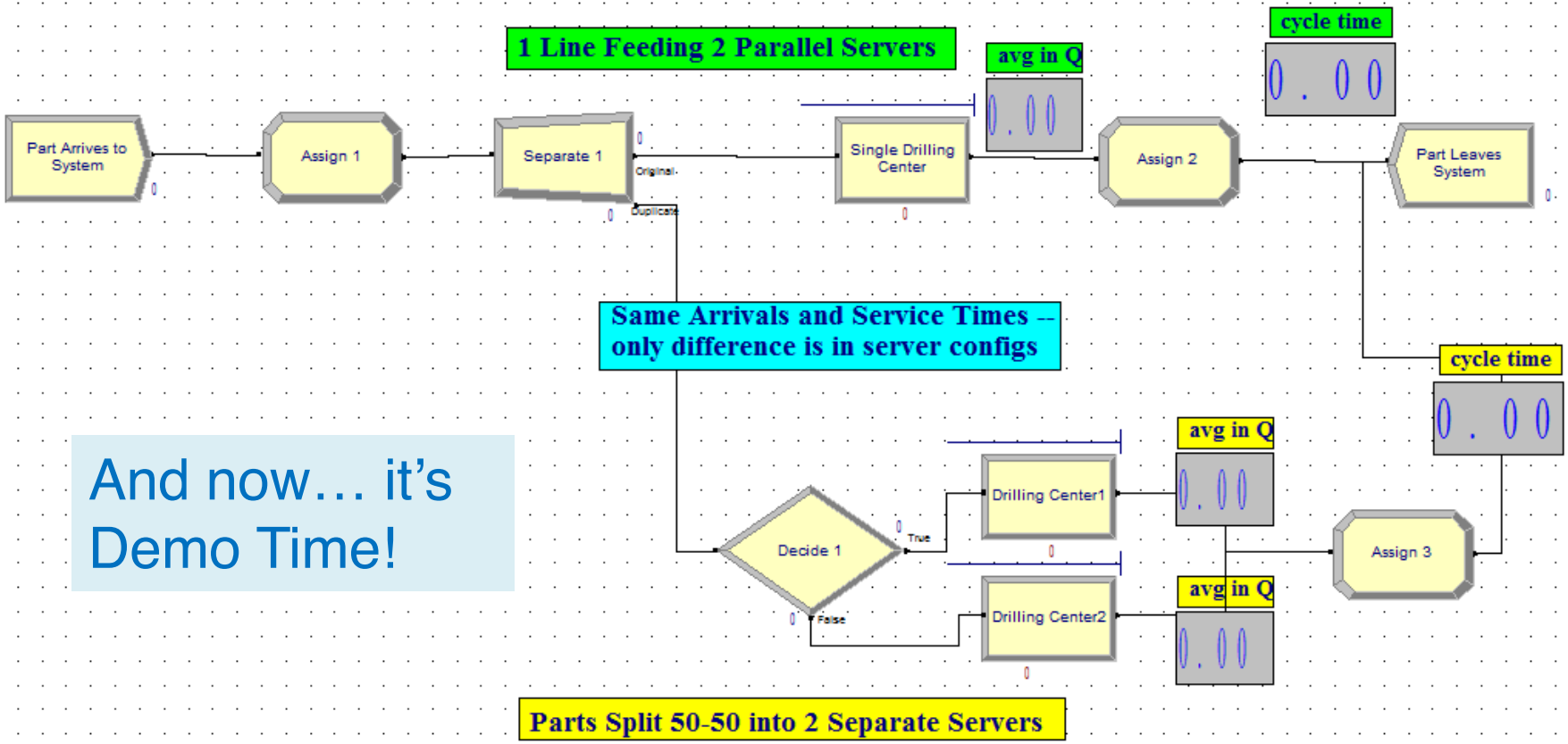
Last Lesson: We worked on an (s,S) inventory policy example.

This Lesson: Should we use one line feeding into two parallel servers or separate lines feeding into two individual servers?

Idea: We'll use a very cool trick called common random numbers to do an apples-to-apples comparison.

Game Plan

- Option A: Customers show up and join one line in front of two identical servers. They go to whichever server is available first.
- Option B: Customers randomly choose which of two lines (in front of single servers) to join.
- Will compare which of A or B is better by using:
  - The exact same customer arrivals (thanks to a Separate module), and
  - The same service times for a particular customer whether or not he's doing A or B (thanks to an early Assign module).
- Almost certainly, Option A is better (why?)
- Matching up the arrival and service times makes things easier for us statistically. "Common Random Numbers"



And now… it's Demo Time!

Summary

This Time: Used Arena to compare two different server configurations for a simple queueing system.

Next Time: We'll look at a kraaAaZy re-entrant queueing system. Very non-intuitive, very kool. Simulation was the first way people used to analyze these things.

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A Crazy Re-entrant Queue

Lesson Overview

Last Lesson: We compared different queueing strategies – one line vs. two lines.

This Lesson: A more-interesting system – a re-entrant queue.

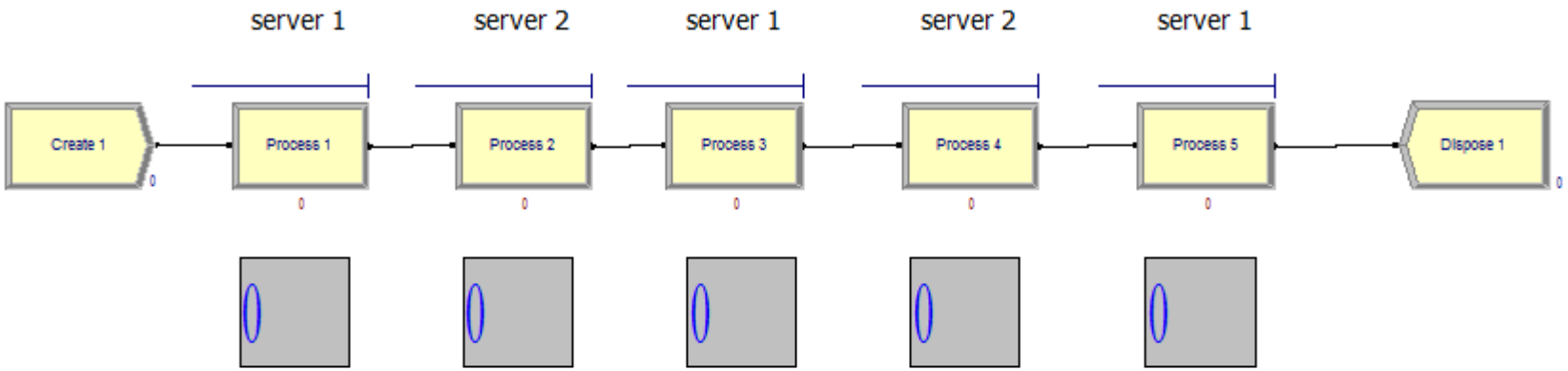
Idea: If you re-use servers and mess around with priorities, you can get some pretty non-intuitive outcomes!

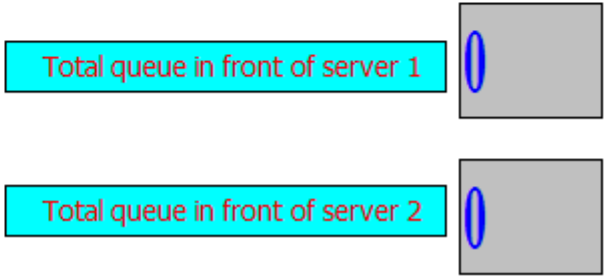
Re-entrant Queues

- Customers go to Server 1, then to Server 2, then back to Server 1, back to 2, and finally back to 1. That is, 1 → 2 → 1 → 2 → 1.
  - These returns are why we call the queues "re-entrant".
  - They're depicted in Arena as 5 separate Process modules with Seize-Delay-Release trios. (It's OK to Seize the same server in different Process modules.)
- This seems like a perfectly boring model. Let's make it interesting.
  - All service times are exponential. Here are the means:

    1 (0.1) → 2 (0.5) → 1 (0.1) → 2 (0.1) → 1 (0.5)
  - …and the customer priorities:

    1 (low) → 2 (high) → 1 (medium) → 2 (low) → 1 (high)
  - Thus, on the customer's 3rd visit to Server 1, he has a high-priority EXPO(0.5) service time.





Get ready for… Demo Time!

You're gonna see mind-blowing behavior!

Summary

This Time: So cool, so very cool.
Words escape me.

Next Time: We're going to get smart… literally!

SMARTS files! ☺

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SMARTS and Rockwell Files

Lesson Overview

Last Lesson: Re-entrant Q's and phenomenal behavior!

This Lesson: Rockwell has hidden away some beautiful little gems: SMARTS files and demos.

Idea: These make great bedtime reading.

SMARTS + Rockwell Demos

- SMARTS: Very nice tutorial files organized by subject area.
  - E.g., there's a SMARTS file to create customers with a time-dependent arrival rate that varies according to an equation (an expression).
  - 100s of SMARTS files
- Rockwell has also prepared many professional demos.
- Libraries > Documents > Rockwell Software > Arena
- Some Typical Examples that we'll demo:
  - SMARTS - Arrivals Varying Rate via Expression
  - SMARTS - Queues Evaluate Conditions Before Proceeding
  - Rockwell Emergency Room
  - Rockwell Mission to Mars

Demo Time!

GTx

Summary

This Time: Looked at several Rockwell SMARTS and demo files.

Next Time: We'll demo a easy-looking yet fairly sophisticated manufacturing cell, along with a couple of variations involving transporters and conveyors.

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A Manufacturing System

Lesson Overview

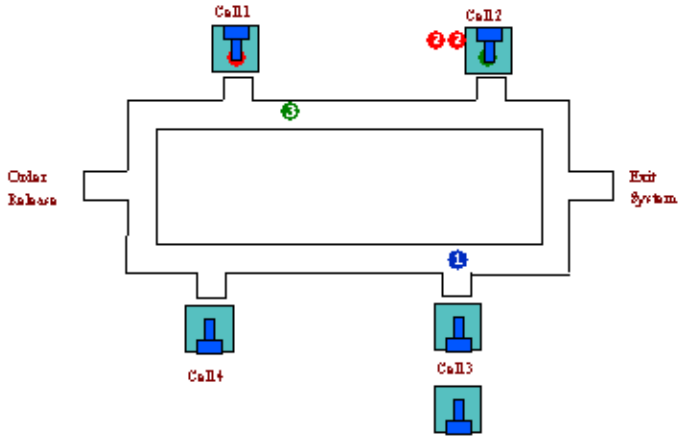
Last Lesson: Cool SMARTS and Rockwell demos.

This Lesson: We'll demo a easy-looking yet fairly sophisticated manufacturing cell, along with a couple of variations involving transporters and conveyors.

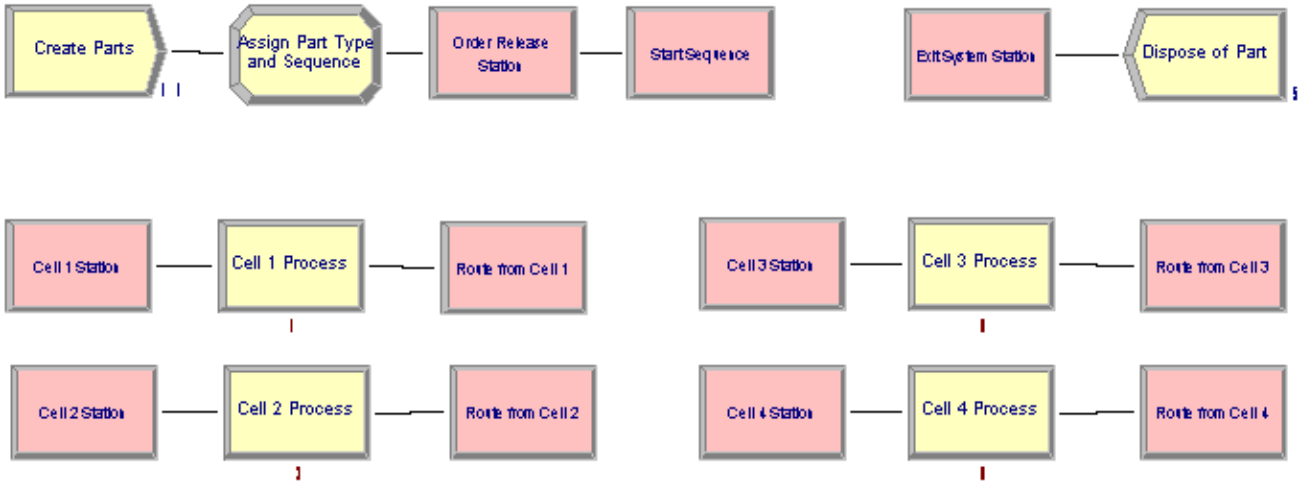
Idea: Introduce movement and multiple part paths. Extremely useful stuff that generalizes!

Description

- Manufacturing cell with 3 types of parts.
- Each part type follows a different path ("sequence") thru the system.
  - Different service times at each station (depending on part type and place in visitation sequence).
  - E.g., Part type 2's visit stations 1 > 2 > 4 > 2 > 3, each with different service times.
- Movement requires the Advanced Transfer template
  - Route, Station, Enter, Leave modules
  - Sequences spreadsheet
  - "Advanced Sets" (which is where the sequences come in).
- Parts can move in a variety of ways:
  - By themselves, transporters, conveyors.
  - Requires construction of transporter and conveyor paths


Cell1
Cell2
Order Release
Exit System
Cell4
Cell3

Demo Time!


Create Parts
Assign Part Type and Sequence
Order Release Station
StartSequence
ExitSystem Station
Dispose of Part
Cell 1 Station
Cell 1 Process
Route from Cell 1
Cell 3 Station
Cell 3 Process
Route from Cell 3
Cell 2 Station
Cell 2 Process
Route from Cell 2
Cell 4 Station
Cell 4 Process
Route from Cell 4

Summary

This Time: We did demos on a small, yet sophisticated manufacturing cell, along with some variants involving movement.

This ends our module on Arena.

- We'll still see Arena later on.
- We only scratched the surface.

Next Time: An entire module on generating Unif(0,1)'s!!!