INTRODUCTION TO ANYLOGIC®

AnyLogic® 8 PLE is a Java based simulation software that can be used to develop:

- *Discrete Event Models*: Here the process/flow chart (sequence of operation) of the system is given importance. The simulation abstracts important events of the continuous process.
- *Agent Based Models:* The simulation is individual centric. We identify the agents, their behaviour, put them in a system and run the simulation. E.g. traffic jam on a busy road, where each vehicle owner can be modelled as an agent with independent decision characteristics.
- *System Dynamics Models*: State variables, differential equations, concept of feedback/loops etc is used to model the system and then simulate it. It is a high level abstraction of the system.
- Tutorials will focus on building Discrete Event Simulation Models.
- **Feel free to use AnyLogic Help Files and the Sample Models provided to learn to build good models!**
- Each building block of AnyLogic is called an OBJECT or BLOCK.
  - Can be thought as a procedure or a function
- These objects are grouped under panels called PALETTE, positioned on left side of screen.
- The palette we will mainly use (at least in the beginning) is called PROCESS MODELING LIBRARY, and under it, BLOCKS.
- Process Modeling Library supports discrete-event, or, to be more precise, *process-centric* modeling paradigm. Using Process Modeling Library Block objects, you can model the real-world systems in terms of entities (transactions, customers, products, parts, vehicles, etc.), processes (sequences of operations typically involving queues, delays, resource utilization), and resources. The processes are specified in the form of flowcharts. AnyLogic flowcharts are hierarchical, scalable, extensible and object oriented, which enables user to model large complex systems at any level of detail.

1. Let's start playing with AnyLogic

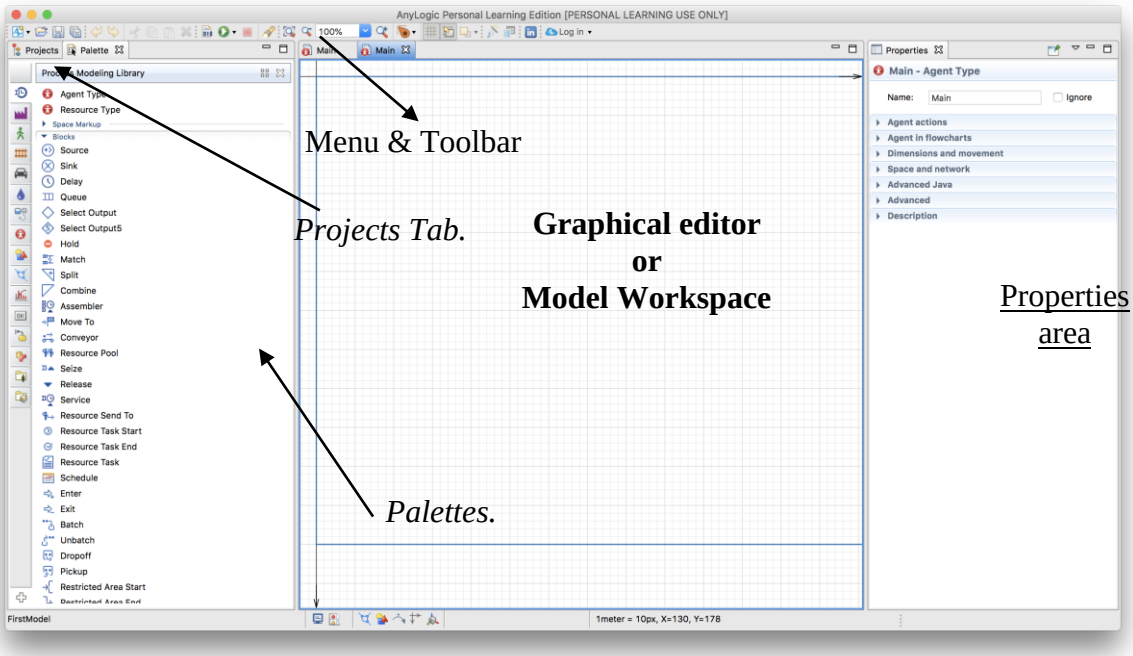
SCENARIO: Consider an ATM where customers arrive at an exponentially distributed inter-arrival time of 5 min. There is only 1 ATM. The customers spend an exponentially distributed time with a mean of 4 min once they reach the ATM. If ATM is busy, arriving customer waits in a queue. Simulate the system for 1 day.

What is the expected number & waiting time in queue?

What is the utilization of the ATM?

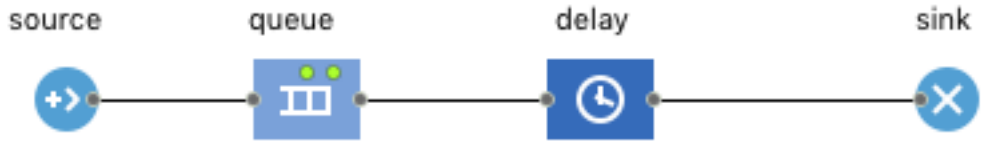
1. Open AnyLogic software. Go to menu, *File >> New>> Model*. In the dialog that opens, given model name as 'FirstModel'. Note the location where the files are stored.
   - Select Model time units as 'minutes'.
   - Click *Finish*.

- AnyLogic Model Building Environment will open.
  - **Graphical editor** is where you build your simulation model.
  - The **Palette** view (on the right) provides list of model elements grouped by categories.
  - The **Projects tab** (on the left top side) provides access to models currently opened in the workspace.
  - The **Properties** view (at the right) is used to view and modify the properties of currently selected model item(s).

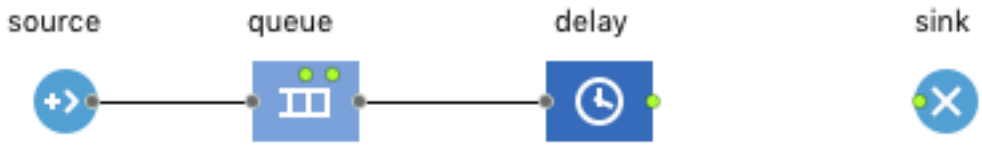


Building the Model

- Go to Process Modeling Library Palette and Blocks section.
- Click, drag & place *SOURCE, QUEUE, DELAY, SINK* into workspace.



- As you move the blocks in editor, they should automatically connect. In case, they do not connect automatically, it is Ok. We can connect them manually as follows:
  - To connect them double click on the Green Circle at end of the block (delay) then drag and click on the next block (sink) circle to join them. (The circles are called as ports)



- Single click on SOURCE, and in the Properties view of SOURCE (right side panel), do:
  - Change 'Arrivals defined by' to *inter-arrival time*
  - Change 'Interarrival time' to *exponential(0.2)* → Note that you specify the λ or rate parameter for the exponential distribution.
  - Change time units to *minutes*
- Single click on QUEUE, and in its Properties view, do the following:
  - Tick 'Maximum Capacity'
  - Tick 'Force Statistics Collection'
- Single click on DELAY, and in its Properties view, do the following:
  - Change 'Name' to *ATM*
  - Change 'Delay time' to *exponential(0.25)*, time units to *minutes*
  - Change 'Capacity' to *1*
  - Tick 'Force Statistics Collection'

- In the Projects view (left side panel), click on 'Simulation:Main'. Now, in the Properties view, click 'Model Time'. In that:
  - Select 'Real time with scale' as *10.*
  - Change 'Stop:' to *Stop at Specified Time*
  - Change 'Stoptime' to *1440* (recall, we need to simulate model for 1 day).
- In the Projects view, click on 'FirstModel'. Now, in the Properties view, see that 'Time Units' is *minutes* →this time unit is used in the entire model, unless otherwise mentioned.

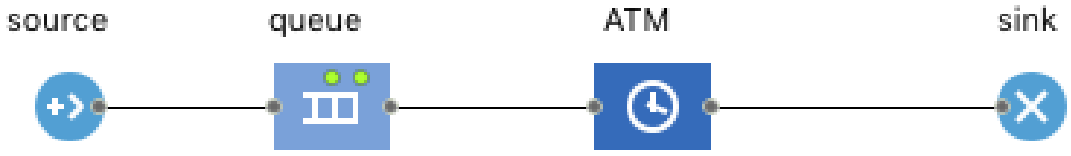
Run the model:

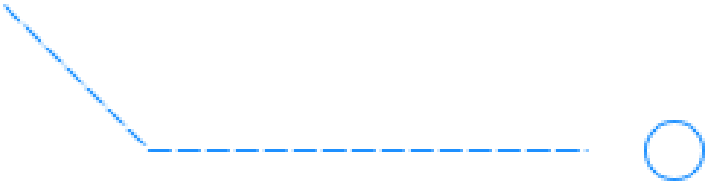
- Click from the Menu at the top of screen: Model>>BUILD
- Then click Model>>Run>>FirstModel or click PLAY button in menu bar
- In the popup window that appears, click the Play button at the bottom left of the window. You should see your model working.
  - At the bottom of the screen there are buttons to Speed up/Slow down the speed of the simulation.
  - At the bottom of the window, you can find out Blue progress bar indicating how much simulation time has progressed. (only visible when the model is run)
  - Click on the SOURCE, QUEUE, and ATM/DELAY blocks to view default dynamic statistics that are collected.
  - You will see that the *Average Number in queue* statistics is collected by default!

Congrats. You have built & run your first DES model!

2. Let's build some animation

Once done with this section, you model should look like figure below.





RESOURCE ANIMATION

- Circle shape to depict ATM machine
  - Open **Space Markup Palette**. Drag & place 'Point Node' into graphical editor are, locating it similar to figure above.
  - Now, click on the Point node circle. In its Properties view:
    - Under General, change 'Name' to *ATMnode*
    - Next to 'Color', click the *Equalt to'* sign. It will make the a text box appear. In it, enter `ATM.size()> 0 ? red : green` → If ATM is idle, then its color will be green, and if busy it will be red.
- Associate the node shape to the DELAY
  - Click 'ATM' (delay module). In its Properties view:
    - Enter for 'Agent Location' as *ATMnode*

QUEUE ANIMATION

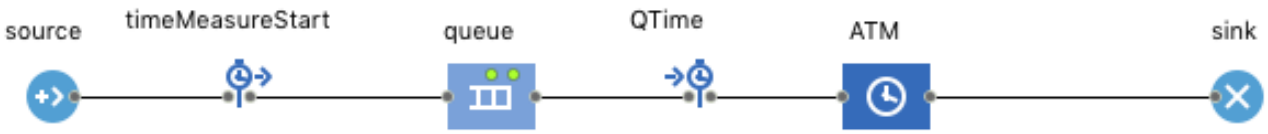
- Draw path to depict queue in front of ATM machine
  - Go to Space Markup Palette. Double click on the 'Path' (the picture of polyline will turn into a pencil)
  - In the graphical editor area, draw the line pattern from left to right by clicking , as shown in figure below. Double click to finish.
  - Now, click on the 'Path'. In its Properties view:
    - Change 'Name' to *Qpath*

- Associate the line with the queue
    - Click 'Queue' (queue module). In its Properties view:
        - Enter for 'Agent Location' as *Qpath*

Run the model, as per the steps given earlier, to view the animations. Speed up your simulation to view the animation. You will that observe that the customers are shown by default as coloured circles.

3. Let's now collect Time in Queue statistics

- Spread out your model blocks so that there is sufficient space between *Sink* and *Queue*; and space between *queue* and *ATM delay*.
- From Process Modeling Library, We shall use 'TIMEMEASURESTART' and 'TIMEMEASUREEND' blocks.
    - TimeMeasureStart as well as TimeMeasureEnd compose a pair of objects that measure the time the entities spend between them.
- Drag 'TimeMeasureStart' and Drop it on the line connecting *source* and *queue*.
- Drag 'TimeMeasureEnd' and drop it on the line connecting *queue* and *ATM delay*.
- Click on timeMeasureEnd. In its Properties view, Under General:
    - Change 'name' to *QTime*
    - Select for 'TimeMeasureStart block' as `timeMeasureStart` by clicking the Green Plus button
    - Enter for 'Dataset capacity' as `1000`
- Model to look like this.

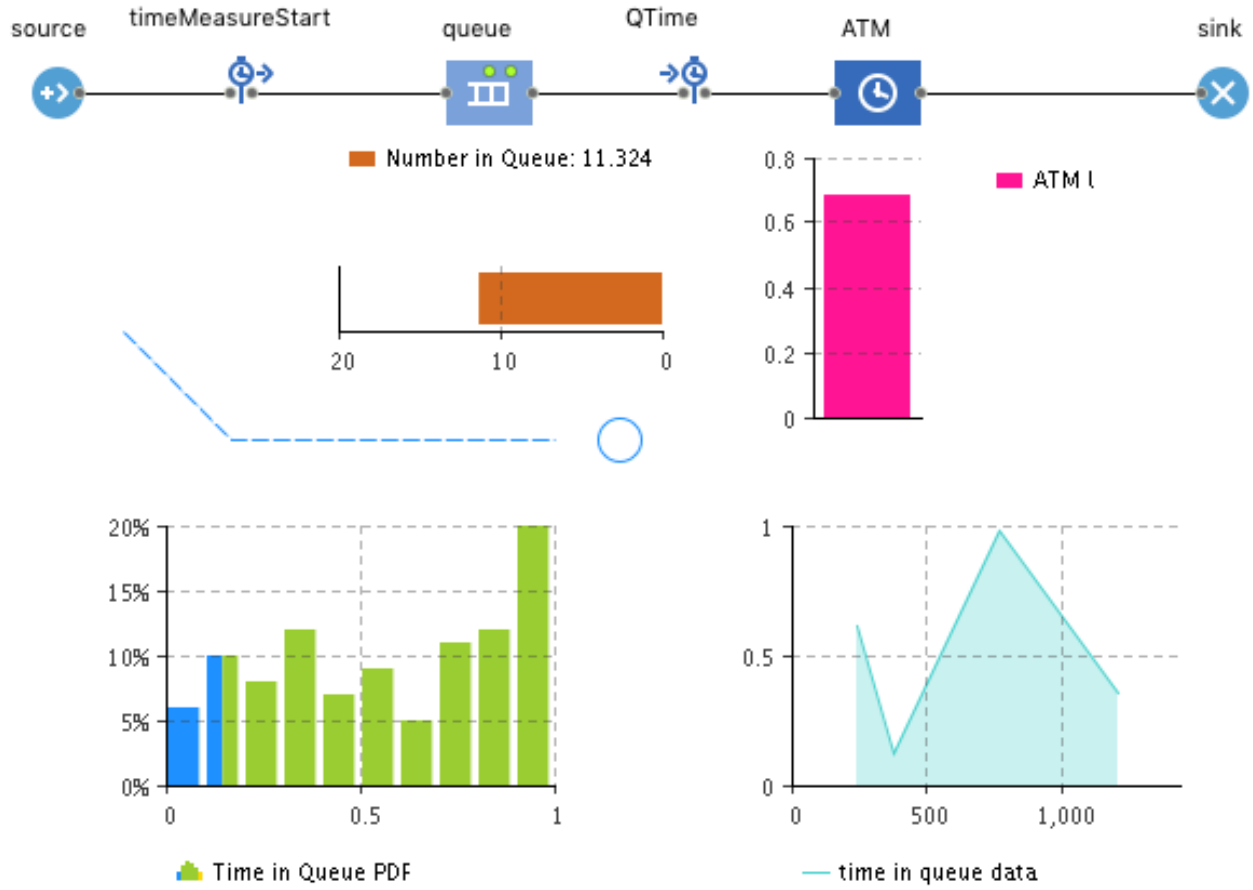


Now, Run the model, as per the step given earlier.

- During the run if you click on *QTime* you can view the time in queue statistics.

4. Let's VISUALISE the statistics

At the end of this section, your model to look like the figure below:



TO DISPLAY THE MEAN NUMBER IN QUEUE AS IT CHANGES.

- From Analysis palette, Drag & place 'Bar Chart' block in graphical editor area. (below the Queue, and resized as shown in figure above)
- Now, click on the bar chart. In its Properties view, under Data:
  - Click '+ Add data item'
  - Enter 'Title' as *Average Number in Queue*
  - Change 'Value' as `queue.statsSize.mean()`
    - Note: *statsSize* is the statistics on number in Queue that is collected by AnyLogic if the parameter forceStsiticsCollection is set to true in the queue block.
  - Under Appearance: Set Bars Direction to *Horizontal Right aligned* (4th option)
  - Under Legend: Set "Position" to *Top* (4th option)

TO DISPLAY TIME IN QUEUE OBSERVATIONS OVER TIME.

- From Analysis palette, Drag & place 'Time Plot' block in graphical editor area (bottom-right as shown in figure above)
- Now, click on the time plot chart. In its Properties view,
  - Under Data:
    - Click '+ Add data item'
    - Choose 'Data Set'
    - Enter 'Title' as *Time in Queue Data*
    - Change 'Data Set' as `QTime.dataset`
  - In Data Update section:
    - Change 'Display up to' as *1000*
  - In Scale section
    - Change 'Time Window' as `1440`

TO DISPLAY THE MEAN UTILIZATION.

- From Analysis palette, Drag & place 'Bar Chart' block in graphical editor area. (below the ATM Delay, and resized as shown in figure above)
- Now, click on the bar chart. In its Properties view, under Data:
  - Click '+ Add data item'
  - Enter 'Title' as *ATM Utilization*
  - Change 'Value' as `ATM.statsUtilization.mean()`
    - Note: *statsUtilization* is the statistics on delay utilization that is collected by AnyLogic if the parameter forceStsiticsCollection is set to true in the delay block.
  - Under Legend: Set "Position" to *Right* (3rd option)

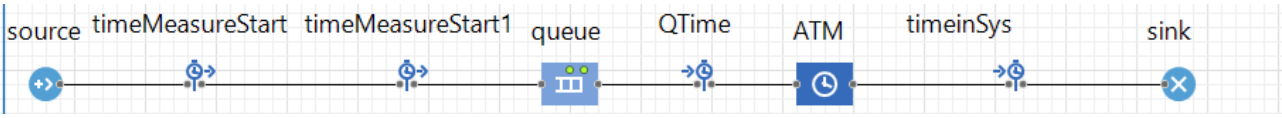
TO DISPLAY THE PDF OF THE TIME IN QUEUE OBSERVATIONS

- Open **Analysis Palette**. Drag & place 'Histrogram' element in editor area (bottom-left in figure above)
- Now, click on the historgram chart. In its Properties view,
  - Check *'Show PDF'*
  - Under Data:
    - Click '+ Add Histogram data'
    - Under 'Title', replace *'Histogram Data Title'* as *Time in Queue PDF*
    - Change 'Histrogram' as `QTime.distribution`

RUN the model, as per the steps given earlier.

5. Include Time in System statistics

At the end of this section, your model to look like the figure below:



- From Process Modeling Library, we need to insert a pair of TimeMeasureStart and TimeMeasureEnd blocks.
  - Drag 'TimeMeasureStart' and Drop it on the line connecting *timeMeasureStart* and *queue*.
  - Drag 'TimeMeasureEnd' and drop it on the line connecting *AT ATM delay* and *sink.*
  - Click on timeMeasureEnd. In its Properties view, Under General:
    - Change 'name' to *timeinSys*
    - Select for 'TimeMeasureStart block' as `timeMeasureStart1` by clicking Green Plus button
    - Enter for 'Dataset capacity' as `1000`.

- To create a chart there is a shortcut, as follows.
- Right click on *timeinSys* block (the *timeMeasureEnd* block you just created). In the pop-up menu, select ‘Create Chart’ and ‘distribution’
- You will now see a distribution chart appearing on your screen! Move it where want on the screen. Click on the chart and go to its Properties
    - Enter ‘Title’ as *Time in System PDF*
- Note that to obtain the mean time in system statistics, you can click on the *timeinSys* block during runtime. The statistics are displayed in a popup.

RUN the model, as per the steps given earlier.

6. Interesting Modelling scenarios

1. What if a total of (say) 75 customers are alone to be processed/simulated?

   Implies, **no** more than 75 entities are to be created!

   - Go to 'Source' properties.
     - Select 'Limited number of arrivals'
     - Change 'Maximum number of arrivals', as *75* → This ensures that the module does not create more than 75 entities.
   - RUN your model! See simulation results

Unselect 'Limited number of arrivals' in 'Source' Properties for subsequent scenarios

2. What if there is not enough waiting space in the queue?
   - Change Queue capacity to 7 in Queue properties (uncheck 'Maximum Capacity')
     - What should new customer do if they see a full queue?
     - What happens when more customers arrive than the model can handle?
   - **RUN your model to observe what happens…**
     - You should see that *by default* AnyLogic throws runtime error!

   When customers arrive and find that the queue is full, they should leave the system. This behavior is termed as *balking* or *preemption*. To model this:

   - Go to Properties of queue and Under Advanced, tick 'Enable Preemption'
   - From Process Modeling Library, drag & drop a 'Sink' module near queue.
   - The queue to automatically connect with the sink. If NOT: connect the TOP LEFT Green Dot from queue block to the sink.

- RUN your model again to observe what happens… The new sink module counts the number customers who leave on seeing that the queue is full.

3. Customers get frustrated after waiting in queue for sometime, and leave. How to model this?
   - Suppose customers wait time tolerance threshold is about 4 to 8 minutes. If their actual wait time is more than their threshold (they are not serviced by then), then they will leave the queue (and perhaps come some other time). To model this:
     - Go to Properties of queue:
       - Under Advanced, Tick 'Enable exit on timeout'
       - In 'Timeout' as *uniform(4, 8) minutes*
     - From Process Modeling Library palette, drag & drop another 'Sink' module near queue.
     - Connect the TOP RIGHT Green Dot from queue block to the sink
   - RUN your model again to observe what happens… The new sink module counts the number of customers who leave frustrated as their wait time is too long.

4. How do I get the different result each time I run the model?

Now, you must have seen that each time you run the model you are getting the same results. This is because you used Fixed Seed.

- In the Projects view (left side panel), click on 'Simulation:Main'. Now, in the Properties view, click 'Randomness'. In that your will see 'Fixed seed' is set at 1.
- To get different results do this: Select 'Random Seed'

Now, run the model repeatedly. You will get the different results.

5. If we have TWO ATMs to service the customers, how much will it reduce the waiting time and the % of customers who leave without using ATM? How are the ATMs' utilizations?
    - Run the existing model. Note down the results.
    - To model above scenario of 2 ATMS, we need to increase resource capacity to 2!
        - Open *ATM* (delay) block. Change 'Capacity' to *2*
    - Run and compare results with single ATM case.
    - Do we need to use 'Random seed' or 'Fixed Seed' when we run the models?

6. What if customers arrive in **batches of 2**? (e.g. customers arriving at a hotel)
    - To model this:
        - Go to Properties of 'Source'.
        - Check 'Multiple Agents per arrival'
        - Make 'Agents per Arrival', as *2*. 'Agents per arrival' is the number of customers that will enter the system at a given time with each arrival.
    - Remember to increase ATM queue capacity to say 50 or 100.
    - RUN your model! Observe simulation results

-- End of Notes --