Spatial Arrangemnts in Surgery Centers and Clinics

A simulation approach

North Dakota State University in partnership with HKS Architects

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The goal of the research position was to use AnyLogic, a process modeling software, to model and simulate ambulatory care facilities. Using different metrics such as employee utilization, employee walking distances, room utilization, patient waking distances and wait times, the spatial arrangement of the ambulatory care facilities could be analyzed and adjusted accordingly to improve the characteristics of the room.

This GRA was funded through HKS Architects based in Dallas, Texas. The Liaisons for this Graduate Research Assistantship were Tom Harvey, a Principal and Academic Healthcare Practice Leader, and Upali Nanda, the Vice President and Director of Research at HKS.

Simulations in Healthcare

Simulations in healthcare have been extensively in the past years to improve efficiency and quality of care. There are many programs out there that can do this. MedModel, FlexSim, Simul8 Healthcare, AnyLogic. There are many options out there that can give a great idea on what to expect when running a healthcare service. Many of these simulation programs are not directly built to analyze the spaces or the built environment to help with the design of the healthcare building.

http://simul8healthcare.com/wp-content/uploads/2013/06/Logo-Box-16.png
http://www.anylogic.com/images/playVideo1.jpg
http://talumis.com/wp-content/uploads/2014/01/FlexSimHealthCare-300x160.jpg

The history of computer simulations started in WWII through the development of the atomic bomb. Stanisław Ulam had been invited to join the Manhattan Project and worked on hydrodynamic calculations on the explosive lenses required for a workable bomb. Being unable to determine a closed-form expression or apply a deterministic algorithm, he explored the use of computer calculations to find his answers. This was the first recorded use of computer simulation to solve a problem. This method was then named the Monte Carlo method described as a broad class of computational algorithms that rely on repeated random sampling to determine numerical results.

The method has proven to give better results than human intuition in regards to predictions of failure or cost overruns. The Monte Carlo methods are used in three distinct problem classes: optimization, numerical integration, and probability distribution. This project will deal with the optimization side of simulation.

Objectives and Ideas to be Explored

· Model the entire process of an ambulatory care facility.
· Model the walking distances of employees and patients
· Minimize the walking distances of employees and patients
· Provide a logic map of a patient path when going into a clinic
· Compare different clinic arrangements with the different metrics.

How AnyLogic Works

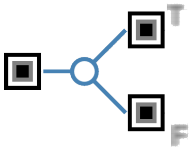
AnyLogic is an agent based simulation software that is entirely Java based. This means it is fairly simple to make changes and create custom functions that use the software to its fullest potential.

Using simple logic flow diagrams one can visually program the simulation through what are called model blocks. They carry out functions to create entities, move entities, make them wait for a specified time, make them interact with other entities, and then make them exit the system.

Examples of these blocks are shown below. Getting + with them will help to understand the flow charts later in this report.

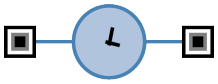
Source

Generates entities. Is usually a starting point of a process model.



Select Output

Routes the incoming entities to one of the two output ports depending on (probabilistic or deterministic) condition. The condition may depend on the entity as well as on any external factors.

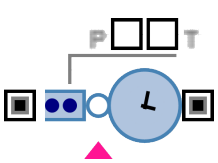


Delay

Delays entities for a given amount of time. The delay time is evaluated dynamically, may be stochastic and may depend on the entity as well as on any other conditions.

Move To

Moves the agent/entity to a new location in the network. If any resources are attached to the entity, they will move with it. The speed will be the entity speed regardless of the attached resources speed.



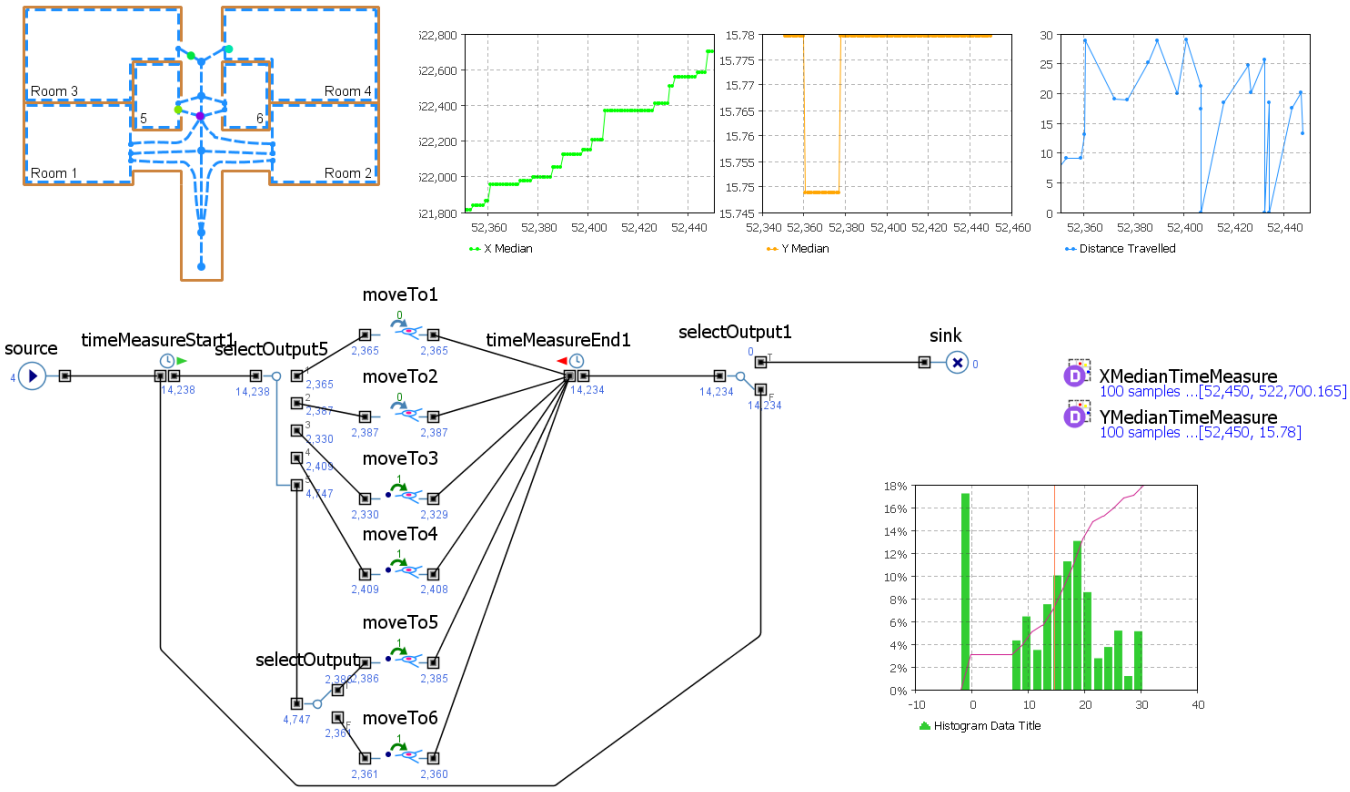
Service

Seizes a given number of resource units, delays the entity, and releases the seized units. Is equivalent to a sequence Seize, Delay, Release and should be used if the entity does not need to do anything but execute a delay between seize and release.

Pedestrian Modeling

The strengths of the pedestrian modeling library is that it tracks location data on every single pedestrian entity. This means there is collision detection with the other pedestrians meaning you can test to see how congested the hallways may get at peek usage.

You can also show the density of the pedestrian walking through the space. This is helpful for showing potential building wear spots that need to be monitored.

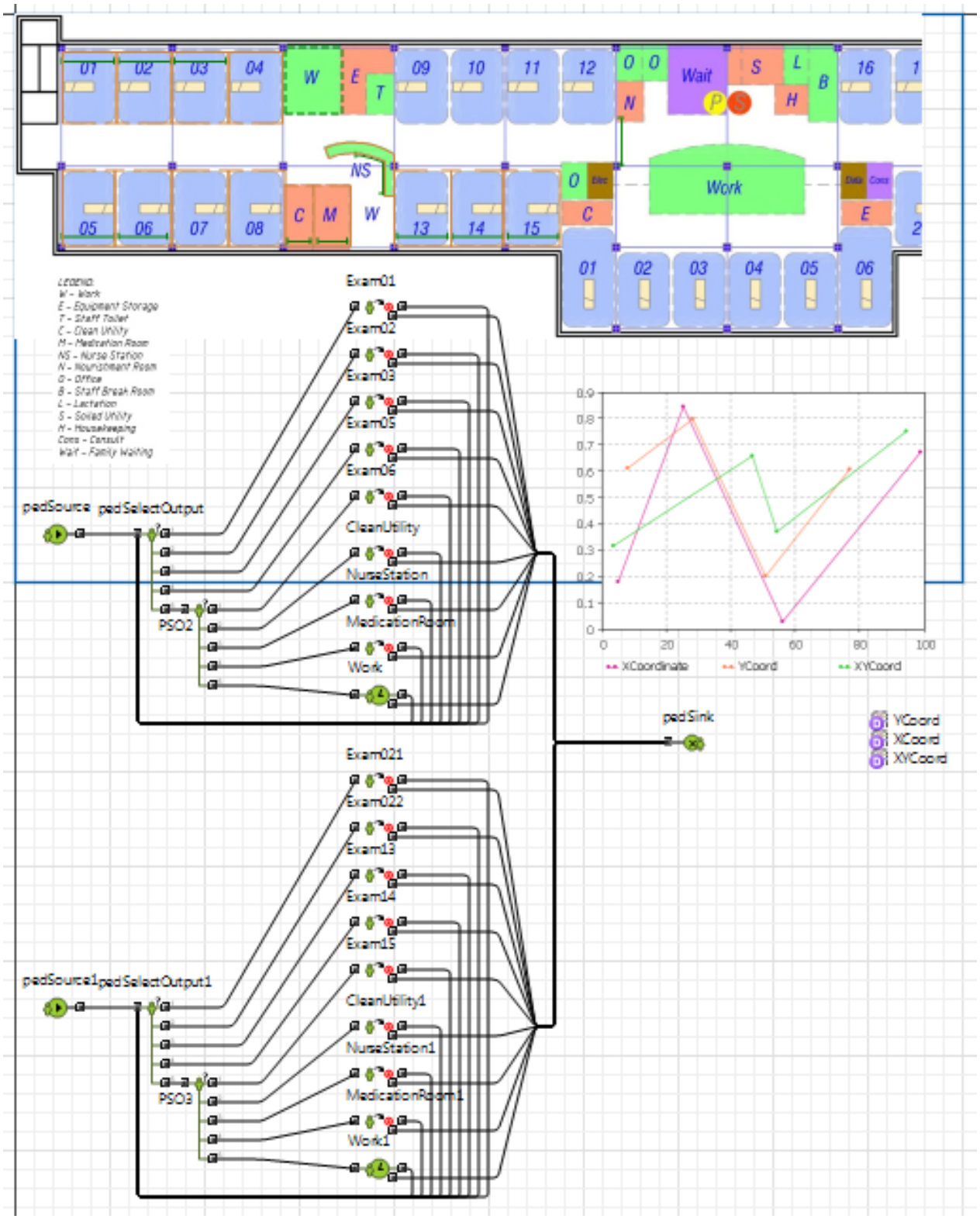


This model's purpose is to determine the function needed to plot the distance travelled by a single nurse. With this function we can apply it to a larger scale model system.

The system uses a start time and end time and by knowing the speed, we can easily find the distance as Velocity x Time = Distance. Unfortunately this method does not allow for measurement of the different entities that depend on this one. The only way to measure the distances for a role in the clinic model, is to have a completely different logic tree specifically for that role.

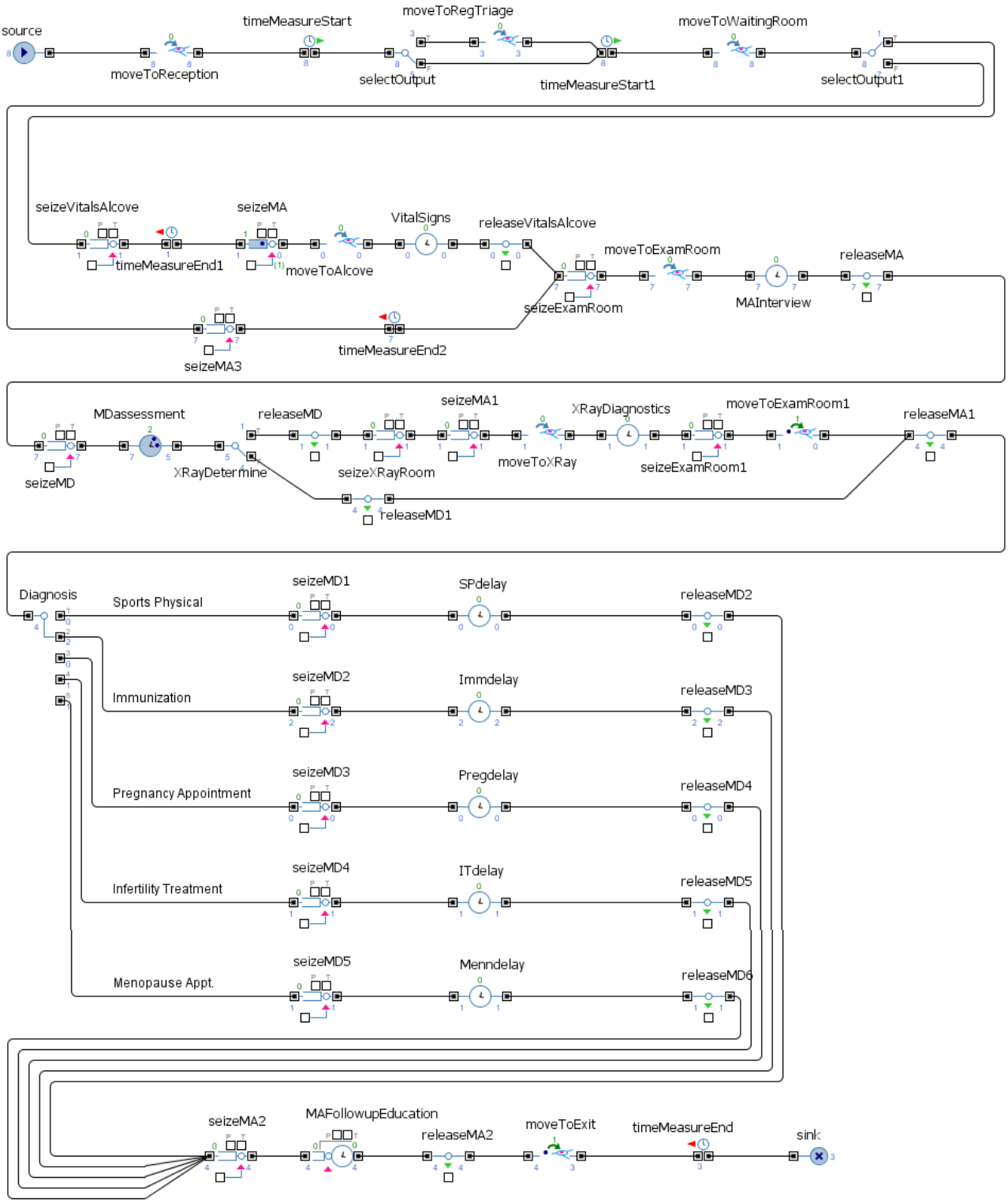
That is impossible to model because it's the patients that call for and determine the movement of the nurses.

This model shows what is needed to be done to model two different nurses having to visit multiple spaces. This is a double loaded clinic corridor design that HKS uses for its bed unit configurations. Ideally there would be wait times at each of the different spaces but the limitations of the software do not allow for this, so the effect is simulated by just traveling to one space and moving on to the next. The walking distances will be the same, the time however will not.



Process Modeling

The process modeling library is used to model systems. It takes each component of a complex system, and breaks it down into smaller processes. The main functinos used are [moveTo] [seize], [selectOutput], and [delay].

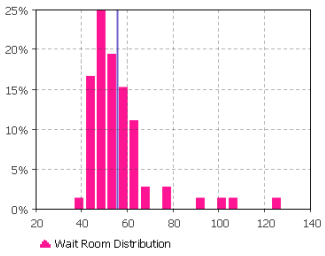


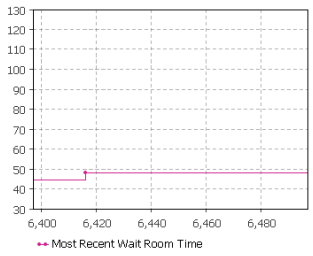
Kaysville Clinic

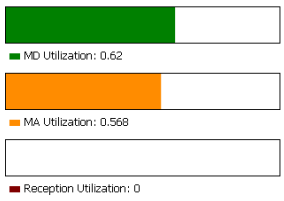
Below is the model that the previous logic map is linked to. Patients enter on the right, visit the reception counter, then depending on whether it is a drop in or a scheduled appointment, they will visit the registration/triage room then go to the waiting room.

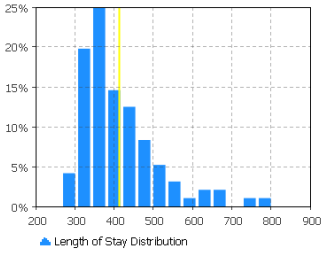
After that the vitals alcove is reserved as well as a nurse is called. The nurse take the patient to the vitals alcove does the procedure then seizes an exam room and takes them to the room. The health interview is conducted the nurse is released and the doctor is called on. The doctor gives their assessment, determines if an X-ray is needed. If needed the doctor is released the x-ray technician is called, the patient is moved to the x-ray room, the x-ray procedure is conducted, and then the patient is returned back to the exam room.

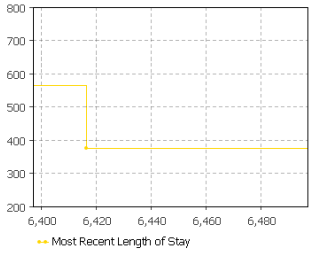
The different procedure is then chosen whether it be a sports physical, immunization, pregnancy appointment, infertility treatment, or menopause appointment. After the appointment is completed, the patient is then dismissed and the nurses and doctors go back to their home locations.

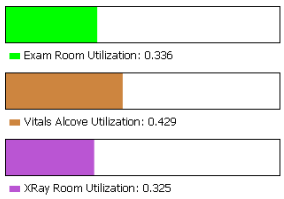




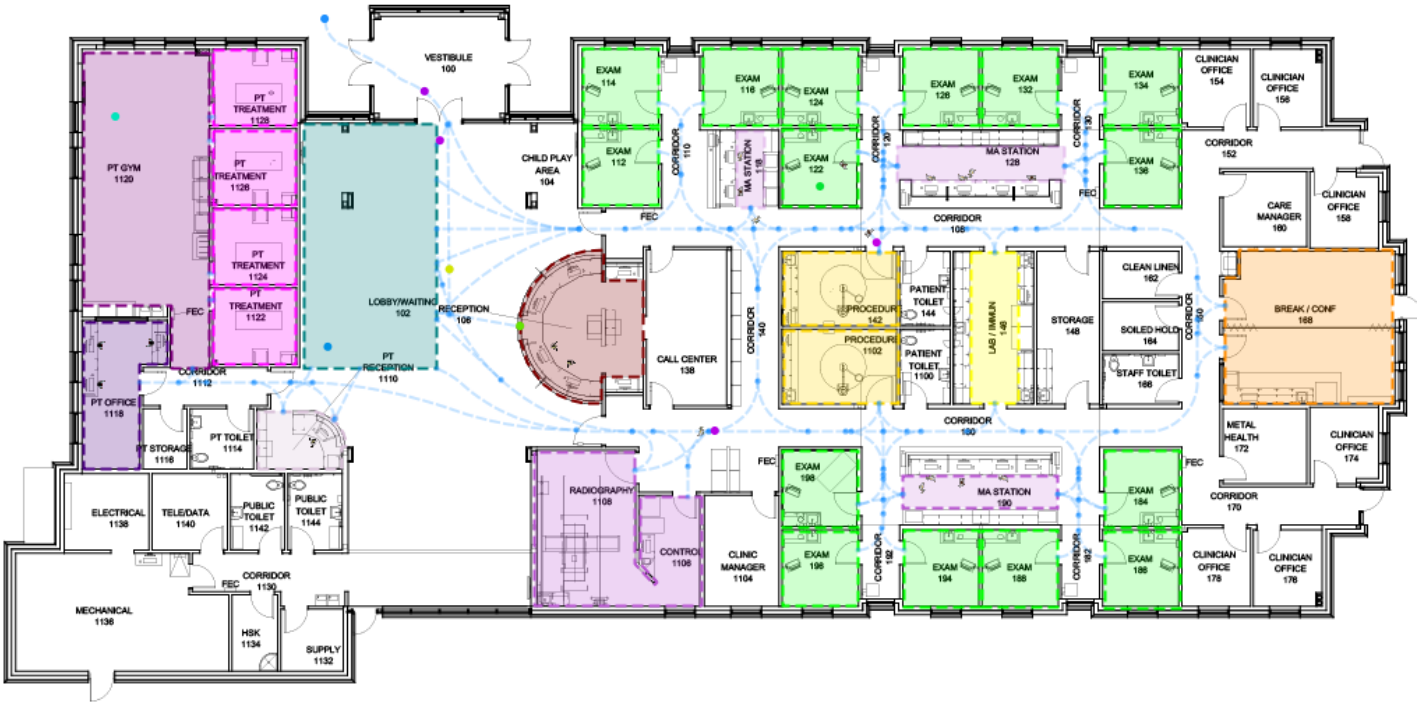


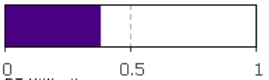


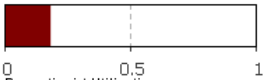


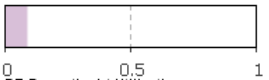


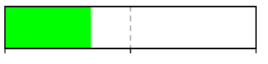
Riverton Clinic

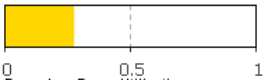


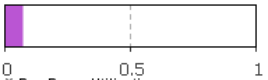


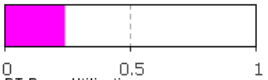


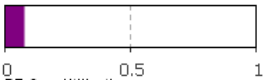


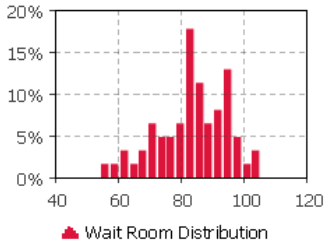


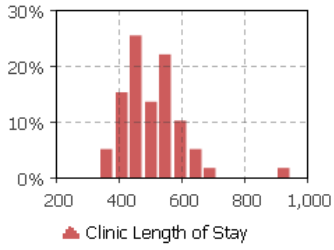


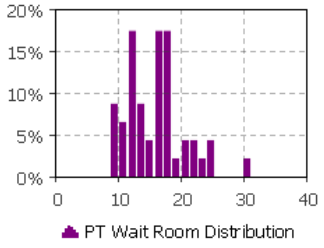


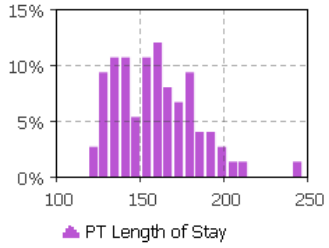








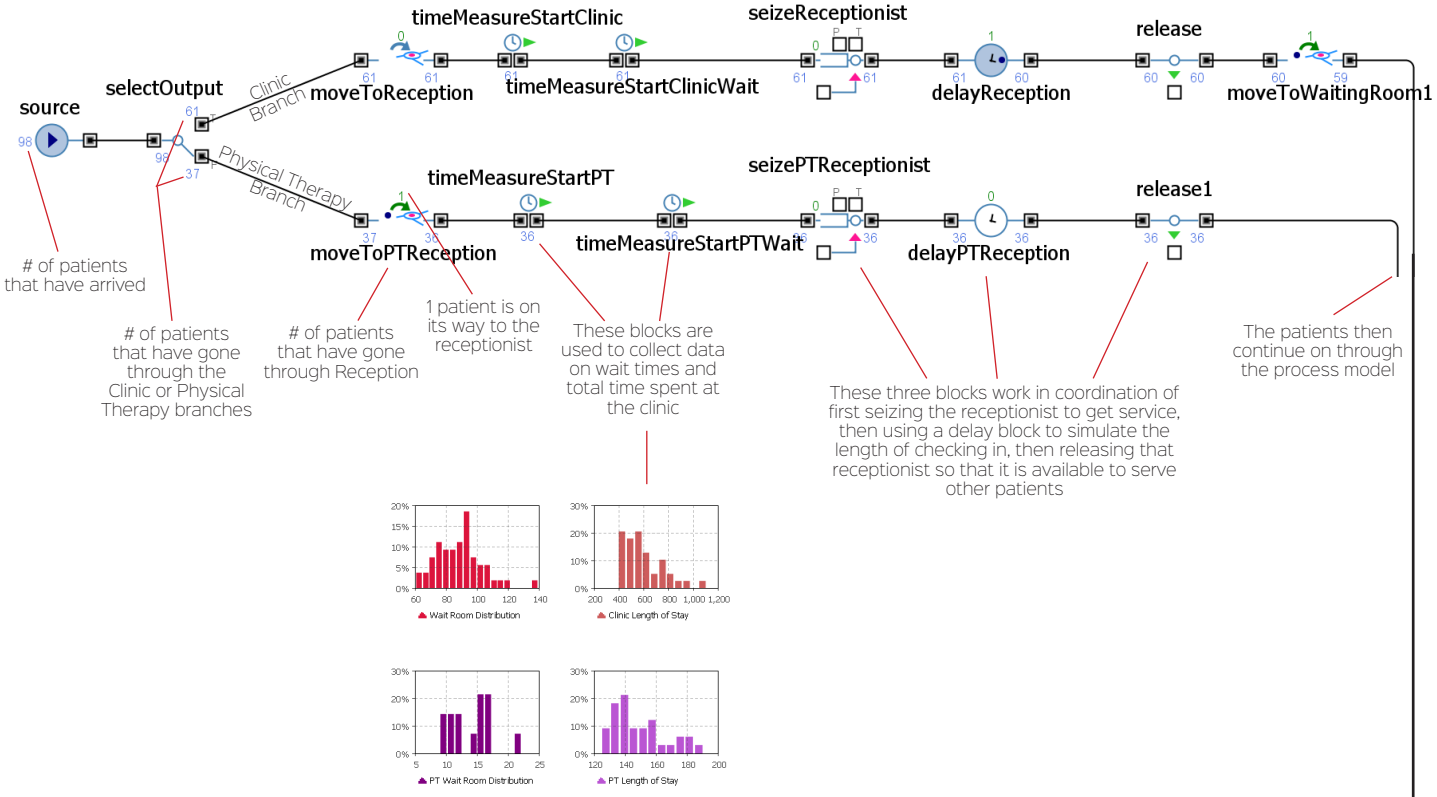




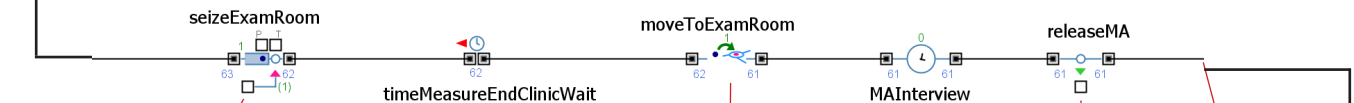
This is the second model that I created. Using the same process model as the Kaysville clinic, I just modified the model to add a Physical Therapy branch and removed the triage and vitals alcove sections. The model collects statistics on room utilization, staff utilization, wait times, and lengths of stay.

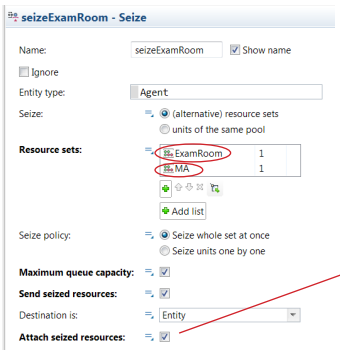
Below I will describe each step in detail explaining how anylogic deals with the different systems and how the branching into different processes work.

Understanding the Process Model



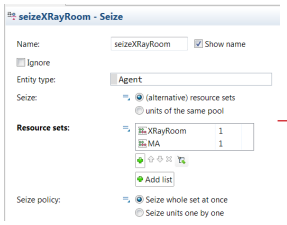
After registration is complete, the exam is to be conducted. To do that both an MA and an exam room is needed. If available, both of them are seized through the seizeExamRoom block





Now that the resources (Exam Room and MA) have been seized, the MA "attaches" to the patient and brings them to the seized exam room.

After the interview takes place, the nurse is released from that patient, and is availble to be seized by another.



In the case that an X-ray is needed, the doctor is released, a nurse and the Radiography Room is seized

Once the resources are available and seized, the patient is taken to the Radiography Room

The x-ray is performed

The x-ray room is released and the patient goes back to its original exam room

Once the patient and nurse get back to the exam room, the nurse is released and the patient moves on to the procedure phase

MDassessment

releaseMD

moveToXRay

releaseXRayRoom

releaseMA1

seizeMD

XRayDetermine

seizeXRayRoom

XRayDiagnostics

moveToExamRoom1

releaseMD1

Once the MA interview has taken place, an assessment by the MD is to take place. With the room already seized by the patient, only seizure of an MD is needed.

After the assessment the doctor determines if an X-ray is needed. It is set to a ratio of 1:9 needing an X-Ray.

In the case that an X-ray is not needed, the docotr is released and the patient moves on to the procedure phase

Diagnosis

Sports Physical

seizeSportPhysical

SPdelay

releaseMD2

Immunization

seizeImmunization

Immdelay

releaseMD3

Pregnancy Appointment

seizePregnancyAppointment

Pregdelay

releaseMD4

moveToProcedure1

Infertility Treatment

seizeInfertilityTreatment

ITdelay

releaseMD5

moveToProcedure

Menopause Appt.

seizeMenopauseAppt

Menndelay

releaseMD6

With diagnosis complete, the patient moves to the different procedures needed for treatment. The necessary resoruces are then seized.

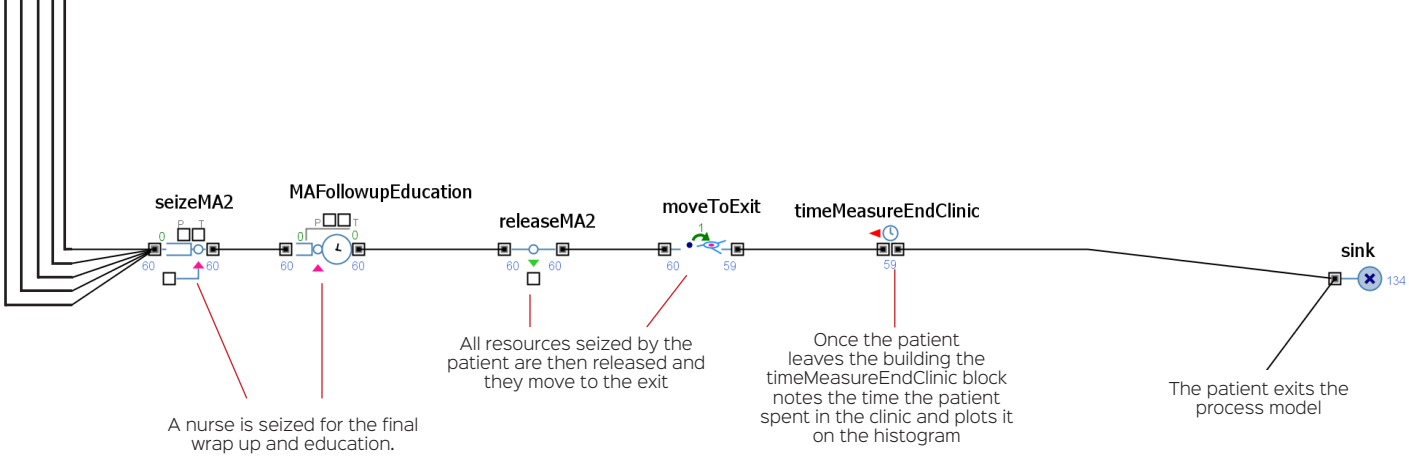
Resources seized

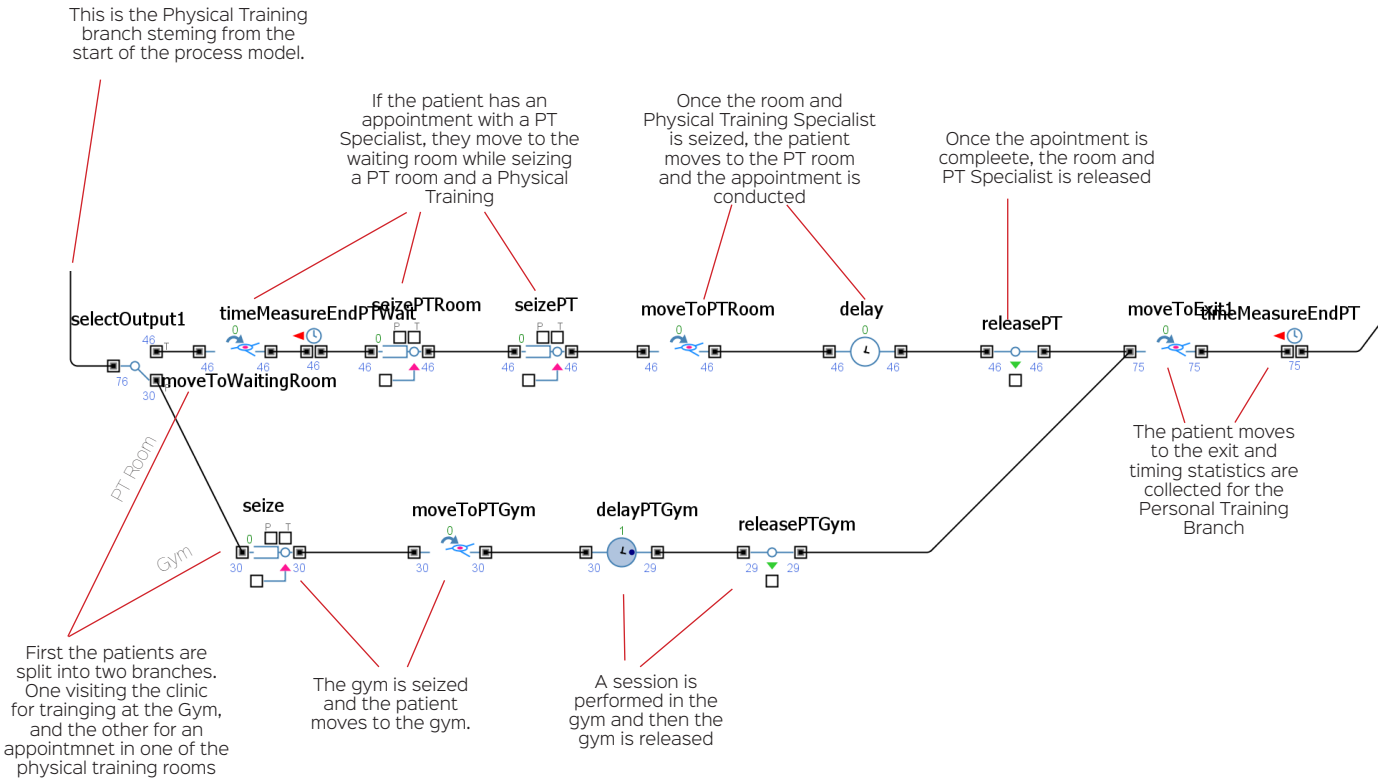
Sports Physical: 1 MD
Immunization: 1 MD
Pregnancy Appointment: 1 MD, 1 Procedure Room
Infertility Treatment: 1 MD, 1 MA, 1 Procedure Room
Menopause Appt.: 1 MD

Since a procedure room is needed to complete the Pregnancy Appointment, and Infertility Treatment, moveTo commands are used to move the patient to the procedure rooms

The procedures are conducted

Once the procedures are completed, the unneeded resources are released and the patient returns to the exam room for the wrap up


seizeMA2
MAFollowupEducation
releaseMA2
moveToExit
timeMeasureEndClinic
sink
A nurse is seized for the final wrap up and education.
All resources seized by the patient are then released and they move to the exit
Once the patient leaves the building the timeMeasureEndClinic block notes the time the patient spent in the clinic and plots it on the histogram
The patient exits the process model


This is the Physical Training branch steming from the start of the process model.
If the patient has an appointment with a PT Specialist, they move to the waiting room while seizing a PT room and a Physical Training
Once the room and Physical Training Specialist is seized, the patient moves to the PT room and the appointment is conducted
Once the apointment is compleete, the room and PT Specialist is released
selectOutput1
timeMeasureEndPTWait
seizePTRoom
seizePT
moveToPTRoom
delay
releasePT
moveToExit1
timeMeasureEndPT
moveToWaitingRoom
PT Room
Gym
seize
moveToPTGym
delayPTGym
releasePTGym
The patient moves to the exit and timing statistics are collected for the Personal Training Branch
First the patients are split into two branches. One visiting the clinic for trainging at the Gym, and the other for an appointmnet in one of the physical training rooms
The gym is seized and the patient moves to the gym.
A session is performed in the gym and then the gym is released

Conclusions

The pedestrian model does a great job of tracking individual players in the set up system. If the full version of AnyLogic was available it would be possible to model an entire clinic and collect distance statistics on all of the different roles in the environment. As it stands the educational version still does a good job of being able to model and produce useful statistics in small simulations. For example, deciding on room assignments for different staff. This part of the software could very effectively be used to determine room arrangement and spaces when time and distance from one space to the next is very important. Currently the software allows you to make a layout and test it. You can compare the results of the different tests and see what layout performs better. The software has no way to suggest the best potential arrangement however. A simulation software being able to suggest a potential layout would be a very big step from where we are now.

The process model does a much better at looking at things in the larger scale. It can deal with multiple types of resources being seized and released as well as using different rooms for multiple purposes. With the model that I built, we could see based on the arrival rate how many staff members are needed as well as how many rooms are needed. Depending on the location and expected patient numbers, we could confidently show how many rooms are needed of certain types. Accurate demographic data would be needed but with that data it would be easy to find the total number of rooms and staff needed for a new clinic.

Programming for clinic designs could become much more reliable and easy. It is no longer intuition, rules of thumb, and a little bit of luck. Using software to simulate building spaces and usage will become much more common. These software programs still have a substantial price tag but as costs go down I could see this being utilized in every substantial building. Stadiums, theaters, schools, community centers, convention centers, anywhere with significant traffic and space needs could use this program for figuring out a very accurate building program. Space, staff, and equipment needs can be very accurately determined.

Works Cited

Anderson, Herbert L. “Metropolis, Monte Carlo, and the Maniac.” People (n.d.): n. pag. Web. <http://library.lanl.gov/cgi-bin/getfile?00326886.pdf>.

“Historical Perspective.” Introduction to Simulation and Modeling: Historical Perspective. University of Houston, n.d. Web. 17 Dec. 2014. <http://www.uh.edu/~lcr3600/simulation/historical.html>.

“Why AnyLogic?” Why AnyLogic? AnyLogic Simulation Software. N.p., n.d. Web. 19 Dec. 2014. <http://www.anylogic.com/features>.