DSL 810 (Data Driven Design)

Instructor: Dr Jay Dhariwal, Dept of Design, IIT Delhi

This handout describes discrete event simulation modelling as an application of data driven design.

What is simulation?

Simulation refers to a collection of methods to imitate the behavior of real systems, typically on a computer with the appropriate software.

What is modelled?

Simulation involves modelling of systems with applications in many different areas at many different scales. Systems can be facilities or processes, either actual or planned, such as:

- A manufacturing plant with machines, people, conveyor belts, etc.
- A bank with customers, servers, teller windows, ATMs, etc.
- An airport with departing passengers checking in, going through security check; departing flight contending for runway slots, arriving flight queues, arriving passenger waiting for their bags, etc.
- A supply chain network of plants, warehouses and transportation links
- An emergency facility in a hospital with personnel, rooms, equipment, etc.
- A fast-food restaurant with different staff, customers and equipment
- A supermarket with inventory control and checkout
- Response of emergency personnel to the occurrence of an unforeseen event
- Modelling to reduce the impact of COVID-19

A system is often studied to measure and improve its performance or design it if it doesn't exist. People may also be interested to find out how the system works.

Why simulation?

Simulation model is useful because in many cases, it can be very difficult, costly or nearly impossible to do physical studies on the system itself. For e.g.:

- One can't experiment with alternative layouts of a manufacturing plant if it hasn't been built.
- Even in an existing plant, it may be quite costly and time consuming to experiment with alternative layouts
- It may be quite hard to run extreme scenarios of say many more customers through a bank
- Messing around with the emergency room staffing in a hospital would be a no-no.

In such cases, it may be better to build a model, validate it and then carry out different scenarios to understand and optimize the system.

Computer Simulation

A mathematical model of the system is usually represented in a computer program using approximations of the real-life system. The simulation model is able to deal with very complicated systems for which traditional tools such as queuing theory, differential equations may not help. However, one needs to be careful in taking care of the uncertainty in terms of inputs to derive meaningful insights from the model.

There are different kinds of simulations.

Static vs. Dynamic: Static where time doesn't play a role.

Continuous vs. Discrete: The state of the system changes continuously in a continuous system.

Deterministic vs. Stochastic: The deterministic systems don't have any random inputs.

We would be focusing on discrete event dynamic simulation which can consider stochastic inputs. A common emphasis on the use of discrete event simulations is to **model queues**. Queues can be found everywhere from manufacturing plants to hospitals to airports to banks to traffic jams, etc. Queues can be of people, parts, data, vehicles, etc. The common questions to answer for queues are:

- How to reduce the waiting times of the entities such as people in banking queues?
- How to optimize the resources such as the number of servers in a bank to balance the customer wait time and the costs to the bank?
- What is the resource utilization for a certain system?
- What should be the maximum number of people in a queue for a banking facility?

Discrete Event Simulation with Arena software

We would be using Arena software for giving a demo of discrete event simulation modeling. Arena is an industry standard worldwide for discrete event simulation software. The student version of Arena software can be downloaded from https://www.arenasimulation.com/academic/students.

Please download the "Getting Started with Arena.pdf" from the help section. Let's look at animated examples of the applications of discrete event simulations.

- Airport Security Line
- Bank Kiosk Example
- Emergency Department
- Public Transportation

- Home Supply Store
- Truck Assembly

We would build the model, simulation, visualization and analysis of an Airport Security Line, following the guidelines in the "Getting Started with Arena.pdf" document.

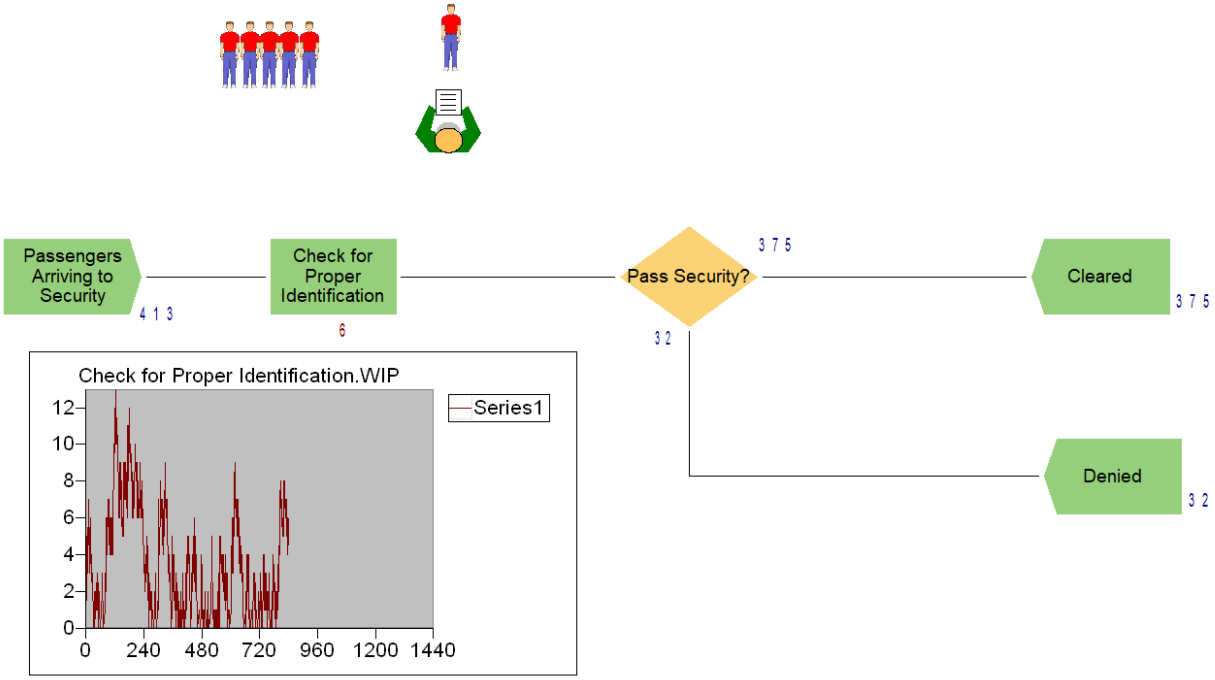

Figure: Screenshot of the Airport Security Line model

Fitting statistical distributions

The data for inter-arrival times and process times can be used to fit statistical distributions using Input Analyzer. Exponential distribution is useful for modeling inter-arrival times and normal/triangular distributions are useful for modelling process times.

How to model an empirical distribution (Page 81 of "Getting Started with Arena")?

Other Tools in Arena

Process Analyzer can be used to analyze various scenarios with the simulation model. For instance, what if the Transportation Security Officer can process applications faster because of better machines, how would it affect the average waiting time of customers?

OptQuest can be used to optimize the parameters for the simulation. For instance, how many Transportation Security Officer would be needed to reduce the average queue length to be less than 5 for the given input parameters of inter-arrival time of customers and the processing time of the Officer?

Research in Data Science

Data Science and Discrete Event Simulation (DES)

Simulation Models: input – **model** - output

Data Analytics: input – black box – output

Simulation Models are slow. Data Farming techniques can be used to use Data Analytics to predict the output from simulation models at the expense of some error. Dhariwal and Banerjee (2017) and Balaji and Ayush's project fall in this category of projects.

Greasley and Edwards (2019) discuss research which integrates DES and Big Data Analytics.

It is also stated that Big Data facilitates the data needs of the DES models.

Jung et al. (2020) uses real time power monitoring data in the form of garment production workers' task times to come up with an approximation algorithm to extract an accurate task time. This task time is fed as input data to a DES model which makes it more accurate than the conventional approach.

Discrete Event Simulation for COVID-19

Christine et al. (2020) discuss about epidemiological modelling and the planning to reduce the impact of COVID-19 via computer simulation. This work should be relevant for the Project Group working on COVID-19 vaccine distribution strategies as well as ICU bed modelling for COVID-19.

Ferguson et al. (2020) discuss about the modelling of ICU bed demand for COVID-19. This work should be relevant to the Project Group working on ICU bed availability for COVID-19.

Asgary et al. (2020) discuss about their drive through simulation tool for mass vaccination for COVID-19.

References

1. Andrew Greasley & John Steven Edwards (2019): Enhancing discrete-event simulation with big data analytics: A review, Journal of the Operational Research Society, DOI: 10.1080/01605682.2019.1678406
2. Dhariwal J. and Banerjee R., 'An approach for building design optimization using design of experiments', Building Simulation, 10 (3), 2017, 323–336.
3. Woo-Kyun Jung, Hyungjung Kim, Young-Chul Park, Jae-Won Lee & Eun Suk Suh (2020): Real-time data-driven discrete-event simulation for garment production lines, Production Planning & Control, DOI: 10.1080/09537287.2020.1830194
4. Christine S.M. Currie, John W. Fowler, Kathy Kotiadis, Thomas Monks, Bhakti Stephan Onggo, Duncan A. Robertson & Antuela A. Tako (2020): How simulation modelling can

help reduce the impact of COVID-19, Journal of Simulation, 14:2, 83-97, DOI: 10.1080/17477778.2020.1751570

5. Ferguson, N., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Cucunubá, Z., Cuomo-Dannenburg, G., Dighe, A., Dorigatti, I., Fu, H., Gaythorpe, K., Green, W., Hamlet, A., Hinsley, W., Okell, L. C., van Elsland, S., Thompson, H., Ghani, A. C. (2020). Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. https://doi.org/10.25561/77482
6. Asgary, A.; Najafabadi, M.M.; Karsseboom, R.; Wu, J. A Drive-through Simulation Tool for Mass Vaccination during COVID-19 Pandemic. Healthcare 2020, 8, 469.

Bibliography

1. Kelton, David, Randall Sadowski, and David Sturrock. 2003. *Simulation with Arena*. McGraw-Hill.